



# Mission Analysis and Feasibility Study for the Recovery System of a Suborbital Rocket

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# 1 Project & Document Overview

This report is the entry point to the documentation generated for the semester-long engineering study titled ***Mission Analysis and Feasibility Study for the Recovery System of a Suborbital Rocket***. The project was conducted as part of the *Space Technologies Minor* at EPFL in close collaboration with the **EPFL Rocket Team**, and spanned 14 weeks (12 ECTS credits).

The goal of the project was to evaluate the feasibility and define the preliminary architecture of a **recovery subsystem** for a student-designed suborbital rocket. This subsystem is responsible for the safe return of the vehicle or its components after flight. The study focuses on the earliest phases of system development and does not involve implementation or detailed design.

The scope is aligned with the early stages of the ECSS project lifecycle:

- **Phase 0 – Mission Analysis:** understanding stakeholder needs and system context.
- **Phase A – Feasibility Study:** evaluating solution concepts and defining the baseline architecture.

## 1.1 Purpose of This Document

This introductory section serves as a navigation aid for readers. It explains how the documentation set is organized, clarifies the logic behind document categorization, and outlines how different types of readers—such as academic supervisors, project reviewers, or future engineers—can engage with the content relevant to their role.

It does not include technical content itself. Instead, it introduces the structure and purpose of each document and provides a roadmap for locating key information.

## 1.2 Key Outputs

The study resulted in the following major deliverables:

- A **baseline system architecture** for the recovery subsystem.
- A **trade-off report** comparing and evaluating architectural concepts.
- A set of **project and technical requirements** for future development phases.
- A **development and verification roadmap** to support continued design activities.

## 1.3 Document Structure and Navigation

This report is structured as a collection of standalone yet interrelated documents, each addressing a specific aspect of the recovery system study. The organization reflects the logical flow of the project—from scoping and planning, through system design and trade studies, to tools and future development.

The documentation falls under two main categories:

- **Technical Documentation:** Describes the engineering and systems aspects of the project, including requirements, architecture, trade-offs, and tools.
- **Project Narration & Guidance (this section):** Serves as a roadmap for navigating the above documents and understanding how they connect within the study's lifecycle.

Unlike a continuous narrative, the documentation is modular by design. Each part can be read independently but is traceable through cross-references and aligned with ECSS systems engineering practices.

Readers are encouraged to select entry points based on their focus:

- For a **systems-level view**, begin with the *System Engineering Plan* and *Trade-off Report*.

- For understanding **design constraints**, refer to the *Project Requirements Documentation* and *Preliminary Technical Requirements*.
- For implementation-oriented readers or future developers, the *Software Design Document* and *Software Development Plan* provide the most relevant insight.

## 1.4 List of Core Documents

Table 1 summarizes the key deliverables of the study. Each document plays a specific role in the development logic and supports the overall goal of defining a feasible and justified recovery system architecture.

**Table 1:** Core project documents and their role

Document Name	Purpose
Project Requirements Documentation	Defines the scope, objectives, and constraints of the project from a mission and stakeholder perspective.
System Engineering Plan	Describes the project’s systems engineering workflow, including methods, lifecycle stages, and integration with future work packages.
Preliminary Technical Requirements	Lists the technical requirements imposed on the recovery system and guides the trade-off and design processes.
Requirements Justification File	Explains the origin and rationale of each technical requirement, with traceability to sources and design logic.
System Concept Trade-off Report	Details the decision-making process and criteria used to select the baseline system architecture.
Pararec-Sim — Software Design & Development Document	Provides a high-level description of the custom simulator and optimiser used for architecture evaluation.

## 2 Project Requirements Document

### 2.1 Introduction

This document defines the project-level requirements for the semester project titled *Mission Analysis and Feasibility Study for the Recovery System of a Suborbital Rocket*. It is part of the overall process documentation and aims to formally capture how project needs were identified, transformed into requirements, and managed throughout the study.

These requirements do not directly constrain the technical design of the recovery system. Instead, they define the boundaries, expectations, and evaluation criteria for the engineering feasibility study itself. In this sense, they guide how the study was conducted, not what the system must ultimately be.

This document supports traceability and transparency by providing:

- A structured overview of the project's scope and its boundaries;
- A step-by-step breakdown of the requirement definition methodology;
- Metadata and traceability between needs and formalized requirements;
- A clear distinction between project-level and system-level requirements.

The complete lists of needs and project requirements are included in the appendices.

#### Title

**Mission Analysis and Feasibility Study for the Recovery System of a Suborbital Rocket**

#### Description and Objectives

This project initiates the early-stage systems engineering work for the recovery subsystem of a student-built suborbital rocket. Its primary driver is the need to formally begin mission analysis, stakeholder need identification, and feasibility evaluation for this subsystem—corresponding to ECSS Phases 0 and A.

*“Thus we would like to start the mission analysis, needs identification and feasibility study (ECSS Project Phase 0 and A) for the recovery subsystem.”*

The project focuses on producing a first iteration of the systems engineer's responsibilities during these phases, including:

- Identifying and structuring stakeholder needs;
- Analyzing the feasibility of candidate recovery concepts;
- Defining an initial baseline system architecture.

In parallel with the technical content, the project applies systems engineering (SE) and project management (PM) practices relevant to this lifecycle stage. The outcome is both a technical and methodological baseline for future development.

#### System Scope and Interfaces

This study focuses solely on the recovery subsystem—defined as the set of hardware and logic responsible for safely returning the rocket (or its components) to ground after flight. It explicitly excludes the avionics system, which is expected to host the sensors, actuators, and deployment logic. Interfaces with avionics are documented, but treated as external dependencies.

Due to the early development stage of the overall rocket, many high-level system requirements and upstream interfaces remain undefined. This uncertainty is acknowledged and addressed through

flexible assumptions and scoping boundaries. The goal is to document and justify a feasible design space, not to finalize a system configuration.

### Phases Covered

The project covers the first two lifecycle phases as defined in ECSS:

- **Phase 0 – Mission Analysis:** Identification of mission goals, stakeholder needs, and high-level constraints.
- **Phase A – Feasibility Study:** Exploration of candidate solutions, definition of technical requirements, and establishment of a baseline architecture.

Deliverables from this study are designed to support the transition to Phase B, where detailed design and implementation begin.

## 2.2 Requirements Definition Process

Requirements in this project were defined and maintained through a lightweight but traceable process appropriate for a Phase 0/A study. The goal was to produce a clear, justified set of project-level requirements that define the scope of work, align expectations, and guide all subsequent activities. The process follows five key steps:

### Step 1: Stakeholder Identification

All stakeholders who influence or are affected by the project were identified. These include both technical actors (EPFL Rocket Team members) and academic supervisors. They provided the initial needs and validation inputs used throughout the study.

### Step 2: Need Capture

Stakeholder inputs were translated into high-level needs. These needs are expressed in natural language, without technical prescriptions, and describe what the project must achieve—without defining how.

### Step 3: Requirements Derivation

Each need was transformed into one or more project-level requirements. The resulting requirements follow ECSS guidance and aim to be specific, verifiable, and aligned with the scope of a feasibility study.

### Step 4: Tagging and Metadata

Each requirement was annotated with a standardized set of metadata fields to support traceability and downstream usage. These fields include criticality, source, rationale, and more.

### Step 5: Review and Update

The requirement set was maintained throughout the project. Formal review points (e.g., MDR, PRR) and informal design feedback loops were used to refine, prioritize, and verify the requirements progressively.

## Stakeholder Roles and Decision Points

- **Systems Engineer (Author):** Manages the requirement database and traceability model.
- **ERT Systems Engineer:** Provides needs and validates requirement scope.
- **Academic Supervisor:** Oversees alignment with project expectations.
- **ERT Team Leads:** Contribute technical inputs and participate in reviews.

Reviews were held at key milestones to validate the requirement set and approve updates based on evolving context.

## 2.3 Stakeholder Summary

For this study, three key stakeholder groups were identified. Their needs directly inform both project-level and system-level requirements.

### Stakeholder List

- **EPFL – eSpace (Academic Supervisor)**
- **EPFL Rocket Team – Spaceshot Project**
- **Launch Support – Esrange Launch Site**

### Roles and Responsibilities

#### EPFL – eSpace and Rocket Team (Supervisory Stakeholders)

- Define project quality expectations, review cadence, and documentation scope.
- Influence process methodology, deliverable format, and project boundaries.

#### Rocket Team – Spaceshot (Technical Stakeholders)

- Impose high-level technical constraints to ensure compatibility with the future rocket system.
- Provide inputs regarding interfaces, feasibility considerations, and system context.

#### Launch Support – Esrange Site

- Impose external operational constraints such as:
  - Maximum drift distance, landing accuracy
  - Submission of recovery risk assessments
  - Analysis of descent trajectory and impact profiles

All project needs and requirements are managed using a consistent set of metadata fields. These annotations support traceability, review, and filtering of the requirement database throughout the project lifecycle. The metadata structure is inspired by ECSS principles and adapted for use within the Obsidian-based project environment.

Each entry—whether a need or a requirement—is annotated with the following metadata:

**Table 2:** Metadata fields used for all needs and requirements

Field	Description	Example / Options
statement_type	Distinguishes between needs and requirements	Need, Requirement
domain	Categorizes as process-related or technical	Project, Technical
name	Short label for identification	“Mission Definition Deadline”



*(continued from previous page)*

Field	Description	Example / Options
text	Full expression of the statement	(Free text)
unique_identifier	Traceable ID assigned to each entry	NEED-001, REQ-005
source	Origin of the statement	ECSS-E-ST-10C, Launch Site, Team Meeting
original_author	Author of the initial entry	“John Doe”
date_entered	First entry date	2025-03-14
last_updated	Date of most recent change	2025-04-16
status	Documentation and review status	Draft, In Review, Approved, Removed
approval_date	Date when entry was approved (if applicable)	2025-04-18
verification_status	Verification progress status	Not Started, Planned, Verified
verification_type	Method of verification	Analysis, Test, Inspection, Demonstration
parent_ID	Parent entry for traceability	REQ-001 or NEED-002
priority	Priority level for implementation	High, Medium, Low
criticality	Whether non-satisfaction impacts project viability	Yes, No
stability	Expected stability over time	Stable, Likely to Change, Incomplete
due_for	Target milestone for completion	MDR, PRR
rationale	Justification for the statement	“Ensures compatibility with recovery timeline”

## 2.4 Requirement Sources

All project-level requirements are derived from authoritative references or validated stakeholder inputs. The principal reference source is the ECSS standard set, selected due to its relevance to early-phase aerospace systems engineering and widespread use across institutional and academic contexts.

The ECSS standards were used for the following reasons:

- They offer a structured approach for requirement generation in feasibility phases;
- They define mandatory review stages and expected deliverables for each phase;
- They align well with academic engineering processes and enable traceability to future industrial contexts.

Other secondary sources—such as internal meetings, past work by the EPFL Rocket Team, and project supervisor feedback—were used to interpret, scope, or prioritize ECSS-derived content. However, they were not used to generate original requirements.

## 2.5 Needs-to-Requirements Traceability

Each project requirement is derived from at least one stakeholder need. This relationship is recorded through explicit traceability links to ensure that all requirements are grounded in justifiable expectations and that no stakeholder input is lost.

Traceability supports:

- **Completeness validation:** All expressed needs must result in corresponding requirements;
- **Justification tracking:** All requirements must trace back to a defined source;

- **Impact analysis:** Changes to needs can be propagated to linked requirements during updates. A graphical traceability model is used to visualize relationships between needs and requirements. The full list of project-level requirements is managed dynamically using a markdown-based system in Obsidian. Each requirement is stored as a separate file and annotated with metadata to support traceability and status tracking.

The table below displays all requirements derived for this project. The table is generated using Obsidian's Dataview plugin and includes core metadata fields such as domain, source, and traceable parent needs.

### Example Dataview Query:

**Listing 1:** Query to list all project-level requirements

```
TABLE
  text as "Text",
  domain as "Domain",
  source as "Source",
  due as "Due",
  parent_requirements as "Parent Statement"
FROM "Semester Project/Project Needs & Requirements"
WHERE contains(statement_type, "Requirement")
SORT length(parent_needs) ASC
```

The rendered result (not shown here) includes the current requirement set as maintained in the knowledge base. Each row links back to its original markdown file, enabling inline editing and review.

## 2.6 Requirement Management Approach

Requirements were managed using **Obsidian**, a markdown-based knowledge management platform. The environment enabled a flexible, version-controlled, and queryable system for authoring, organizing, and visualizing project-level needs and requirements.

### Requirement Authoring

- Each requirement or need is stored in its own `.md` file.
- A custom template ensures consistent structure, including:
  - Descriptive text and rationale;
  - Dropdowns for fields such as status, domain, criticality;
  - Links to parent/child relationships and verification types.
- Requirements derived from ECSS were imported, tagged, and adapted to this structure.

### Querying and Traceability

The **Dataview** plugin enabled all requirement pages to function as a dynamic database:

- Requirements were filtered and sorted by metadata (e.g., by milestone, priority, or stability).
- Tables were embedded into key documentation files and review dashboards.
- Pie charts and status summaries were created using JSON output from Dataview and rendered via the Charts plugin.

### Example Query – Requirements linked to the Trade-off Report:

TABLE

```
    text as "Text",
    priority as "Priority",
    implementation_status as "Implementation Status"
FROM "Semester Project/Project Needs & Requirements"
WHERE
    contains(source, "ECSS-E-ST-10C Rev.1")
    AND contains(unique_identifier, "L.") // Annex L: Trade-off report
    AND !contains(requirement_status, "Removed")
    AND !contains(priority, "Low")
SORT implementation_status ASC
```

This query identifies all high- and medium-priority requirements relevant to the trade-off study, supporting focused review and implementation.

### Version Control

All requirement files were version-controlled using Git. This provided:

- Fine-grained history of changes for each individual requirement;
- Rollback capability during major review cycles;
- Logs of changes to both text and metadata.

### Example Views

The system supported multiple embedded views:

- **Document Requirements View:** All requirements relevant to a specific document shown at the top of that file.
- **Review Task Pages:** Focused lists of entries needing review or update before specific milestones (e.g., PRR).
- **Project Status Overview:** Dashboards aggregating status, stability, and criticality ratings.
- **Full Index Page:** Dynamic list of all requirements with filters and live metadata summaries.

## 3 Systems Engineering Plan

### 3.1 Introduction

This Systems Engineering Plan (SEP) describes the structure, strategy, and outcomes of systems engineering activities conducted during the **Mission Analysis** and **Feasibility Study** phases (ECSS Phase 0/A) for the parachute recovery system.

The purpose of this document is twofold:

1. **To present the work that has been completed** since the beginning of the project—allowing the stakeholders to verify its completeness and alignment with the expected scope.
2. **To outline the activities planned until the Preliminary Requirements Review (PRR)**—enabling the stakeholders to validate and approve the direction and focus of the upcoming work.

The document captures both the methodology and outputs of each major engineering activity, including requirements definition, architecture exploration, interface identification, and trade-off studies.

### 3.2 Activities

#### Phase 0

Activity	Output
Identify Semester Project Needs	Project Needs and Requirements
Define Semester Project Requirements	Project Needs and Requirements
Identify Mission Needs	Mission Needs
Define Mission Requirements	Preliminary Technical Requirements Specifications, Requirement Justification File
Identify Key Technologies and Architectural Decisions	Trade Off Report
Define System Selection Criteria	Trade Off Report
Identify Interface with Past/Current/Future System Engineering Activities	Systems Engineering Plan
Propose Possible System Concepts	Trade Off Report, Mission Definition Document

#### Phase A

Activity	Output
Propose System Solutions	Design Definition File, Design Justification File, Technology Matrix, Product Tree, Mission Operations Concept Document, Function Tree
Identify Risk Related to System Solution	Failure Modes and Effects Criticality Analysis, Risk Assessment Report
Identify Critical Items Related to System Solution	Critical Item List
Define Requirements for Next Lower Level	Preliminary Technical Requirements Specification for Next Lower Level
Propose Initial Verification Plan	Verification Plan

Activity	Output
Propose Initial Technology Plan	Technology Plan
Propose Initial Development Plan	Systems Engineering Plan, Work Breakdown Structure
Identify Interfaces	Interface Requirements Document

### 3.3 Control Activities

#### Process Compliance

To ensure engineering activities are aligned with the stakeholder's needs, A set of project needs and requirements were defined with the **EPFL Rocket Team** before the engineering activities commenced.

#### Review Gates

Reviews with stakeholder within the **EPFL Rocket Team** were conducted throughout the project to validate progress and correct deviations early.

#### Academic Supervision

Biweekly meetings with the academic supervisor served as recurring checkpoints for alignment, feedback, and planning. These meetings supported: - Early identification of technical or organizational issues - Progressive validation of deliverables - Iterative refinement of project scope and priorities

### 3.4 Interfaces with Other Work Packages

#### Completed Work Packages

Past projects inform the current study through three main types of interfaces: 1. **References and Background Sources**  
 2. **Inherited Technical Requirements**  
 3. **Technology Feasibility Inputs**

#### Work Packages Currently Being Worked On

The current study interfaces with two other projects that are also operating within ECSS Phase 0/A: - One project focuses on an **adjacent subsystem** (Payload). - The other works at the **system level**, developing architecture and mission-level requirements. The main form of interface is through requirements that constrain the recovery system's allowable architectures or design variable constraints. These constraints are still under definition and will evolve throughout the study.

#### Future Work Packages

This feasibility study is expected to define the baseline for recovery system development in subsequent phases. The output of this work will serve as a formal input to future work packages through the following.

## 4 Preliminary Technical Requirements Specifications

### 4.1 User Needs Background

The recovery system's requirements originate from a combination of stakeholder expectations (EPFL Rocket Team, Esrange launch constraints), safety considerations, and mission performance objectives. The complete list of needs has been included as an appendix.

### 4.2 Product Perspective

The recovery system complements the rocket's structure, propulsion, avionics, and payload subsystems. It is constrained by the internal volume of the rocket airframe, mass budget limits, and deployment timing compatibility. Unlike orbital reentry systems, which require heat shields and complex guidance, this product is tailored for suborbital trajectories with a focus on simplicity, reliability, and compatibility with a 100 km apogee mission profile.

### 4.3 Product Independence Statement

The recovery system is not fully independent or self-contained. It is designed to rely on the sounding rocket's airframe for structural mounting and support during ascent. The system may also depend on the avionics subsystem for power and deployment initiation, though this interface has not been finalized and will depend on the selected system concept. While the recovery system performs its core function autonomously post-deployment, its integration and operational sequencing are contingent on the broader rocket system's design.

### 4.4 Higher-Tier System Context

The recovery system is a key component of the overall rocket system. It must interface effectively with structural and avionics components to ensure successful deployment and operation. Key interfaces include:

- **Airframe:**
  - Mechanical incorporation within the rocket structure;
  - Attachment to load-bearing elements for structural support.
- **Avionics:**
  - Provision of electrical power;
  - Transmission of deployment commands and operational signals.

### 4.5 Product Life Profile

The recovery system is expected to operate through the following lifecycle phases:

1. **Pre-Launch:** Integration, storage, transport, and final system checks at the launch site;
2. **Ascent — Thrust Phase:** From liftoff to motor burnout, with peak acceleration and vibration loads;
3. **Ascent — Ballistic Phase:** Post-burnout coasting to apogee, involving vacuum conditions and temperature extremes;
4. **High-Altitude Descent:** Initial descent through low-density atmosphere, including deployment events;
5. **Low-Altitude Descent:** Descent in denser atmosphere under parachute(s), subject to lateral winds;

6. **Post-Landing:** Recovery, inspection, and transport of the landed system.

## 4.6 Environmental Constraints

The recovery system must withstand the following environmental conditions:

- **Pre-Launch:**
  - Exposure to ambient temperatures, humidity, and pressure variations;
  - Mechanical shocks during transport;
  - Static loads during handling and integration.
- **Thrust Phase of Ascent:**
  - High acceleration (TBC g-forces);
  - Strong vibration and acoustic loading (TBC frequency range);
  - Rapid altitude change and dynamic pressure increase.
- **Ballistic Ascent:**
  - Near-vacuum external pressure;
  - Low ambient temperatures (down to  $-50^{\circ}\text{C}$  or below);
  - High-altitude winds (e.g., jet streams).
- **High-Altitude Descent:**
  - Cold and low-pressure conditions;
  - Rapid dynamic pressure changes;
  - Aerodynamic instability and potential spin rates.
- **Low-Altitude Descent:**
  - Higher aerodynamic loads due to increased air density;
  - Wind-induced drift affecting landing location.
- **Landing and Post-Landing:**
  - Hard-surface impact loads (e.g., rocks, soil);
  - Risk of water landing (requires corrosion resistance and floatation if applicable);
  - Exposure to environmental contaminants (rain, dust, etc.).

## 4.7 Technical Requirements List

File (9)	Text
<a href="#">Apogee</a>	The system shall be compatible with an apogee ranging from 80 km to 120 km with the target apogee being 100 km.
<a href="#">Final Descent Speed</a>	The recovery system shall lead to a landing velocity of less than 8 [m/s] for any object attached to a parachute.
<a href="#">Airframe Diameter</a>	The recovery system shall be integratable into an airframe with a diameter ranging from 270 to 400 [mm].
<a href="#">Launch Vehicle Dry Mass</a>	The recovery system shall be compatible with a vehicle with a dry mass of 600 [kg].
<a href="#">Horizontal Velocity at Apogee</a>	The recovery system shall be with a horizontal velocity ranging from 0 to TBC [m/s].
<a href="#">Peak Traction Load</a>	The peak vertical acceleration applied onto the recovered system(s)'s structure shall be less than 300 [m/s <sup>2</sup> ].
<a href="#">Optionally Recovered Items</a>	The recovery system should recover the entire rocket.
<a href="#">Recovered Items</a>	The recovery system shall recover the nosecone section.
<a href="#">Touchdown Area</a>	The recovered system(s) shall land no further than 90km down range from launch site.

## 5 Requirements Justification File

### 5.1 Stakeholder Summary

The complete list of stakeholders for the Spaceshot project is documented separately as part of the semester project covering phase 0 and phase A of the spaceshot project. For the scope of this semester project, three primary stakeholders have been identified:

#### Stakeholders

- **EPFL - eSpace (Academic Supervisor)**
- **EPFL Rocket Team – Spaceshot Project Team**
- **Launch Support – Launch Site (Esrangle)**

#### Roles, Responsibilities, and Influence

##### **EPFL - eSpace (Academic Supervisor) and EPFL Rocket Team – Spaceshot**

- Define needs related to the scope, depth, and quality expected from the feasibility study.
- Define procedural needs regarding project reviews, including frequency, content expectations, and validation criteria.
- Influence the methodology, the documentation standard, and the timeline for deliverables.

##### **EPFL Rocket Team – Spaceshot (Technical Stakeholder)**

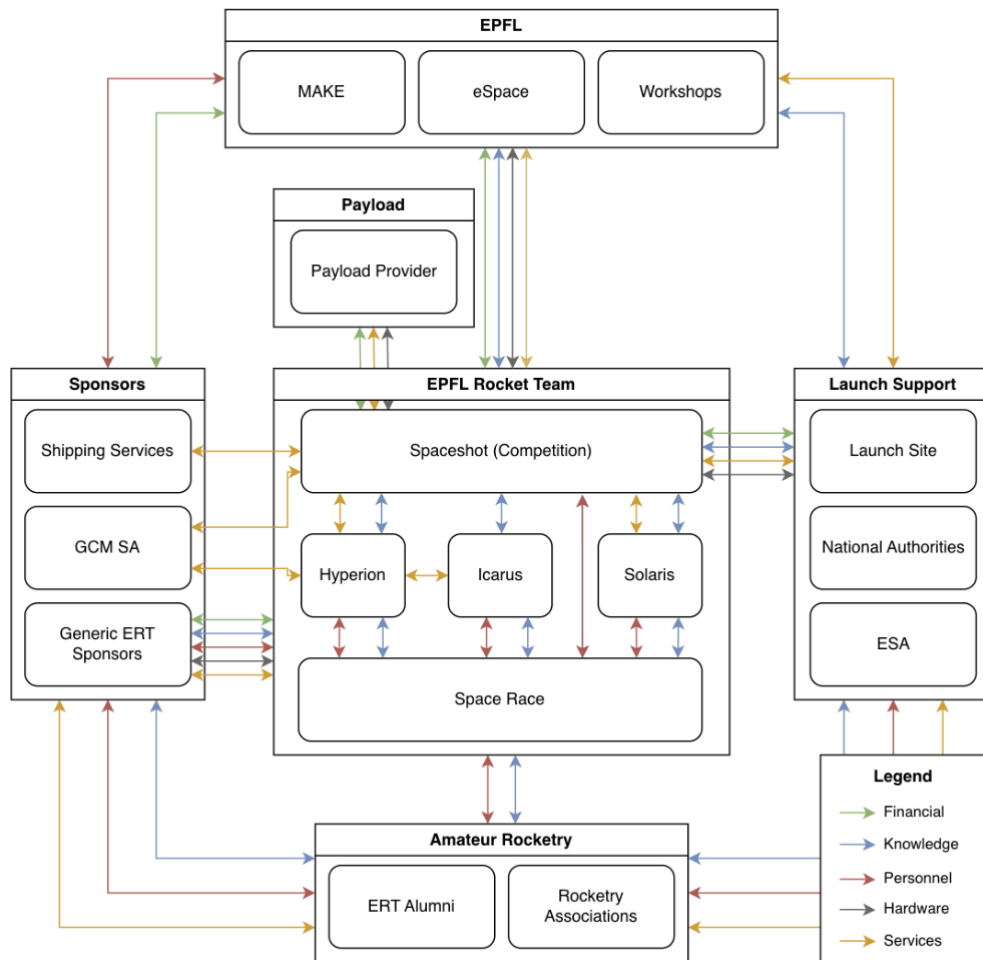
- Impose technical needs and high-level system requirements to ensure that the recovery system remains compatible with the evolving rocket system architecture.
- Act as the technical interface for system-level assumptions, constraints, and design feasibility feedback.

##### **Launch Support – Launch Site (Esrangle)**

- Impose security and operational requirements applicable to the recovery system, including:
  - Performance requirements (e.g., maximum drift distance, landing zone constraints)
  - Documentation requirements (e.g., submission of risk assessments and recovery plans)
  - Analysis requirements (e.g., justification of descent trajectories and impact studies)

These stakeholders play a critical role in defining both the project-level and technical needs, and their inputs are directly reflected in the captured needs and derived project and technical requirements.





**Figure 1:** Stakeholder map (taken from: Truchot and Fuser [2025])

**Table 5:** Preliminary Technical Requirements

ID	Requirement Text	Justification	Source	Verification
Apogee	The system shall be compatible with an apogee ranging from 80 km to 120 km, with a target of 100 km.	The target apogee of 100 km has been set as the mission objective by the rocket team, with a 20% tolerance margin.	EPFL Rocket Team (Stakeholder)	Analysis
Final Descent Speed	The recovery system shall lead to a landing velocity of less than 8 m/s for any object attached to a parachute.	Requirement taken from Espace Safety Manual, Section 6.7.4.	Espace Safety Manual	Analysis
Airframe Diameter	The recovery system shall be integratable into an airframe with a diameter ranging from 270 mm to 400 mm.	Inherited from prior studies; compatible with aerocover-equipped systems.	Truchot, Allenspach (2025 references)	Analysis
Launch Vehicle Dry Mass	The recovery system shall be compatible with a vehicle with a dry mass of 600 kg.	Pre-established constraint to avoid rework of launch transition mechanics.	Truchot (2025)	Analysis
Horizontal Velocity at Apogee	The recovery system shall be compatible with a horizontal velocity from 0 to TBC m/s.	TBD — value not yet defined.	—	Analysis
Peak Traction Load	The peak vertical acceleration on recovered components shall be less than 300 m/s <sup>2</sup> .	Based on deceleration profile from rapid parachute deployment.	Allenspach (Static Load Study)	Analysis
Optionally Recovered Items	The recovery system should recover the entire rocket.	Stakeholder intention to support full-body recovery.	EPFL Rocket Team (Stakeholder)	Analysis

## 6 Trade Off Report

### 6.1 Introduction

This document presents the Trade-Off Report for the recovery subsystem of a suborbital rocket, conducted as part of the ECSS Phase 0/A feasibility study. Its purpose is to document and justify the system-level decision-making process that led to the identification and recommendation of one or more viable recovery architectures. Because the final system will be implemented by future engineering teams, this study serves as a formal baseline that not only guides future development but also provides a transparent and defensible rationale for the decisions made.

The primary objective of this report is to make the decision logic both **transparent** and **traceable**. It does not prescribe a final implementation; rather, it evaluates a wide range of recovery strategies using a structured combination of qualitative and quantitative criteria. These evaluations are framed to match the maturity level expected of ECSS Phase 0/A, focusing on feasibility, architectural soundness, and early validation of assumptions.

**Note:** As a Phase 0/A output, this document is intended to serve as a **decision-support reference**. It is not an implementation plan. The decisions and rationale captured here define a baseline to be carried forward. Unless critical flaws are identified in later phases, these trade-off activities are not expected to be repeated, though future development teams may adapt or extend them as new information becomes available.

#### Scope

This report focuses on the **reasoning** and **evaluation logic** behind architectural decisions—not on fully specifying or detailing every option or subsystem.

#### Document Structure

To maintain clarity and traceability, this document is structured as follows:

- **Trade Study Context**  
Describes the motivation for the study, outlines its role within the broader project, and identifies system boundaries and known biases.
- **Process Overview**  
Details how the trade-off process evolved, how criteria were selected, and how the tiered evaluation structure was applied.
- **Design Space Exploration**  
Outlines the recovery architecture design space and the taxonomy used to categorize candidate systems. Justifies why some branches are explored in depth while others are not.
- **Design Architecture Selection**  
Explains how Tier 1 and Tier 2 evaluations were conducted, presents the results, and defines the most promising system concepts.

### 6.2 Trade Study Context

#### Motivation for the Trade Study

This trade study was initiated as a core activity of the project scope, recognizing that the selection of the recovery subsystem architecture is a foundational decision with long-term consequences. It will guide technical development, influence integration decisions, and shape the allocation of engineering

and financial resources across future phases. Since the system will ultimately be implemented by student engineers not yet involved in the project, it is critical that the chosen architecture is not only **technically sound**, but also **rigorously justified and thoroughly documented** for continuity. Rather than focusing on detailed design selection, the objective of this trade study is to **establish a robust architectural baseline**. Its outcomes are expected to inform future definition work, investment planning, and more detailed subsystem design. If the trade-off is successful, its results should remain valid throughout downstream development and not need to be repeated—only refined as technical maturity increases.

In addition to supporting the current system-level decision, this trade study was also intended to establish a **structured and adaptable methodology**. The use of tiered evaluation, traceable selection criteria, and performance modeling was designed to allow: - **Adaptation to future changes** in constraints, requirements, or weighting of objectives, as new programmatic or technical information emerges. - **Reusability of the approach** for similar trade-offs in other subsystems or future student-led development phases.

The trade study is therefore positioned not only as a decision-support tool for this specific subsystem, but also as a prototype methodology for consistent, auditable architectural decisions within the broader systems engineering framework of the project.

## Evolution of the Trade-Off Approach

The original plan assumed a **uniform and exhaustive trade study**, in which the full design space would be explored and each option systematically evaluated against quantitative selection criteria before selecting the top-performing architecture. However, as the study progressed, the approach evolved into a **staged and adaptive process** out of both necessity and practicality.

- The **depth of exploration** varied depending on the architecture type: options with clear limitations or lower potential were explored more lightly, while promising branches received more detailed treatment.
- A **preliminary feasibility screening** (Tier 1) was introduced to eliminate clearly non-viable solutions early on. This freed up time and modeling resources for more promising candidates.
- A **refined evaluation phase** (Tier 2) focused on a narrower set of alternatives, applying detailed models, performance metrics, and optimization techniques to assess trade-offs more rigorously.
- Rather than forcing a single “optimal” solution, the final objective became to identify a **set of viable and defensible architectures**, each with distinct trade-offs, to serve as a robust foundation for future design work.

This shift in strategy reflected both the complexity of the design space and the practical constraints of the study. In particular, **tight scheduling and limited engineering bandwidth** were critical drivers. The majority of the trade-off study needed to be completed by the Mission Definition Review, held just five weeks after project kickoff. With much of the early phase consumed by requirements definition—and the project conducted alongside academic coursework—efficiency and prioritization became essential. The staged approach allowed the study to focus effort where it was most impactful, while still delivering strong justifications at each decision point.

## Scope and Boundaries of the Trade Study

This trade study focuses exclusively on the **recovery subsystem** of the Spaceshot rocket, considered as a **Level-1 system**. It does not address the overall rocket architecture (Level-0) or other major subsystems such as avionics or structure. The scope is limited to architectural and functional decisions — specifically, defining the **mission scope**, evaluating alternative **architecture-level**

**options** (e.g., full versus partial recovery, types of decelerators), and recommending a preferred system concept. It does **not** extend to detailed subsystem design, component sizing, or mechanism development.

Within this framing, the trade study **includes**: - Definition of the recovery mission scope. - Architecture-level trade-offs between major solution families. - Initial feasibility assumptions based on existing vehicle geometry, mass properties, and lessons learned from previous projects.

The study **excludes**: - Avionics hardware and software development (e.g., triggering, actuation, telemetry). - Detailed structural integration work (e.g., interface hardware, anchoring mechanisms). - Selection of final hardware technologies, design variables, or sizing of subsystem elements.

In terms of **system assumptions and interfaces**: - Recovery is expected to interface with the **structure, payload, and avionics** subsystems. - No formal interface planes were fixed at the time of the study. Structural assumptions (e.g., maximum allowable loads, preliminary mass budgets) are based on early estimates extrapolated from the Firehorn/Nordend architecture, made prior to formal system (system level 0) Phase 0/A activities. These estimates are appropriate for feasibility studies but are expected to evolve during detailed development phases. - The avionics interface remains undefined. Consistent with historical practices from Nordend and Firehorn, recovery is assumed **not responsible** for avionics hardware or software development; recovery equipment is actuated via avionics systems but developed independently.

The architectural recommendations made in this study are designed to be **compatible with the assumed subsystem interfaces**, while recognizing that formal interface definition will be required in subsequent project phases.

Regarding the **baseline context**, no specific architecture was mandated. However, the recovery solutions implemented in previous rockets — particularly parachute-based recovery with reefing and full vehicle recovery — provided an **established reference baseline** that informed feasibility assumptions and option prioritization.

Finally, although subsystem requirements (values) and interfaces will likely evolve as the Spaceshot system definition matures, the architectural decisions proposed here aim to offer **robustness** against foreseeable changes. Minor adaptations and performance re-validations are anticipated but the core architectural direction is intended to remain valid.

## Role of the Trade-Off in the Overall Project

This trade-off study establishes the architectural baseline for the recovery subsystem of the Spaceshot rocket. It defines a critical decision point that will guide all future subsystem design activities, providing a structured and traceable foundation for subsequent project phases. Beyond selecting a preferred recovery concept, the study formalizes a system-level decision-making framework aligned with ECSS Phase 0/A objectives.

Conducted during Phase 0/A of the overall project and in parallel with feasibility studies for other subsystems, this work takes place approximately five years before the planned launch. Its outputs directly support the Mission Definition Review (MDR) and Preliminary Requirements Review (PRR) and the transition toward Phase A & B activities. The study also leverages lessons learned from the Firehorn I project, ensuring that past experiences inform future architectural decisions.

The study integrates into the broader development at multiple levels: its outputs define recovery system expectations, guide the definition of subsystem interfaces, and reduce architectural uncertainty ahead of detailed design phases. The selected architecture is intended to serve as a stable baseline, with only minor refinements expected unless future developments reveal significant flaws. By establishing early clarity, the study aims to mitigate risks of major architectural changes later in the project.

The primary users of the results will be future recovery subsystem engineering teams, systems engineers defining interfaces and verification strategies, and project management teams planning resources and schedules. The study also demonstrates the use of formal trade-off methods within a student-led project, offering a methodology that can be adapted for future architecture-level decisions and strengthening continuity across project generations.

### Acknowledgment of Potential Bias

In the spirit of transparency, it is important to acknowledge potential sources of cognitive bias that could have influenced the trade-off process and architectural recommendations made in this study. The author previously worked on the **Nordend rocket** as an engineer focused on parachute systems with reefing, and later served as a **systems engineer for the Firehorn I rocket**. During the Firehorn I project, the architectural decisions for the recovery system were made based on more limited trade-off studies and less formal systems engineering processes compared to the approach followed in this study. A parachute-based recovery system incorporating reefing stages was ultimately selected for Firehorn I.

Given this background, there is a recognized risk of **confirmation bias** — a tendency to favor solutions that resemble previously implemented architectures, particularly those involving parachute systems with reefing. Familiarity with these technologies and positive past project experiences could unintentionally influence the assessment of competing options, especially under conditions of limited time or incomplete data.

Mitigation of this bias was attempted through: - Formalization of a structured, tiered evaluation process. - Documentation and transparency of each evaluation step. - Explicit definition and use of objective selection criteria wherever feasible.

Nevertheless, readers and future reviewers should remain aware of this background when interpreting the trade-off outcomes and recommendations.

## 6.3 Process Overview

The trade-off process for the recovery subsystem was structured with two primary objectives: to ensure **traceability and clarity** of the decision-making logic, and to develop a **repeatable, adaptable methodology** for future applications. Recognizing the complexity of early architectural choices and the limited availability of detailed technical data, the process intentionally balanced **qualitative screening** with **quantitative performance evaluation**. This balance allowed efficient resource use without sacrificing decision robustness, particularly under the tight scheduling constraints of the semester project.

The overall process was organized into four sequential phases: - **Design Space Exploration**: Identify the full range of potential architectural options and categorize decisions using a structured taxonomy. - **Selection Criteria Definition**: Define a multi-tiered evaluation framework, linking stakeholder values to screening and scoring criteria. - **Evaluation of Design Solutions**: Apply the criteria in a phased manner—first through qualitative feasibility screening (Tier 1), then through quantitative performance modeling and optimization (Tier 2). - **Recommendations and Conclusions**: Synthesize evaluation outcomes into a set of viable architecture recommendations, each representing a distinct balance of trade-offs.

A visual representation of the process is provided below, illustrating how the design space was progressively narrowed through successive evaluation gates.

### Phase 1: Design Space Exploration

The first phase focused on **mapping the decision landscape**. A design space taxonomy was developed to organize architecture decisions into logical categories (e.g., mission framing choices, decelerator types, deployment methods). Options were sourced through literature reviews, ECSS standards, lessons learned from prior projects (Firehorn, Nordend), and recovery system design manuals. Each option was documented with a description, and initial pros and cons to support downstream evaluation.

### Phase 2: Selection Criteria Definition

Given the diversity and number of possible options, a **two-tiered evaluation system** was defined:

- **Tier 1 criteria** focused on fast, mainly qualitative feasibility screening, allowing early elimination of clearly unsuitable options.
- **Tier 2 criteria** targeted more detailed, quantitative comparison between viable architectures. These criteria related to performance metrics (e.g., mass, structural load, drift distance) that could only be evaluated through modeling.

Selection criteria were linked to high-level stakeholder objectives, ensuring that the architectures retained through the process aligned with the overall mission priorities. Cutoff thresholds were set for certain Tier 1 criteria to allow efficient elimination without requiring exhaustive evaluation of all metrics for low-performing options.

### Phase 3: Evaluation of Design Solutions

In Tier 1, each design option was assessed against the defined feasibility criteria. Options failing to meet the minimum thresholds were documented and discarded, with justification based on engineering judgment and reference sources.

In Tier 2, a **custom analytical model** was developed to simulate the performance of full architecture candidates. This model enabled estimation of key metrics such as drift, system mass and opening loads. A **Genetic Algorithm (GA)** optimization approach was applied to optimize design variables (e.g., deployment altitudes, parachute sizing) for each architecture, allowing fair comparison of optimized candidates rather than arbitrary configurations.

Architectures were then compared using the Tier 2 criteria, focusing on identifying a **set of high-performing solutions** along the Pareto front, each representing different trade-offs between key objectives.

### Phase 4: Recommendations and Conclusions

The trade-off process culminated in the recommendation of **several architectures**, each offering distinct advantages depending on future mission priorities and system evolution. Rather than prescribing a single optimal solution, the study offers a **portfolio of viable choices** that can be refined as constraints, requirements, and available technologies mature.

The structured, tiered methodology is designed to be flexible: while the Tier 1 feasibility screenings are expected to remain stable, Tier 2 evaluations may need adjustment if significant changes occur in system-level requirements or available technologies. Nonetheless, the overall architecture recommendations are intended to provide a robust foundation for recovery system development in subsequent phases.



## 6.4 Design Space Exploration

This section presents the full range of architectural and technological options considered for the recovery subsystem. It defines the “design universe” from which all later trade-off decisions are drawn, serving as the foundation for the Tier 1 and Tier 2 evaluation phases.

The primary goal of this section is to ensure **transparency, traceability, and breadth** in the decision-making process. Each option is described and categorized to allow downstream reviewers, engineers, and decision-makers to understand what was considered, why it was included, and how it compares to other alternatives. The design space exploration also supports future re-evaluation by providing a well-documented set of baseline possibilities.

Only **design decisions** are included here. These define how a recovery architecture is conceptually framed. This section does **not** cover **design variables**, which are quantitative parameters (e.g., geometry or timing values) optimized later through simulation and analytical modeling.

The design space includes: - **Mission-level framing decisions** (e.g., full vs. partial recovery) - **Decelerator types** (e.g., parachutes, IADs, propulsive systems) - **Deployment and enabling mechanisms** (e.g., reefing, clustering, flat-spin deployment)

Excluded from this section are subsystem-level implementation details and numerical design parameters, which are evaluated separately during performance modeling.

The **depth of exploration** is not uniform across all categories. Certain branches—such as parachute technologies—were investigated more thoroughly based on: - Prior team experience (e.g., Nordend, Firehorn) - Preliminary feasibility and maturity - Relevance to likely candidate architectures

In contrast, less common or less feasible branches, such as helicopter-based recovery or propulsive landing, were included with minimal detail.

This design space forms the **core input** to the trade-off process. A total of **22 decision categories** and **137 decision options** are captured. These are progressively filtered through Tier 1 evaluation and used to construct candidate architectures for Tier 2 modeling and optimization.

### Design Space Taxonomy

To structure the wide variety of architectural decisions involved in recovery system design, a **design space taxonomy** was developed. This taxonomy serves multiple purposes: it helps **organize the decision space**, supports **modular documentation**, and clarifies how different design elements relate to one another. It also improves **traceability** across the evaluation and documentation process. Each design decision category is tagged with three **attribute labels**: - **Level** — describes the abstraction tier of the decision. - **Role** — captures the logical function or purpose of the decision in the trade-off. - **Type** — indicates whether the decision introduces a new design path or modifies an existing one.

These attributes were **not used directly in the evaluation process**, but they improve documentation clarity and may support future decisions around **responsibility assignment** (e.g., which subsystem team owns the decision) or **sequencing** (e.g., which decisions must be made early in the design process).

### Attribute Definitions



Attribute	Definition	Possible Values
<b>Level</b>	Describes the structural tier of the design decision in the system hierarchy, from broad mission choices to specific implementations.	Tier-0 Mission Framing, Tier-1 Architectural Structure, Tier-2 Technology Group, Tier-3 Implementation Detail
<b>Role</b>	Describes the logical function or purpose of the design decision (i.e., what kind of reasoning or input governs it).	Principle, Architecture Decision, Technology, Configuration, Constraint, Design Strategy
<b>Type</b>	Describes how the decision behaves in the design space—either by introducing a new path (Driver) or tuning an existing one (Modifier).	Set Driver, Set Modifier

### Attribute Option Definitions

Attribute	Option	Definition
<b>Level</b>	<b>Tier-0 Mission Framing</b>	High-level decisions about mission intent, operating environment, and core system behavior.
	<b>Tier-1 Architectural Structure</b>	Defines the major system architecture, overall recovery configuration, and structural breakdown.
	<b>Tier-2 Technology Group</b>	Represents families of candidate technologies within an architecture or subsystem.
	<b>Tier-3 Implementation Choice</b>	Focuses on detailed technology selection, parameter tuning, configuration logic, and subsystem integration.
<b>Role</b>	<b>Principle</b>	A guiding physical or operational concept that constrains or initiates downstream design logic.
	<b>Architecture Decision</b>	A major system design choice shaping overall structure and behavior.
	<b>Technology</b>	A selectable technology or method available within a given architecture.
	<b>Configuration</b>	A tunable parameter, quantity, or structural choice used to adjust a selected system or technology.
	<b>Constraint</b>	A condition or requirement derived from mission, safety, or system-level limitations.
<b>Type</b>	<b>Design Strategy</b>	A cross-cutting design logic or integration pattern that governs how elements interact or are grouped.
	<b>Set Driver</b>	Creates a new design branch with cascading influence on other decisions.
	<b>Set Modifier</b>	Refines or tunes an existing design branch without changing the overall design path.

## Overview of Design Decision Categories

The recovery system design space was decomposed into **22 distinct decision categories**, each associated with a specific role and abstraction tier in the design hierarchy. These categories were classified using the attribute taxonomy described in the previous section: **Tier**, **Role**, and **Type**. The table below summarizes all identified decision categories:

Category Name	Tier	Role	Type
Mission Scope	Tier-0 Mission Framing	Architecture Decision	Set Driver
Decelerator Type	Tier-0 Mission Framing	Principle	Set Driver
Landing Zone	Tier-0 Mission Framing	Architecture Decision	Set Driver
Aero Dynamic Decelerator Types	Tier-1 Architectural Structure	Architecture Decision	Set Driver
Partial Recovery Types	Tier-1 Architectural Structure	Architecture Decision	Set Driver
Full Recovery Types	Tier-1 Architectural Structure	Architecture Decision	Set Driver
Orientation at Touchdown	Tier-1 Architectural Structure	Architecture Decision	Set Driver
Recovery Module Storage Area(s)	Tier-1 Architectural Structure	Architecture Decision	Set Driver
Solid Textile Parachute Types	Tier-2 Technology Group	Technology	Set Driver
Slotted Parachute Types	Tier-2 Technology Group	Technology	Set Driver
Rotating Parachutes	Tier-2 Technology Group	Technology	Set Driver
Maneuverable (Gliding) Parachutes	Tier-2 Technology Group	Technology	Set Driver
Inflatable Aerodynamic Decelerators Types	Tier-2 Technology Group	Technology	Set Driver
Attached IAD	Tier-2 Technology Group	Technology	Set Driver
Trailing IAD	Tier-2 Technology Group	Technology	Set Driver
Impact Attenuation Systems	Tier-3 Implementation Choice	Technology	Set Modifier
Buoyance Device	Tier-3 Implementation Choice	Technology	Set Modifier
Reefing	Tier-3 Implementation Choice	Technology	Set Modifier
Deployment Mechanism	Tier-3 Implementation Choice	Technology	Set Modifier
Clustering	Tier-3 Implementation Choice	Design Strategy	Set Modifier
Supersonic Deployment Requirement	Tier-3 Implementation Choice	Constraint	Set Modifier
Flat-Spin	Tier-3 Implementation Choice	Constraint	Set Modifier
Number of Stages	Tier-3 Implementation Choice	Configuration	Set Modifier

This classification enables consistent referencing throughout the evaluation process and supports **layered design analysis**.

## Sources and References

The recovery system design options were identified and documented using a broad range of sources. These sources include: - **Past EPFL Rocket Team projects**, such as *Firehorn* and *Nordend*, which provided firsthand engineering experience and served as contextual baselines. - **External literature and studies**, which expanded the range of candidate technologies and offered insights into modeling practices and historical implementations. - **Design handbooks** and technical manuals that formalize recovery system engineering practices and standard architectures.

No formal weighting or ranking was assigned to the sources. Internal knowledge (from *Firehorn* and *Nordend*) was treated with the same consideration as external sources.

**Note:** The sources listed below were primarily used to define and describe the **design options** themselves. Other references—such as performance evaluations, modeling techniques, or historical applications—are cited in the individual design option pages or referenced during the evaluation phase.

ID	Title	Type
1	Design of a Helicopter System Recovery for a Sounding Rocket, Caldeira et al. [2024]	Paper (Research)
2	Parachute Recovery Systems, Knacke [1992]	
3	Flat-Spin Recovery System, Fall [1964]	Paper (Application Technique)
4	Supersonic Inflatable Aerodynamic Decelerators for use on Sounding Rocket Payloads, Miller et al. [2023]	Paper (Technology Assessment)
5	Estimating Mass of Inflatable Aerodynamic Decelerators Using Dimensionless Parameters, 8th [2011]	Paper (Mass Estimation Technique)
6	A Historical Review of Inflatable Aerodynamic Decelerator Technology Development, Smith et al. [2010]	Paper (Historical Review of Technology Development)
7	STATE-OF- THE-ART STUDY FOR HIGH-SPEED DECELERATION AND STABILIZATION DEVICES, C and A [1966]	Study (State of The Art)
8	Comparison of Various Parachute Deployment Systems for Full Rocket Recovery of Sounding Rockets, EUC [2019]	Paper (Architecture Selection)

## Design Decision Tables

This section presents the full set of design options identified during the **Design Space Exploration** phase. Each **decision category**—representing a specific architectural or technological choice—is documented using a standardized table format. These tables provide a **side-by-side overview** of the options available, along with their key attributes and trade-offs.

Each table includes: - A **short description** of the option. - The **primary sources** that informed its identification or rationale. - A summary of **pros**, **cons**, and **main risks** associated with the option. - Where applicable, a **diagram or sketch**.

The purpose of these tables is strictly **exploratory**: - No filtering, selection, or prioritization is applied at this stage. - All options are retained.

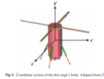
The following pages include one table per design decision category.

## Mission & Architectural Choices

### Mission Scope

File (2)	Source	Description	Pros	Cons	Risks	Diagram / Image
<a href="#">Full Recovery</a>	-	Recover the entire rocket, including propulsion and structural systems.	Enables full post-flight analysis; minimizes environmental pollution; enables public display or reuse.	Increased weight and system complexity; may reduce payload capacity.	System may exceed mass or complexity limits; difficult to qualify under tight development timelines.	
<a href="#">Partial Recovery</a>	-	Recover only part of the rocket (e.g. payload or avionics).	Lighter system; fewer subsystems to develop; lower cost.	Loss of valuable hardware; less comprehensive post-flight data.	Local regulations may prohibit uncontrolled impact of unrecovered parts.	


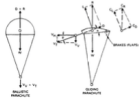
### Decelerator Type

File (3)	Source	Description	Pros	Cons	Risks	Diagram / Image
<a href="#">Aero Dynamic Decelerator</a>	-	Uses parachutes, ballutes, or inflatable drag surfaces to increase drag and slow descent through atmospheric braking.	Well-understood, flight-proven system; lightweight and passive; low power demand.	Performance strongly dependent on atmospheric density and dynamic pressure profiles.	Over-constrains flight profile (e.g., coast phase duration); risk of failed deployment.	
<a href="#">Helicopter System Recovery</a>	-	Recovery using rotary wings via the autorotation phenomenon, enabling controlled, safe landings and potential system reuse. Offers flexibility in mission planning and can support applications like atmospheric research thanks to adjustable descent profile.	Flexible mission concepts; potential for reusability; controllable descent path.	No spaceflight heritage; may be aerodynamically unstable at high speed.	Too complex to develop within current team and time constraints.	
<a href="#">Propulsive Landing</a>	-	Landing using engine reignition with thrust vector control (TVC) and aerodynamic control surfaces to decelerate and stabilize descent.	Enables highly precise landings; no need for a large landing zone.	Extremely complex and expensive; requires real-time engine control and redundancy.	Too complex to develop with available resources and time.	

### Landing Zone

File (2)	Source	Description	Pros	Cons	Risks	Diagram / Image
<a href="#">Impact on Land</a>	-	Final touchdown occurs on solid terrain (e.g. desert or field).	Easier to locate and recover post-landing; vehicle remains stationary; accessible by ground vehicle.	May require an impact attenuation device to reduce damage on impact.	Possible structural damage on hard surface; may destroy part of the rocket.	
<a href="#">Impact on Water</a>	2	Final touchdown occurs on water.	Allows for harder landings with reduced structural damage; potentially softer deceleration.	May require a buoyancy device to remain afloat; adds complexity.	If buoyancy system fails, rocket could sink and be unrecoverable.	

## Aero Dynamic Decelerator Types

File (5)	Source	Description	Pros	Cons	Risks	Diagram / Image
<a href="#">Inflatable Aerodynamic Decelerators</a>	2, 4	Inflatable drag devices (e.g., ballutes, IADs) that deploy and inflate to increase drag during descent. Useful in thin atmospheres or high-altitude entry.	Low mass; compact storage; scalable; effective at high speeds and altitudes.	Complex inflation system; sensitive to aerodynamic heating and flutter.	Failure to fully inflate can result in insufficient deceleration or instability.	
<a href="#">Maneuverable Parachute</a>	2	Gliding parachutes capable of controlled turning and forward flight, enabling guided landings to target zones. Used in sport and precision recovery applications.	Can steer toward target; extended glide range; enables soft landings.	Larger footprint; reduced drag compared to traditional parachutes.	Requires active guidance or skilled control to ensure accuracy.	
<a href="#">Rotating Parachute</a>	2	Features angled vents or asymmetric shapes to generate rotation, improving stability and increasing projected area through centrifugal force.	High drag coefficient; stabilizing spin; good for compact deployment.	Difficult to scale up; complex suspension geometry; deployment failures at large size.	Wrap-up of canopy or failed spin initiation can cause total failure.	
<a href="#">Slotted Parachute</a>	2	Uses slits or openings to control porosity and improve performance across various Mach regimes. Includes ribbon, ringslot, ringsail, and disk-gap-band variants.	Tunable performance; can operate at subsonic and supersonic speeds; reduces canopy stress.	Requires careful porosity selection; more complex manufacturing.	Improper porosity may result in excessive opening forces or low drag performance.	
<a href="#">Solid Textile Parachute</a>	2	Classic non-porous fabric parachute type (e.g. flat circular, hemispherical), traditionally used for descent and recovery. Offers high drag performance and simple deployment.	Proven and widely used; reliable; simple construction.	Can have poor stability; limited supersonic capability.	Risk of canopy collapse or oscillation if not properly reefed or sized.	

## Partial Recovery Types

File (3)	Source	Description	Pros	Cons	Risks	Diagram / Image
<a href="#">Recover Nosecone and Avionics</a>	-	The nosecone and avionics are recovered together as a single unit.	Balances mass and value retention; retains both data and payload.	Slightly heavier recovery system	-	
<a href="#">Recover only Avionics System</a>	-	Only the avionics bay (flight computer, sensors, etc.) is recovered.	Preserves critical flight data; small recovery system; low mass.	Payload is lost	-	
<a href="#">Recover only Nosecone</a>	-	Only the nosecone containing the payload, is recovered.	Minimizes recovery system mass; protects valuable payload; simple.	Avionics and propulsion systems are lost; limited data retrieval.	-	

## Full Recovery Types

File (3)	Source	Description	Pros	Cons	Risks	Diagram / Image
<a href="#">Multi-Bodied Recovery</a>	-	The rocket separates into multiple modules, each with its own dedicated recovery system.	Modular; optimized recovery per module; scalable architecture; allows decoupling recovery of propulsion stage later in development.	Increased complexity; Two recovery systems.	Timing issues or misdeployment could result in collision or incomplete recovery.	
<a href="#">No Rocket Separation</a>	-	The entire rocket descends as a single rigid body, without separating into stages or modules.	-	High mass. Larger aerodynamic decelerator required.	-	
<a href="#">Separate rocket but keep both bodies attached to a single recovery system</a>	-	The rocket separates (e.g., nosecone and body), but both parts remain connected via a common parachute system.	Single recovery system; reduced chute mass compared to multi-body recovery;	Complex rigging;	Failure of tether or imbalance could cause collision or spin during descent.	

## Driving Technology Choices

### Solid Textile Parachute Types (Source ID: 2)

Type	Constructed Shape (Dc/D0)	Inflated Shape (Dp/D0)	Drag Coef. CD Range	Opening Force Coef. COE (1/Mass)	Avg. Angle of Oscillation (°)	General Application	Diagram / Image
Flat Circular	1.00	0.67 – 0.70	0.75–0.8	~1.7	±10 to ±40	Descent, Obsolete	
Conical	0.93 – 0.95	0.70	0.70–0.9	~1.8	±10 to ±30	Descent, M < 0.5	
Biconical	0.90 – 0.95	0.70	0.70–0.92	~1.8	±10 to ±30	Descent, M < 0.5	
Triconical Polyconical	0.90 – 0.95	0.70	0.80–0.96	~1.8	±10 to ±20	Descent, M < 0.5	
Extended Skirt 10% Flat	0.86	0.66 - 0.70	0.78–0.87	~1.4	±10 to ±15	Descent, M < 0.5	
Extended Skirt 14.3% Full	0.81 – 0.85	0.66 - 0.70	0.75–0.90	~1.4	±10 to ±15	Descent, M < 0.5	
Hemispherical	0.71	0.66	0.62–0.77	~1.6	±10 to ±15	Descent, M < 0.5, Obsolete	
Guide Surface (Ribbed)	0.63	0.62	0.28–0.42	~1.2	0 to ~2	Stabilization, Drogue, 0.1 < M < 1.5	
Guide Surface (Ribless)	0.66	0.63	0.30–0.34	~1.4	0 to ~3	Pilot, Drogue, 0.1 < M < 1.5	
Annular	1.04	0.94	0.85–0.95	~1.4	<~5	Descent, M < 0.5	
Cross	1.15 – 1.19	0.65 - 0.72	0.60–0.85	1.1 to 1.2	0 to ~3	Descent, Deceleration	















### Slotted Parachute Types (Source ID: 2)

Type	Inflated Shape (Dp/D0)	Inflated Shape (Dp/D0)	Drag Coef. CD Range	Opening Force Coef. COE (1/Mass)	Avg. Angle of Oscillation (°)	General Application	Diagram / Image
Flat (Fist%) Ribbon	1.00 – 0.87	0.67	0.45–0.5	~1.05	0 to ±3	Drogue, Descent, Deceleration, Obsolete	
Conical Ribbon	0.93 – 0.70	0.70	0.50–0.55	~1.05	0 to ±3	Descent, Deceleration, 0.1 < M < 2.0	
Conical Ribbon (Varied Porosity)	0.90 – 0.70	0.70	0.55–0.80	1.05 to 1.30	0 to ±3	Drogue, Descent, Deceleration, 0.1 < M < 2.0	
Ribbon Hemisflo	0.71 – 0.62	0.62	0.30–0.46	1.00 to 1.30	~2	Supersonic, Drogue, 1.0 < M < 3.0	
Ringslot	0.86 – 0.75	0.67 to 0.70	0.57–0.65	~1.05	0 to ±5	Extraction, Deceleration, 0.1 M < 0.9	
Ringsail	0.86 – 0.75	0.69	0.75–0.85	~1.10	±5 to ±10	Descent, M < 0.5	
Disc-Gap-Band	0.73 – 0.65	0.	0.52–0.58	~1.30	±10 to ±15	Descent, M < 0.5	

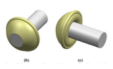
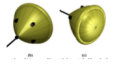
### Rotating Parachutes (Source ID: 2)

Type	Constructed Shape D <sub>t</sub> /D <sub>D</sub>	Inflated Shape D <sub>p</sub> /D <sub>o</sub>	Drag Coef. CDn Range	Opening Force Coef. C <sub>x</sub> (1/Mass)	Avg. Angle of Oscillation (°)	General Application	Diagram / Image
Rotafoil	1.0	~0.90	0.85–0.99	1.05	±2	Drogue, D0 < 7	
Vortex Ring	1.9	N/A	1.5–1.8	1.1 – 1.2	±2	Descent, Small D0	
Sandia RFD	1.0	~0.9	1.25	1.1	±2	Drogue	


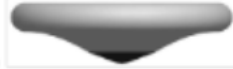

## Manoeuvrable (Gliding) Parachutes (Source ID: 2)

Type	Area Ratio ( $S_w/S_0$ )	CR Range	Glide Ratio (L/D) Max	General Application	Diagram / Image
Tojo, TU Slots, etc.	1.0	0.85–0.90	0.5–0.7	Descent	 
LeMoigne (Paracommander)	1.0	0.90–1.00	1.1	Descent	 
Parawing (Single Keel)	1.0	0.90–1.10	2.0–2.5	Descent	 
Parawing (Twin Keel)	1.0	1.00–1.10	2.8–3.0	Descent	 
Parafoil	0.27	0.75–0.85	2.8–3.5	Descent	 
Sailwing	0.80–0.90	N/A	2.8–3.5	Descent	 
Volplane	0.60	N/A	2.0–3.0	Descent	 

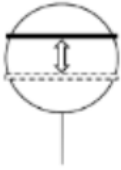

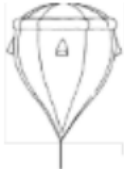

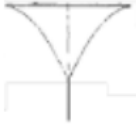
## Inflatable Aerodynamic Decelerators Types

File (2)	Source	Description	Pros	Cons	Risks	Diagram / Image
<a href="#">Attached IAD</a>	6	An inflatable aerodynamic decelerator directly connected to the vehicle structure. It inflates to increase drag during atmospheric entry.	Compact and structurally simple. Enables earlier deployment.	Exposed directly to high-speed flow and heating. Higher drag in transonic regime than trailing types.	Fabric damage due to high thermal and aerodynamic loads. Risk of structural failure during inflation.	
<a href="#">Trailing IAD</a>	6	A decelerator that trails behind the vehicle and inflates within the wake region. Typically connected via a towline to take advantage of reduced dynamic pressure.	Better thermal and aerodynamic environment due to wake shielding. Lower drag in transonic regime. Uses less material for equal performance in some scenarios.	Requires a long towline, increasing system mass. More complex deployment dynamics.	Risk of entanglement or towline failure. Inadequate drag if inflation fails.	

## Attached IAD

Type	Source ID	Description	Pros	Cons	Risks	Diagram / Image
Stacked-Toroid	5					 Stacked Toroid Blunted Cone
Tension Cone	5					 Tension Cone
Isotenoid	6					 Isotenoid

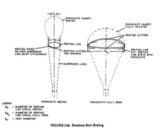
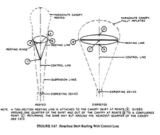
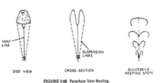
## Trailing IAD

Type	Source ID	Description	Pros	Cons	Risks	Diagram / Image
Sphere w/Fence	2, 6					 <p>Sphere w/Fence</p>
Teardrop W/Fence	6					 <p>Teardrop w/Fence</p>
Isotensoid	6, 4					 <p>Isotensoid</p>
Torus	6					 <p>Torus</p>
Tension cone	6					 <p>Tension Cone</p>




## Set Modifiers

### Reefing

File (7)	Source	Description	Pros	Cons	Risks	Diagram / Image
<a href="#">Continuous Disreefing</a>	2	Concept where reefing follows a force-time profile via automated line payout. Investigated but not operationalized.	Theoretically allows smooth, optimized inflation.	No practical implementation to date.	Development complexity; unproven reliability.	
<a href="#">Fixed Pocketband Reefing</a>	2	Used in high-porosity ribbon/ringslot parachutes to stabilize inflation when porosity exceeds limits.	Improves stability for specific porosities.	Limited to niche cases; lacks inflation control flexibility.	May hinder proper deployment if misapplied.	
<a href="#">No reefing</a>	2	Parachute deploys to full inflation without any staged delay.	Simplest deployment system; fewer failure points.	High opening shock; unsuitable for high-speed descents.	May exceed structural limits or cause failure at deployment.	
<a href="#">Skirt Reefing</a>	2	The most common reefing technique where rings and a continuous reefing line restrict canopy opening. Reefing cutters release the line to allow gradual deployment.	Widely used; effective force control; compatible with many canopy types.	Requires pyrotechnic cutters and control systems.	Cutter failure may prevent full deployment or cause premature inflation.	
<a href="#">Skirt Reefing with Control Line</a>	2	Uses a two-section reefing line guided around the canopy and controlled by a single line for manual or sensor-based disreefing.	Allows continuous or dynamic reefing;	Complex routing and tension balancing.	May fail to disreef if control line does not payout properly.	
<a href="#">Slider Reefing</a>	2	A slider (fabric with grommets) passes over suspension lines to delay canopy inflation. Common in sport gliders.	Simple, reusable.	Not suitable for high-speed or large cargo applications.	-	
<a href="#">Vent Reefing</a>	2	A line is attached to the center of the parachute vent; pulling it reduces drag area and increases drag coefficient temporarily.	Allows high drag configurations; suitable for annular/airfoil types.	Complex actuation; risks suspension line wrap.	-	

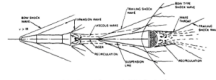
### Deployment Mechanism

File (5)	Source	Description	Pros	Cons	Risks	Diagram / Image
<a href="#">Deployment by Rocket Extraction</a>	2	A rocket pulls the parachute bag, enabling line-first deployment.	Clean, controlled deployment; minimizes forces on the vehicle.	Requires careful integration of rocket components; thermal protection for nearby elements; requires extra pyrotechnics; requires extra safety procedure	Rocket malfunction could result in no deployment or damage to the vehicle or parachute.	
<a href="#">Drogue Gun</a>	2	A drogue gun operates like a pistol, with a piston-fired slug that ejects from the vehicle upon command. This slug travels into clean airflow behind the vehicle and pulls a bridle that either deploys the pilot chute directly or extracts a deployment bag containing it.	Simple and compact	Limited energy compared to mortars; can only handle lighter parachutes.	Misfire or misalignment can prevent clean extraction.	
<a href="#">No Deployment Mechanism</a>	2	Parachute is deployed by environmental forces alone (e.g., gravity or airflow after ejection).	Simplifies system; fewer failure modes.	Less predictable behavior; complex to design for consistent deployment; not adapted for deploying from spinning or tumbling systems or systems with large forebody	Risk of delayed or no deployment due to orientation or airflow conditions.	
<a href="#">Parachute Mortar</a>	2	A cannon-like deployment that fires the parachute assembly away from the wake into clear airflow, using inertia rather than pull.	Very powerful; can deploy heavy parachutes reliably from unstable orientations.	High reaction force on vehicle; bulky and heavy system.	Damage from recoil, or incomplete bag strip if not enough velocity.	
<a href="#">Static-Line Deployment</a>	2	A fixed-length cord connects the parachute to the rocket, automatically extracting it when the nosecone separates.	Very reliable for low-altitude or short-delay deployments.	No control over timing once released; line must be correctly sized and routed.	Entanglement if line tension isn't sufficient or geometry isn't controlled.	


### Clustering

File (2)	Source	Description	Pros	Cons	Risks	Diagram / Image
<a href="#">Clustering</a>	2	A parachute cluster consists of two or more parachutes used to stabilize, decelerate, or lower a payload or air vehicle. It allows distribution of load across multiple canopies.	Easier fabrication, rigging, and handling; supports wide payload ranges; higher system reliability; improved descent stability; shorter filling time than single large parachutes	Increased complexity in deployment; synchronization issues; drag reduction due to interference; higher total weight and volume; variation in disreef times; lead/lag inflation risks	Asynchronous inflation can cause line entanglement, increased loads on early-opening parachutes, and potential canopy collisions.	
<a href="#">No Clustering</a>	2	The system uses a single large parachute to handle the full recovery load instead of distributing it across several smaller chutes.	Simpler deployment system; avoids synchronization issues;	Harder to fabricate, rig, and handle; lower redundancy; greater consequences if the parachute fails	Higher risk of complete failure in case of malfunction or misdeployment of the single canopy.	

## Supersonic Deployment Requirement

File (2)	Source	Description	Pros	Cons	Risks	Diagram / Image
<a href="#">Subsonic Deployment</a>	2	Systems that require deployment below Mach 1. Simplifies deployment environment.	Less demanding materials	May constrain trajectory profile	Limits coast or reentry time flexibility	 <p>FIGURE 146: Supersonic Flow Around a Vehicle Reentry Body</p>
<a href="#">Supersonic Deployment</a>	2	Systems that can deploy at Mach 1+ speeds. Enables high-speed missions and reduces coast time.	Higher entry speed possible	Requires high strength and thermal protection	Risk of deployment failure or structural failure	

## Flat-Spin

File (2)	Source	Description	Pros	Cons	Risks	Diagram / Image
<a href="#">Flat Spin</a>	3	The recovered body is aerodynamically unstable, causing it to enter a controlled tumble or spin during descent. This increases drag and reduces speed.	Reduces ballistic coefficient; lowers parachute inflation loads; no need for active stabilization.	Difficult to control trajectory precisely; spin may damage sensitive internal components; Requires a deployment mechanism for the recovery system.	-	
<a href="#">No Flat Spin</a>	2	The recovered body is aerodynamically stabilized to prevent tumbling or spinning during descent, resulting in a more controlled reentry profile.	Predictable flight path;	Higher parachute inflation loads.	-	

## Number of Stages

File (2)	Source	Description	Pros	Cons	Risks	Diagram / Image
<a href="#">Multi-Stage</a>	-	Uses at least two stages (e.g., drogue + main) to decelerate.	Optimized for speed control and safe landing.	More complex sequencing; more mass.	Deployment timing failure could lead to system loss.	
<a href="#">Single-Stage</a>	-	A single recovery system handles deceleration and landing.	Simpler, fewer parts; less potential failure points.	May not handle high-speed or heavy payload well.	Too fast or too unstable descent; harder landing.	

## Impact Attenuation Systems

File (5)	Source	Description	Pros	Cons	Risks	Diagram / Image
<a href="#">Air Bags</a>	2	Inflatable textile bags that absorb impact by controlled gas compression and venting. Stored deflated and inflated just before ground contact.	Reusable; compact storage; adjustable design; efficient energy absorption per unit weight.	Complex inflation and venting system; tuned to a specific energy level.	Over- or under-inflation can cause bounce, underperformance, or early termination of descent.	
<a href="#">Crushable Impact Attenuators</a>	2	Use materials like aluminum honeycomb, foam, or paper that deform on impact to absorb energy. Often used for cargo drops and primarily absorb vertical energy.	Simple; no active systems; good for heavy payloads; lightweight for absorption effectiveness.	Not reusable; limited to one-time use; bulky when unpacked.	If material fails or is over-compressed, insufficient energy absorption may occur.	
<a href="#">No Impact Attenuation</a>	-	No impact attenuation system is used; relies solely on parachute or aerodynamic braking for safe touchdown.	Simplifies recovery system; no extra mass or components.	High loads on structure; limits landing surface options.	High risk of structural damage or loss depending on descent speed and surface condition.	
<a href="#">Retrorocket</a>	2	Use downward-facing rockets to decelerate the vehicle just before touchdown. Suited for high-mass landers requiring low impact acceleration.	High energy-to-weight ratio; allows very low impact velocity; deployable before ground contact.	Requires precise timing and ignition; adds mass and complexity.	Misfire or mistiming could lead to excessive impact velocity or hard landing.	
<a href="#">Skirt Jet Retrorocket</a>	2	A retrorocket concept where slotted rocket tubes are arranged around the vehicle's skirt to direct thrust close to the ground, improving efficiency. Tested for the Apollo command module.	-	Experimental; less flight heritage; complex nozzle integration.	Poor thrust alignment could destabilize descent or induce tilt at touchdown.	

## Buoyance Device

File (2)	Source	Description	Pros	Cons	Risks	Diagram / Image
<a href="#">Buoyance Device</a>	-	A dedicated system (e.g., inflatable bags or flotation structures) added to keep the rocket afloat after water landing.	Protects hardware from submersion.	Adds weight and complexity; requires deployment or inflation system.	Failure to deploy or puncture may result in sinking or total loss.	
<a href="#">No Buoyance Device</a>	-	The rocket structure is designed to be naturally buoyant without additional flotation mechanisms.	Simpler and lighter; no separate system needed.	Limited buoyancy margin; may not perform well in rough sea states.	Risk of partial submersion or tipping, making recovery difficult.	

## Summary and Transition

The design space established in this section includes **137 distinct options** distributed across **22 decision categories**, covering a wide range of architectural strategies, enabling technologies, and

mission framing choices. This extensive mapping reflects the diversity of potential recovery approaches and ensures that no viable concept is prematurely excluded from consideration.

While the **level of detail varies** between categories—depending on perceived feasibility, historical relevance, and available information—all options were retained at this stage to promote **completeness and traceability**. Some paths are more mature and better understood; others are exploratory or speculative, but included to preserve openness in the early phases of system definition.

In the sections that follow, this design universe will be **progressively refined** through feasibility screening (Tier 1), performance-based evaluation (Tier 2), and synthesis of recommended architectures. The goal is to transition from this broad exploratory baseline to a focused set of **justified and robust architecture options** aligned with project needs and constraints.

## 6.5 Selection Criteria Definition

### Purpose of Selection Criteria

Selection criteria provide a **structured and traceable basis** for comparing design options throughout the trade study. They enable consistent evaluation and justification by translating stakeholder needs and abstract project objectives into measurable metrics.

By defining criteria early, the study ensures that filtering and scoring are applied systematically, allowing for consistent comparisons and well-documented decisions—especially important in early-phase studies with limited time and modeling resources.

### Stakeholder Involvement and Derivation Process

The selection criteria were developed through early discussions with systems engineers from the EPFL Rocket Team, who served as the primary stakeholders for this study. Their goals and concerns—such as minimizing development risk—were formally captured in the Project Requirements Document and used as the foundation for defining evaluation metrics.

Qualitative objectives like “**reduce development complexity**” were transformed into more operational proxies such as **Technology Readiness Level (TRL)**, allowing for easier and more consistent evaluation. In parallel, performance-driven criteria such as **system mass**, **volume**, and **drift distance** were included to assess the functional viability and effectiveness of candidate architectures. Some selection criteria exhibit clear dependencies or partial overlaps—for example, multiple metrics may reflect different aspects of system complexity. These interrelations were acknowledged during the definition process, but no attempt was made to de-correlate or consolidate them. The criteria were instead treated as complementary indicators, each offering a distinct perspective on stakeholder priorities or design implications. This approach favors transparency and traceability, even at the cost of introducing some redundancy.

The criteria were reviewed during academic supervision meetings and formal milestone reviews. While no formal validation mechanism was used, this feedback loop helped clarify definitions and ensured alignment with stakeholder expectations. Explicit weighting of criteria was not implemented in this iteration of the trade study but may be introduced in future phases.

### Rationale for a Multi-Tier System

A single-tier evaluation framework was initially considered but quickly dismissed due to its practical limitations. Evaluating every technology or architecture with full modeling would have required disproportionate effort, while relying solely on qualitative scoring would have reduced the precision and credibility of later-stage decisions.

Instead, a **two-tier evaluation system** was adopted to balance analytical rigor with time and resource constraints. **Tier 1** enables rapid screening of design options using qualitative or easily assessable criteria, allowing clearly unsuitable or infeasible solutions to be eliminated early. **Tier 2** focuses on a reduced set of viable architectures, applying detailed modeling, simulation, and optimization to compare their performance.

This approach avoids unnecessary modeling work on poor candidates while preserving in-depth evaluation for high-potential solutions, ensuring both efficiency and decision quality.

### Definition of Tier 1 Criteria

**Tier 1 criteria** serve as a first-level filter for individual technologies and design options. They are qualitative or low-effort metrics that assess fundamental feasibility, maturity, and resource requirements. These criteria were applied at the **individual technology level**, not at the level of full system architectures.

The primary goal of Tier 1 evaluation is to eliminate clearly unsuitable or low-potential options before committing effort to detailed modeling. This includes technologies that:

- Violate project constraints (e.g., too immature or costly).
- Offer significantly lower performance relative to alternatives.
- Impose high development complexity or integration risk.

**Cutoff Logic** Not all Tier 1 criteria were applied uniformly across every option. Instead, a **cutoff-based logic** was used:

- If a **single Tier 1 criterion** scored below an acceptability threshold, the technology was typically **removed from further study**.
- These thresholds were set based on engineering judgment:
- Some were **strict and binary** (e.g., TRL too low to ensure reliability).
- Others were **relative or comparative** (e.g., significantly heavier than competing options).

This screening process ensured that resources were focused on options that were feasible, promising, and aligned with project needs.

## Tier 1 Selection Criteria

Criteria	Value Type	Description	Justification	Applied To
TRL (Technology Readiness Level) Outside of The EPFL Rocket Team	Qualitative (e.g., TRL 1-9)	Maturity level of the technology based on external developments.	Ensures that the technology is sufficiently mature and proven outside of the team. Reduces risk of adopting unproven solutions.	Technology
TRL (Technology Readiness Level) at The EPFL Rocket Team	Qualitative (e.g., TRL 1-9)	Internal maturity level based on prior experience within the team.	Accounts for the team's experience and familiarity with the technology, impacting development effort and risk.	Technology
Development Complexity	Qualitative (High / Medium / Low)	Estimated complexity and effort required to develop the technology.	High development complexity increases schedule and resource risks.	Technology
COTS Solution Availability	Qualitative (Yes / Partial / No)	Availability of Commercial Off-The-Shelf solutions for the technology.	Presence of COTS solutions can provide a low-risk backup option or reduce development effort if needed.	Technology
Weight Efficiency (Relative)	Relative Ranking (1st, 2nd, ...)	Relative ranking of weight efficiency across all evaluated technologies.	Weight directly impacts rocket performance and recovery system effectiveness. Helps eliminate excessively heavy solutions.	Technology
Volume Efficiency (Relative)	Relative Ranking (1st, 2nd, ...)	Relative ranking of volume efficiency across all evaluated technologies.	Volume constraints are critical in small-scale rocketry. This criterion helps filter out bulky solutions early.	Technology
Development Cost Estimate	Qualitative (High / Medium / Low)	Estimated development cost of the technology.	Allows early filtering of technologies that would require unsustainable development budgets or effort.	Technology

## Definition of Tier 2 Criteria

**Tier 2 criteria** are applied at the **system architecture level**, once candidate technologies have passed Tier 1 screening and have been assembled into full recovery concepts. These criteria evaluate the combined performance, feasibility, and complexity of integrated systems—each consisting of a set of interacting technologies, design choices, and operating assumptions.

Unlike Tier 1, which focuses on early-stage filtering, Tier 2 introduces **both quantitative and qualitative metrics** that require in-depth modeling, estimation, or system-level analysis. The evaluation of Tier 2 criteria is supported by a dedicated **performance modeling tool**, introduced in a later section, which allows simulation of recovery behavior and estimation of key performance metrics.

Tier 2 evaluation is used to:

- Compare **complete system architectures** on the basis of operational feasibility and performance.
- Prioritize systems that best balance stakeholder goals (e.g., safety, reliability, cost, scalability).
- Justify the selection of a small set of preferred architecture(s) for recommendation.

## Tier 2 Selection Criteria

Criteria	Value Type	Description	Justification	Applied To
System TRL Outside of The EPFL Rocket Team	Qualitative (e.g., TRL 1-9)	Maturity level of the overall system concept based on external developments.	Ensures that the system concept is based on technologies with demonstrated external maturity, reducing development risk.	System
System TRL at The EPFL Rocket Team	Qualitative (e.g., TRL 1-9)	Internal maturity level of the system concept based on the team's experience and past projects.	Accounts for the team's experience and familiarity with the technologies and system as a whole, impacting development effort and risk.	System
Development Complexity	Qualitative (e.g., High / Medium / Low)	Estimated technical and organizational complexity required to develop the full system.	High development complexity increases schedule and resource risks.	System
Count of Single Points of Failure	Quantitative (e.g., number of SPOFs)	Number of failure modes that would result in total mission failure without redundancy.	Helps identify systems that are inherently less reliable and require additional mitigation measures.	System
Mass Estimation	Quantitative (e.g., kg)	Estimated total mass of the recovery system integrated into the rocket.	Mass impacts overall rocket performance and payload capacity; lighter systems are preferred.	System
Volume Estimation	Quantitative (e.g., m <sup>3</sup> )	Estimated total volume occupied by the recovery system in the rocket.	Volume constraints affect the integration and design flexibility of the rocket airframe.	System
Opening Forces / Deployment Forces	Quantitative (e.g., N)	Maximum force applied on the system and rocket structure during deployment.	Excessive forces can damage the rocket structure or recovery system, impacting safety and performance.	System
Touchdown Speed	Quantitative (e.g., m/s)	Estimated impact speed of the rocket at landing with the recovery system deployed.	Determines the risk of hardware damage at landing and the overall safety of recovery operations.	System
Environmental Adaptability	Qualitative (High / Medium / Low) or Quantitative (Safety Margins)	Capability of the system to perform reliably under varying environmental conditions (wind, temperature, etc.).	Ensures system performance is maintained in real flight conditions, reducing operational risk.	System



Criteria	Value Type	Description	Justification	Applied To
Growth Potential	Quantitative (e.g., System Mass & Volume as a function of Payload Mass)	Flexibility of the system to be adapted or scaled with different payload requirements.	Promotes long-term usability and scalability of the system across future missions.	System
Risk and Safety Assessment	Qualitative / Quantitative (Number & severity of risks)	Overall risk profile of the system, including operational and safety hazards.	Helps ensure that the selected system does not introduce unacceptable risks to mission success or safety.	System
Life Cycle Cost Estimate	Quantitative (e.g., CHF or \$)	Total estimated cost of development, production, operation, and maintenance over the system's life cycle.	Enables cost-informed decision-making and helps avoid financially unsustainable solutions.	System
Development Duration Estimate	Quantitative (e.g., months)	Estimated time required to fully develop and qualify the system concept.	Ensures that the selected system can be developed within the project timeline constraints.	System



## 6.6 Evaluation of Selection Criteria

This section presents the evaluation of design options based on the selection criteria defined earlier in the report. A two-tiered screening methodology was used:

- **Tier 1 (Basic Feasibility Screening)**
- **Tier 2 (Detailed Trade-Off Analysis)**

This progressive filtering approach helps streamline the decision process by focusing detailed effort on concepts that are already proven to be broadly feasible. For transparency, rejected options are listed with the criterion that caused rejection, along with a short rationale. Options that passed Tier 1 will be fully evaluated in Tier 2.

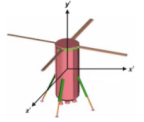
### Tier 1 Selection

#### Mission & Architectural Choices

##### Mission Scope

File (2)	Rejection Criteria	Rationale	Decision Status	Diagram / Image
Full Recovery	-	-	Selected	
Partial Recovery	-	-	Selected	


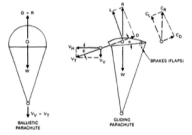
##### Decelerator Type

File (3)	Rejection Criteria	Rationale	Decision Status	Diagram / Image
Aero Dynamic Decelerator	-	-	Selected	
Helicopter System Recovery	<ul style="list-style-type: none"> <li>TRL out</li> <li>Development Complexity</li> </ul>	Concept is only documented in academic literature and lacks demonstrated implementation or existing prototypes	Rejected with Reason	 <p>Fig. 4 Coordinate system of the first stage's body. Adapted from [1]</p>
Propulsive Landing	<ul style="list-style-type: none"> <li>Development Complexity</li> <li>Development Cost</li> </ul>	Requires complex control systems and is prohibitively expensive to qualify and acceptance test within the scope of this project.	Rejected with Reason	

##### Landing Zone

File (2)	Rejection Criteria	Rationale	Decision Status	Diagram / Image
Impact on Land	-	-	Selected	
Impact on Water	-	-	Selected	

##### Aero Dynamic Decelerator Types

File (5)	Rejection Criteria	Rationale	Decision Status	Diagram / Image
Inflatable Aerodynamic Decelerators	<ul style="list-style-type: none"> <li>Development Complexity</li> <li>Development Cost</li> </ul>	Development of inflatable aerodynamic decelerators involves complex structural design, inflation control, and deployment sequencing. The associated cost and effort required to design, prototype, and test such systems exceed the scope and resources of this project.	Rejected with Reason	 <p>Inflatable</p>
Maneuverable Parachute	<ul style="list-style-type: none"> <li>Weight Efficiency</li> <li>Development Complexity</li> </ul>	The ability to guide the parachute is not required for this mission, and implementing maneuverability would add unnecessary weight and complexity due to additional control hardware and software.	Rejected with Reason	
Rotating Parachute	<ul style="list-style-type: none"> <li>Requirement Compliance</li> </ul>	Rotating parachutes are not compatible with large payloads and have limited reliability, making them unsuitable for meeting mission requirements.	Rejected with Reason	 <p>Rotating Parachute</p>
Slotted Parachute	-	-	Selected	
Solid Textile Parachute	-	-	Selected	

## Partial Recovery Types

File (3)	Rejection Criteria	Rationale	Decision Status	Diagram / Image
Recover Nosecone and Avionics	-	-	Selected	
Recover only Avionics System	<ul style="list-style-type: none"> <li>Requirement Compliance</li> </ul>	This option does not comply with the requirement to recover the nosecone, which contains the payload and must be retrieved for mission success.	Rejected with Reason	
Recover only Nosecone	-	-	Selected	

## Full Recovery Types







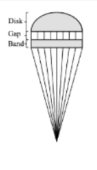
File (3)	Rejection Criteria	Rationale	Decision Status	Diagram / Image
Multi-Bodied Recovery	-	-	Selected	
No Rocket Separation	-	-	Selected	
Separate rocket but keep both bodies attached to a single recovery system	<ul style="list-style-type: none"> <li>Weight Efficiency</li> <li>Volume Efficiency</li> </ul>	This configuration provides no clear advantage over unseparated recovery while introducing additional mass and volume penalties.	Rejected with Reason	

## Driving Technology Choices




### Solid Textile Parachute Types (Source ID: 2)

Type	Constructed Shape (Dc/D0)	Inflated Shape (Dp/D0)	Drag Coef. CD Range	Opening Force Coef. COE (1/Mass)	Avg. Angle of Oscillation (°)	General Application	Diagram / Image
Flat Circular	1.00	0.67 – 0.70	0.75–0.8	~1.7	±10 to ±40	Descent, Obsolete	
Conical	0.93 – 0.95	0.70	0.70–0.9	~1.8	±10 to ±30	Descent, M < 0.5	
Biconical	0.90 – 0.95	0.70	0.70–0.92	~1.8	±10 to ±30	Descent, M < 0.5	
Triconical Polyconical	0.90 – 0.95	0.70	0.80–0.96	~1.8	±10 to ±20	Descent, M < 0.5	
Extended Skirt 10% Flat	0.86	0.66 - 0.70	0.78–0.87	~1.4	±10 to ±15	Descent, M < 0.5	
Extended Skirt 14.3% Full	0.81 – 0.85	0.66 - 0.70	0.75–0.90	~1.4	±10 to ±15	Descent, M < 0.5	
Hemispherical	0.71	0.66	0.62–0.77	~1.6	±10 to ±15	Descent, M < 0.5, Obsolete	
Guide Surface (Ribbed)	0.63	0.62	0.28–0.42	~1.2	0 to ~2	Stabilization, Drogue, 0.1 < M < 1.5	
Guide Surface (Ribless)	0.66	0.63	0.30–0.34	~1.4	0 to ~3	Pilot, Drogue, 0.1 < M < 1.5	
Annular	1.04	0.94	0.85–0.95	~1.4	<~5	Descent, M < 0.5	
Cross	1.15 – 1.19	0.65 - 0.72	0.60–0.85	1.1 to 1.2	0 to ~3	Descent, Deceleration	








## Slotted Parachute Types (Source ID: 2)

Type	Inflated Shape (Dp/D0)	Inflated Shape (Dp/D0)	Drag Coef. CD Range	Opening Force Coef. COE (1/Mass)	Avg. Angle of Oscillation (°)	General Application	Diagram / Image
Flat (Fist%) Ribbon	1.00 – 0.87	0.67	0.45–0.5	~1.05	0 to ±3	Drogue, Descent, Deceleration, Obsolete	
Conical Ribbon	0.93 – 0.70	0.70	0.50–0.55	~1.05	0 to ±3	Descent, Deceleration, $0.1 < M < 2.0$	
Conical Ribbon (Varied Porosity)	0.90 – 0.70	0.70	0.55–0.80	1.05 to 1.30	0 to ±3	Drogue, Descent, Deceleration, $0.1 < M < 2.0$	
Ribbon Hemisflo	0.71 – 0.62	0.62	0.30–0.46	1.00 to 1.30	~2	Supersonic, Drogue, $1.0 < M < 3.0$	
Ringslot	0.86 – 0.75	0.67 to 0.70	0.57–0.65	~1.05	0 to ±5	Extraction, Deceleration, $0.1 M < 0.9$	
Ringsail	0.86 – 0.75	0.69	0.75–0.85	~1.10	±5 to ±10	Descent, $M < 0.5$	
Disc-Gap-Band	0.73 – 0.65	0.	0.52–0.58	~1.30	±10 to ±15	Descent, $M < 0.5$	 Disc-Gap-Band Parachute

## Rotating Parachutes (Source ID: 2)

Type	Constructed Shape D <sub>t</sub> /D <sub>0</sub>	Inflated Shape D <sub>p</sub> /D <sub>0</sub>	Drag Coef. CDn Range	Opening Force Coef. C <sub>x</sub> (1/Mass)	Avg. Angle of Oscillation (°)	General Application	Diagram / Image
Rotafail	1.0	~0.90	0.85–0.99	1.05	±2	Drogue, $D_0 < 7$	
Vortex Ring	1.9	N/A	1.5–1.8	1.1 – 1.2	±2	Descent, Small D0	
Sandia RFD	1.0	~0.9	1.25	1.1	±2	Drogue	

## Manoeuvrable (Gliding) Parachutes (Source ID: 2)

Type	Area Ratio (Sw/S0)	CR Range	Glide Ratio (L/D) Max	General Application	Diagram / Image
Tojo, TU Slots, etc.	1.0	0.85–0.90	0.5–0.7	Descent	
LeMoigne (Paracommander)	1.0	0.90–1.00	1.1	Descent	
Parawing (Single Keel)	1.0	0.90–1.10	2.0–2.5	Descent	
Parawing (Twin Keel)	1.0	1.00–1.10	2.8–3.0	Descent	
Parafoil	0.27	0.75–0.85	2.8–3.5	Descent	
Sailwing	0.80–0.90	N/A	2.8–3.5	Descent	
Volplane	0.60	N/A	2.0–3.0	Descent	

## Reefing

## Deployment Mechanism

FIGURE 6-4 Two Typical Rocket-Ejector Methods.

## Clustering


Diagram / Image

### Supersonic Deployment Requirement

ROW TYPE  
SHOCK WAVE



## Flat-Spin

File (2)	Rejection Criteria	Rationale	Decision Status	Diagram / Image
Flat Spin	<ul style="list-style-type: none"> <li>Development Complexity</li> <li>Requirement Compliance</li> </ul>	-	Rejected with Reason	
No Flat Spin	-	-	Selected	

## Number of Stages

File (2)	Rejection Criteria	Rationale	Decision Status	Diagram / Image
Multi-Stage	-	-	Selected	
Single-Stage	-	-	Selected	

## Impact Attenuation Systems

File (5)	Rejection Criteria	Rationale	Decision Status	Diagram / Image
Air Bags	<ul style="list-style-type: none"> <li>Weight Efficiency</li> <li>Volume Efficiency</li> <li>Development Complexity</li> <li>Development Cost</li> </ul>	Airbags introduce significant mass and volume penalties and require complex inflation and sequencing systems. Their development and testing would also incur high costs, making them unsuitable given the project's constraints.	Rejected with Reason	
Crushable Impact Attenuators	-	-	Selected	
No Impact Attenuation	-	-	Selected	
Retrorocket	<ul style="list-style-type: none"> <li>Development Cost</li> <li>Development Complexity</li> </ul>	Retrorockets require precise control, timing, and integration with the descent system. The associated development cost and complexity are excessive.	Rejected with Reason	
Skirt Jet Retrorocket	<ul style="list-style-type: none"> <li>Development Cost</li> <li>Development Complexity</li> </ul>	Skirt jet retrorockets demand highly precise timing and pose additional technical risks. Their integration adds significant development complexity and cost, which are not justifiable.	Rejected with Reason	

## Buoyance Device

File (2)	Rejection Criteria	Rationale	Decision Status	Diagram / Image
Buoyance Device	-	-	Selected	
No Buoyance Device	-	-	Selected	

## Tier 2 Selection

The Tier 2 selection process is focused on performing a fair and traceable comparison between fundamentally different recovery system architectures. Its purpose is to evaluate each architecture not based on arbitrary sizing, but on its **optimized configuration**, thereby enabling a higher-quality selection decision that reflects realistic performance trade-offs.

**Architecture Optimization** To support this process, a dedicated **system concept generator** has been developed. This software performs architecture-specific optimization using a genetic algorithm and a physics-based simulation. The tool automatically explores the design space for each candidate architecture, subject to constraints and objectives, to identify a **feasible and near-optimal configuration**.

The three architectures currently under evaluation are:

1. **Full recovery with no separation**
2. **Nosecone-only recovery**

### 3. Full recovery using two distinct systems

Each architecture is optimized independently. Once a best-performing configuration is identified for each, these optimized concepts will serve as the input to the Tier 2 selection.

**Selection Process** After optimization, the shortlisted architecture concepts will be evaluated using the Tier 2 selection criteria.

### Current Status

The architecture optimization runs are still in progress. The Tier 2 comparison will be completed once:

- Optimization has converged for all three architecture types
- Final scores and constraint compliance are validated
- System-level performance plots and metrics are compiled

## 7 Pararec-Sim — Software Design & Development Document

### 7.1 Introduction

This document records the **architecture, requirements, design choices and development strategy** for the minimum-viable product (MVP) of *Pararec-Sim*—a Python tool for sizing and analysing multi-stage parachute recovery systems. It supersedes separate “design” and “development” files: everything needed for the Preliminary Requirements Review (PRR) now lives here.

#### Scope

The document covers the full MVP feature set. Interfaces intended for post-MVP extensions are noted, but detailed design of those future capabilities is out of scope.

## Needs

## Entire Software

#	Need statement	Rationale
N-1	Provide <b>physics-based simulation of parachute descent, drift and loads</b> for all planned flight regimes.	Engineers must verify performance & compliance at each design review.
N-2	<b>Evolve with system maturity</b> : allow models (drag, mass, failure rates, CFD tables, etc.) to be swapped or refined without re-writing the whole program.	Keeps the tool relevant as the design is iterated and new test data appear.
N-3	Support both <b>deterministic and probabilistic analyses</b> (Monte Carlo / reliability) once uncertainty data become available.	Range safety & certification require dispersion envelopes and confidence levels.
N-4	Enable <b>batch studies &amp; optimisation loops</b> driven by external scripts or built-in algorithms.	Weight minimisation, cut-timer tuning, reefing schedule optimisation.
N-5	Offer <b>traceable input &amp; output formats</b> with metadata (model version, commit ID, run settings) aligned to ECSS documentation practice.	Auditors need to reproduce analyses years later.
N-6	Integrate with <b>external data sources and tools</b> (wind database, requirements database, flight-test telemetry, CFD results).	Eliminates manual data re-entry errors.
N-7	Provide <b>programmable and human-friendly interfaces</b> (command-line, Python API, optional GUI) so that both automation and ad-hoc studies are easy.	Different user profiles: system engineers, research students, range analysts.
N-8	Deliver <b>result visualisation &amp; reporting hooks</b> (plots, CSV/JSON exports, dashboards) for rapid review and for inclusion in mission documents.	Speeds up decision cycles.
N-9	Be <b>verifiable and validated</b> : include built-in test cases, unit tests and “golden flights” so that every code change can be confidence-checked.	Maintains credibility of results.
N-10	Achieve <b>acceptable performance</b> (wall-clock time & memory) for hundreds to thousands of Monte Carlo cases on a laptop or small cluster.	Allows timely trade-offs during design reviews.
N-11	Be <b>platform-agnostic and open-source-friendly</b> (compiles/runs on Linux, macOS, Windows; uses permissive dependencies) to ensure longevity and collaboration.	University teams and suppliers use mixed environments.
N-12	Provide <b>extensive user and developer documentation</b> including an “interface control document” for every public API.	Lowers onboarding effort and enforces configuration control per ECSS-E-ST-40.
N-13	Maintain a <b>documented Software Design Document (SDD)</b> and <b>Software Development Plan (SDP)</b> covering architecture, verification strategy, configuration management and release process.	Required by ECSS-Q-80 for software projects and critical for long-term maintainability.



## First Implementation

#	Need statement	Rationale for MVP
M-1	Simulate <b>single-stage or multistage free-body and parachute descent</b> under vertical, axisymmetric motion with fixed drag coefficients.	Sufficient fidelity to discriminate major architecture options.
M-2	Accept <b>simple, declarative input files</b> (e.g., YAML/JSON) describing vehicle mass, drag area, deployment altitude, wind-at-altitude table.	Quick to edit by non-software specialists.
M-3	Compute and output <b>key performance metrics</b> : peak opening load, max dynamic pressure, landing speed, horizontal drift distance.	Directly support go/no-go trade criteria.
M-4	Provide a <b>command-line interface</b> to run one case or a small parameter sweep from a shell script.	Allows batch studies without extra UI work.
M-5	Produce <b>plain-text and CSV results</b> plus one summary plot (altitude vs. time) per run.	Easy to paste into trade-study spreadsheets and reports.
M-6	Include <b>unit tests for fundamental equations</b> (drag force, atmosphere lookup) and one “golden case” regression test.	Ensures numerical stability while code is still small.
M-7	Be <b>installable with one command</b> (e.g., <code>pip install pararec-sim-mvp</code> or a standalone ZIP) with minimal external dependencies.	Engineers can start using it within minutes.
M-8	Expose <b>well-documented extension points</b> (e.g., abstract base class for a DragModel) even if only one concrete model exists today.	Sets the groundwork for later evolution without massive refactor.
M-9	Ingest a <b>library of technology options</b> (parachute types, stage counts, reefing schemes, attachment hardware) including their design variables and any pre-defined performance correlations.	Lets the optimiser “pick & mix” building blocks when forming candidate architectures.
M-10	Provide an <b>architecture-assembly engine</b> that can combine compatible technology options into complete system definitions according to simple compatibility rules supplied in the input file.	Automates creation of feasible design candidates; avoids hand-crafting every variant.
M-11	Include a <b>generic optimisation driver</b> capable of exploring the discrete combinations and continuous design variables (e.g., genetic algorithm with user-settable population size & iterations).	Rapidly identifies promising architectures without exhaustive manual sweeps.
M-12	Allow users to <b>declare objective functions and constraints</b> (e.g., minimise mass, constrain landing speed 6 m/s) in the same input file.	Keeps optimisation logic data-driven and avoids code edits when study criteria change.
M-13	Output <b>ranked results and basic Pareto data</b> (objective values and constraint violations) in CSV/JSON plus an optional scatter-plot image.	Enables quick visual trade-off analyses and easy import into existing decision decks.

#	Need statement	Rationale for MVP
M-14	Store <b>run metadata and random seeds</b> so that every optimisation can be reproduced exactly and resumed if interrupted.	Essential for traceability and incremental improvement during architecture down-selection.
M-15	Permit <b>multiple independent optimisation cycles</b> (e.g., different random seeds or initial populations) to be executed automatically in one command.	Enables assessment of optimiser repeatability and robustness.
M-16	After the cycles finish, <b>compute and report convergence / similarity metrics</b> (e.g., hyper-volume delta, best-objective spread, Pareto-set overlap) and flag significant discrepancies.	Gives users confidence that the identified optima or Pareto front are not artefacts of a single run.
M-17	Perform <b>automatic input-file validation and compatibility checks</b> (e.g., parachute type must match reefing scheme, stage count 1).	Prevents wasted optimiser time on impossible or nonsensical designs.
M-18	Offer a <b>one-at-a-time sensitivity-analysis mode</b> that perturbs each design variable $\pm$ and reports the resulting change in key metrics.	Quickly reveals which variables drive performance, guiding requirements refinement.
M-19	Generate an <b>optional consolidated report</b> (Markdown or simple HTML) that bundles input summary, optimiser settings, top-N solutions, plots and convergence stats.	Saves manual work assembling review slides or documentation for down-selection meetings.

## Requirements

Req ID	Requirement statement	Type	Derived from	Required for initial version?
GS-01	The software <b>shall simulate the vertical descent trajectory</b> of the recovery system from apogee to landing by numerically integrating the equations of motion.	F	N-1	Yes
GS-02	The software <b>shall simulate horizontal drift</b> due to atmospheric winds and cross-range motion, providing time-history and final lateral displacement outputs.	F	N-1	Yes
GS-03	The software <b>shall compute parachute loads</b> (opening force, steady-state drag force, line tension) throughout deployment(s) and descent.	F	N-1	Yes
GS-04	The software <b>shall allow physics sub-models (e.g., drag, mass variation, failure-rate tables) to be added, replaced or removed at run-time</b> via a documented plug-in interface.	F	N-2	Yes
GS-05	The software <b>shall execute Monte-Carlo analyses</b> in which any input parameter can be specified as a statistical distribution (normal, uniform or user-defined) and shall record the resulting distribution of key performance metrics.	F	N-3	No
GS-06	The software <b>shall expose a public Python API that enables external scripts to launch batches of simulations and optimisation loops without spawning new processes.</b>	F	N-4	No
GS-07	Every output file <b>shall embed traceability metadata</b> (software semantic version, Git commit hash, input-file checksum, model plug-in identifiers, date-time stamp).	NF	N-5	Yes
GS-08	The software <b>shall import wind-profile data</b> from CSV files conforming to ICD-WIND-01.	F	N-6	No
GS-09	The software <b>shall export simulation summaries</b> in JSON files conforming to ICD-RESULT-01.	F	N-6	Yes
GS-10	The software <b>shall provide a command-line interface (CLI)</b> for running individual cases, sweeps and optimisations.	F	N-7	Yes
GS-11	The software <b>shall provide a Python package API</b> that exposes the same capabilities as the CLI.	F	N-7	No
GS-12	On user request the software <b>shall generate publication-quality plots</b> (PNG and SVG) of altitude-, velocity- and load-time histories.	F	N-8	Yes
GS-13	The codebase <b>shall include an automated test suite (unit, integration, regression) that achieves 80 % statement coverage</b> when run with <code>pytest-cov</code> .	NF	N-9	Yes

Req ID	Requirement statement	Type	Derived from	Required for initial version?
GS-14	On a reference laptop (Intel i7-12700H, 16 GB RAM) <b>the software shall complete 1 000 Monte-Carlo simulations of the baseline scenario in 10 minutes.</b>	NF	N-10	No
GS-15	The software <b>shall install and run on Windows 10+, Ubuntu 22.04 LTS and macOS 13+</b> using only OSI-approved-licence dependencies.	NF	N-11	Yes
GS-16	Each tagged release <b>shall publish a user manual</b> covering installation, basic usage and input-file schema.	NF	N-12	Yes
GS-17	The project <b>shall maintain and version-control a Software Design Document (SDD) and a Software Development Plan (SDP) compliant with ECSS-Q-80.</b>	NF	N-13	Yes

### Initial Implementation

Req ID	Requirement statement	Type	Derived from
MVP-01	The MVP <b>shall simulate vertical, axisymmetric descent</b> of the recovery system.	F	M-1
MVP-02	The MVP <b>shall support up to ten parachute stages</b> in the descent simulation. (be more precise on differenece in between recovery state and unreefing)	F	M-1
MVP-03	The MVP <b>shall use fixed drag-coefficient values</b> for every parachute stage. (maybe modify for super and subsonic?)	F	M-1
MVP-04	The MVP <b>shall read one JSON scenario file</b> per run.	F	M-2
MVP-05	The MVP <b>shall validate the scenario file against schema input-v0.1.</b>	F	M-2
MVP-06	The MVP <b>shall compute and record the peak opening load</b> for each run.	F	M-3
MVP-07	The MVP <b>shall compute and record the maximum dynamic pressure</b> for each run.	F	M-3
MVP-08	The MVP <b>shall compute and record the landing speed</b> for each run.	F	M-3
MVP-09	The MVP <b>shall compute and record the horizontal drift distance</b> for each run.	F	M-3
MVP-10	The MVP <b>shall provide the CLI command pararec-sim.</b>	F	M-4
MVP-11	The CLI <b>shall offer a run sub-command to execute a single scenario.</b>	F	M-4
MVP-12	The CLI <b>shall offer a sweep sub-command to execute a parameter sweep.</b>	F	M-4
MVP-13	Each run <b>shall output a plain-text summary file.</b>	F	M-5
MVP-14	Each run <b>shall output a CSV time-series file.</b>	F	M-5

Req ID	Requirement statement	Type	Derived from
MVP-15	Each run <b>shall output a PNG plot of altitude versus time.</b> (and a drift over time, a dynamic pressure over and a vertical velocity over time, )	F	M-5
MVP-16	Each run <b>shall output a PDF document summarising the results.</b>	F	M-5
MVP-17	The test suite <b>shall include unit tests for drag-force computation.</b>	NF	M-6
MVP-18	The test suite <b>shall include unit tests for ISA atmosphere lookup.</b>	NF	M-6
MVP-19	The test suite <b>shall include a regression test verifying the golden-case altitude-time curve within <math>\pm 1</math> % RMS error.</b>	NF	M-6
MVP-20	The MVP <b>shall be installable via <code>pip install pararec-sim</code> with no compiled extensions.</b>	NF	M-7
MVP-21	The MVP <b>shall expose an abstract base class <code>DragModel</code> in the public namespace.</b>	F	M-8
MVP-22	The MVP <b>shall discover concrete <code>DragModel</code> implementations via Python entry-points.</b>	F	M-8
MVP-23	The MVP <b>shall read technology-option files in JSON format from a user-specified folder.</b>	F	M-9
MVP-24	The MVP <b>shall generate candidate system architectures by applying compatibility rules contained in a rule file.</b>	F	M-10
MVP-25	The MVP <b>shall include a built-in genetic-algorithm optimiser.</b>	F	M-11
MVP-26	The built-in optimiser <b>shall handle 50 discrete and 20 continuous design variables.</b>	F	M-11
MVP-27	Users <b>shall define optimisation objectives in a JSON file.</b>	F	M-12
MVP-28	Users <b>shall define optimisation constraints in a JSON file.</b>	F	M-12
MVP-29	After optimisation, the MVP <b>shall write <code>pareto.csv</code> containing the non-dominated solutions.</b>	F	M-13
MVP-30	After optimisation, the MVP <b>shall generate a PNG scatter plot of the first two objectives.</b>	F	M-13
MVP-31	Each run <b>shall write <code>run_meta.json</code> recording start/finish timestamps, random seed, git hash, input checksum and optimiser settings.</b>	NF	M-14
MVP-32	When invoked with <code>--rep N</code> , the MVP <b>shall execute N independent optimisation runs using unique random seeds.</b>	F	M-15
MVP-33	The MVP <b>shall compute the hyper-volume indicator for every Pareto set produced.</b>	F	M-16
MVP-34	The MVP <b>shall flag the optimisation as “Not Converged” if the maximum pairwise hyper-volume difference among runs exceeds 5 %.</b>	F	M-16
MVP-35	The MVP <b>shall abort with an explanatory message if any input file fails schema validation.</b>	F	M-17
MVP-36	When invoked with <code>--sensitivity</code> , the MVP <b>shall perturb each design variable by <math>\pm 5</math> % (or <math>\pm 1</math> for discrete).</b>	F	M-18
MVP-37	The sensitivity run <b>shall output a CSV table of resulting metric changes.</b>	F	M-18
MVP-38	When invoked with <code>--report</code> , the MVP <b>shall generate a Markdown file <code>report.md</code> that includes the input summary.</b>	F	M-19
MVP-39	The generated report <b>shall include optimiser settings and the top-5 ranked solutions.</b>	F	M-19

Req ID	Requirement statement	Type	Derived from
MVP-40	The generated report <b>shall include convergence metrics and embedded plots.</b>	F	M-19
MVP-41	The MVP <b>shall compute and record the total canopy + rigging + hardware mass</b> for each candidate architecture, using the values defined in the technology-option library.	F	-
MVP-42	The software <b>shall estimate the packed volume</b> of the recovery system for every candidate architecture.	F	-
MVP-43	The software <b>shall account for wake-interference drag reduction</b> when multiple bodies are aligned in the flow.	F	-
MVP-44	The software <b>shall model the reduction of drag coefficient in the supersonic regime</b> using user-selectable correlations.	F	-
MVP-45	The software <b>shall allow suspension-line length to modify the effective drag area</b> through a configurable law.	F	-
MVP-46	The software <b>shall compute canopy opening time</b> based on user-selectable inflation models and record the value in the results file.	F	-

## 7.2 System Overview & Context

### Product Definition

*Pararec-Sim* is a **command-line Python application** that combines physics-based trajectory simulation with a genetic-algorithm optimiser. Its primary purpose is to size and evaluate multi-stage parachute recovery systems for a sounding rocket, reporting metrics such as opening load, landing speed and drift.

### External Context

Actor / Data	Role in MVP
<b>Systems engineer (end-user)</b>	Launches the CLI, inspects results.
Wind-profile CSV	Supplies altitude-dependent wind data.
Super-system constraints JSON	Provides rocket-level properties.
Mission constraints JSON	Defines acceptance criteria.
Technology-option library JSON	Catalogue of parachute and reefing options.
Matplotlib	External library for plotting time histories.

### Top-level Data Flow

1. **Simulation path:** Load scenario → validate → assemble architecture → simulate → compute metrics → write CSV/JSON, plots, report.
2. **Optimisation path:** Load optimisation config → iterative loop (*assemble* → *simulate* → *evaluate* → *log*) → final Pareto set and visuals.

### MVP Use-Cases

- Deterministic run: `pararec-sim run <scenario.json>`
- Parameter sweep: `pararec-sim sweep <grid.json>`
- Architecture optimisation: `pararec-sim sweep -optimise <study.json>`
- Sensitivity analysis: `pararec-sim -sensitivity <scenario.json>`

## 7.3 Static Architecture Overview

The *Recovery Simulator* repository is split into five logical layers, each residing in its own top-level package. Dependencies flow strictly downward (Figure 2), keeping the import graph acyclic and test-friendly.

1. **Domain Model** — `models/` PurePython data classes that capture the physical state of the rocket and its environment: `Environment` (atmospheric profiles and look-ups), `Section` (an air-frame segment), `SectionState` (per-timestep kinematics) and `RecoveryStage` (parachute or ballistic phase). These files contain *no* I/O or plotting code.
2. **Simulation Core** — `sim/` The engine that advances the state in discrete time. `simulation.py` drives the update loop and delegates bookkeeping to `results.py`, which can also render diagnostic plots. The simulator is deliberately stateless outside its parameters, enabling repeated calls from optimisation routines.
3. **Optimisation Layer** — `opti/` Search heuristics that wrap the simulator. A common `evaluator.py` scores each candidate design, while concrete strategies live in separate modules (`genetic_optimizer.py`).



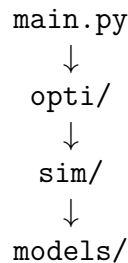
`random_optimizer.py`, etc.). `config_builder.py` translates JSON/YAML design files into the simulator's expected input schema.

**4. Configuration — `config/`** Declarative scenario data (`design_variables.json`, `constraints.json`, parachute database) plus the `ConfigLoader` utility that performs validation and casting. Keeping numbers out of code promotes reproducibility.

**5. Presentation — `outputs/`** Auto-generated artefacts: plots, logs and optimiser run folders. Nothing in the source tree imports from this directory.

The repository root contains an orchestration script, `main.py`, which performs the following pipeline:

1. Load scenario via `ConfigLoader`.
2. Instantiate an optimiser of choice, which repeatedly:
  - (a) converts the candidate vector with `config_builder.py`,
  - (b) calls `sim.run_simulation()`,
  - (c) receives a scalar fitness from `evaluator.py`.
3. Persist the best design and forward the run summary to `sim.results` for plotting.



**Figure 2:** Layered dependence—only downward arrows exist.

## 7.4 Life-cycle Model & Development Plan

### MVP Phase (Spring 2025)

Development follows a compact, six-week **V-model**:

1. **Requirements** → **Design**: requirements baselined; architecture drafted.
2. **Implementation**: focussed weekly coding sprints.
3. **Verification**: unit and integration tests run continuously.
4. **Release**: MVP was supposed to be demonstrated at the PRR (week of **26 May 2025**), however the developer ran out of time.

One primary developer drives the effort; weekly informal check-ins replace formal stage reviews, and this document is updated incrementally.

### Post-MVP Evolution (subject to continuation)

If the EPFL Rocket Team continues development, *Pararec-Sim* will adopt an **evolutionary life-cycle** aligned with rocket programme phases. Each semester delivers a minor release (v2.x, v3.x, ...), and feature branches merge only after an internal design review and automated quality checks.

### Configuration & Change Management

- Branch model: `main` (stable), `dev` (integration), feature branches per capability.
- Semantic versioning: *major* = rocket phase, *minor* = semester, *patch* = hot-fix.



- Every change is tracked by a GitHub issue linked to at least one requirement ID. Breaking interface changes require a formal change-request and may only ship in a minor release.

### **Future Work Disclaimer**

Sections describing capabilities beyond the MVP serve only as planning place-holders; continuation depends on EPFL Rocket Team approval.

## 8 Conclusion

### 8.1 Summary of Results

The semester project resulted in the development of foundational tools and documentation to support future recovery system design activities for the EPFL Rocket Team. Key outcomes include:

- A first version of a custom simulator and architecture optimizer tailored to the evaluation of recovery system configurations. This tool provides a reusable framework that can be refined in later phases.
- An initial set of project and technical requirements for the recovery system, providing structure and traceability for future work packages.
- A documented methodology for system architecture trade-off analysis, aligned with ECSS practices, which can be applied or adapted for future subsystems and missions.

### 8.2 Outlook and Upcoming Work

Several critical tasks remain before a recovery system baseline can be formally proposed:

- Further debugging and validation of the simulator and optimizer are required to enable consistent architecture evaluation and convergence toward optimal solutions.
- A structured risk assessment and FMECA (Failure Modes, Effects, and Criticality Analysis) must be conducted to ensure the feasibility and safety of the candidate architectures.

These activities will form the bridge between this feasibility-phase work and the future preliminary design phase.

### 8.3 Limitations and Recommendations

The current phase did not culminate in the selection of a final baseline architecture. This limits the immediate usability of the study's outputs for the EPFL Rocket Team. Moving forward, two main pathways are available:

- **Restart the trade-off process:** using the established methodology and requirements but beginning anew with improved tools and clearer evaluation criteria.
- **Iteratively complete the existing process:** by refining the simulator and continuing from the current state to derive a decision.

Both paths are viable, but care should be taken to reduce complexity and ensure traceability of assumptions moving forward.

### 8.4 Self-Assessment and Autocritique

From a personal development perspective, the semester project was a success. It enabled learning in systems engineering practices, rocket recovery systems, and structured project documentation under ECSS guidance. The process of building and attempting to apply a custom simulator provided valuable practical experience.

However, from the standpoint of delivering a usable system architecture for the EPFL Rocket Team, the project fell short of expectations. The root cause of this outcome lies in scope mismanagement: the project attempted to simultaneously achieve the following:

1. Define and formalize system-level and project-level requirements.
2. Establish a trade-off methodology from scratch.
3. Explore and document a large recovery system design space.

4. Implement a custom simulation and optimization tool.

This ambitious scope resulted in rapid progression across multiple fronts, but incurred significant technical debt—particularly in the traceability and maturity of architectural decisions. In hindsight, the project would have benefited from a stronger focus on one single objective, particularly the simulator development. Topics 1–3 could have been treated more lightly or deferred to parallel efforts.

Nevertheless, the groundwork laid by this project can serve as a valuable stepping stone if its outputs are carefully consolidated and extended.

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# Project Needs

File (37)	Text	Domain	Parent statement
<a href="#">Apogee</a>	The system shall be compatible with a target apogee of 100 km.	Technical	<ul style="list-style-type: none"><li><a href="#">Recovery System for Sounding Rocket</a></li></ul>
<a href="#">Apogee Margin</a>	The acceptable apogee over/under-shoot margin will be determined during the project, taking into account performance variations and technical constraints.	Technical	<ul style="list-style-type: none"><li><a href="#">Apogee</a></li></ul>
<a href="#">Deliverables per Review</a>	A comprehensive list of deliverables required for each review shall be documented.	Project	<ul style="list-style-type: none"><li><a href="#">Review Plan</a></li><li><a href="#">ECSS Compliance</a></li></ul>
<a href="#">Dependability Metric</a>	Dependability metrics shall be established during the project.	Project	<ul style="list-style-type: none"><li><a href="#">Trade Off</a></li></ul>
<a href="#">Descoping Options</a>	Potential descoping options shall be identified and documented.	Project	<ul style="list-style-type: none"><li><a href="#">Technical and Program Recommendations</a></li></ul>
<a href="#">Development Complexity</a>	The expected development complexity shall be taken into account during the system selection.	Project	<ul style="list-style-type: none"><li><a href="#">Trade Off</a></li><li><a href="#">Student Organisation Constraints</a></li></ul>
<a href="#">ECSS Compliance</a>	All of the documentation prepared should aim to be ECSS compliant.	Project	<ul style="list-style-type: none"><li><a href="#">Launch Site Documentation</a></li><li><a href="#">Preliminary Study</a></li></ul>
<a href="#">Estimated Monetary Range</a>	An estimated budget range for the chosen system concept shall be established during the project to guide financial planning and decision-making.	Project	<ul style="list-style-type: none"><li><a href="#">Selected System Description</a></li><li><a href="#">Monetary Budget</a></li></ul>
<a href="#">Exisiting Technologies</a>	The Technology Readiness Level (TRL) of relevant existing technologies shall be evaluated during system concept selection.	Project	<ul style="list-style-type: none"><li><a href="#">Trade Off</a></li></ul>
<a href="#">Expected Performance</a>	The expected performance of the chosen system shall be established during the project.	Project	<ul style="list-style-type: none"><li><a href="#">Selected System Description</a></li></ul>
<a href="#">Facility Constraint</a>	The project shall take into account constraints linked to available facilities.	Project	<ul style="list-style-type: none"><li><a href="#">Student Organisation Constraints</a></li></ul>
<a href="#">Interface Identification</a>	Interfaces with other subsystems shall be identified for the selected system concept and documented.	Project	<ul style="list-style-type: none"><li><a href="#">Selected System Description</a></li></ul>
<a href="#">Launch Site Compatibility</a>	The chosen system shall be compatible with the potential launch sites which have already been identified.	Technical	<ul style="list-style-type: none"><li><a href="#">Recovery System for Sounding Rocket</a></li></ul>
<a href="#">Launch Site Documentation</a>	One of the intended audiences for the documentation should be launch site officials reviewing the system design.	Project	<ul style="list-style-type: none"><li><a href="#">Launch Site Compatibility</a></li></ul>
<a href="#">Monetary Budget</a>	A maximum monetary budget constraint shall be identified and documented.	Project	<ul style="list-style-type: none"><li><a href="#">Student Organisation Constraints</a></li></ul>
<a href="#">Performance Metrics</a>	Performance metrics for the system shall be defined and documented during the project.	Project	<ul style="list-style-type: none"><li><a href="#">Trade Off</a></li><li><a href="#">Expected Performance</a></li><li><a href="#">Selected System Description</a></li></ul>
<a href="#">Preliminary Study</a>	The project shall focus exclusively on the preliminary study of the system.	Project	<ul style="list-style-type: none"><li><a href="#">Recovery System for Sounding Rocket</a></li></ul>
<a href="#">Recommendation for Future Work</a>	Recommendations for future work packages shall be provided.	Project	<ul style="list-style-type: none"><li><a href="#">Preliminary Study</a></li></ul>
<a href="#">Recovery System for Sounding Rocket</a>	The study shall focus on identifying potential system-level solutions for the recovery system of a sounding rocket.	Project	-
<a href="#">Reusable Software</a>	If any software is developed, it should aim to be reusable (see ECSS-Q-ST-80C).	Project	<ul style="list-style-type: none"><li><a href="#">Preliminary Study</a></li></ul>
<a href="#">Review Plan</a>	A review plan shall be established for the project.	Project	-
<a href="#">Risk Threshold</a>	As part of the system concept selection, the project shall define acceptable risk thresholds and document them within the risk analysis.	Project	<ul style="list-style-type: none"><li><a href="#">Safety</a></li><li><a href="#">Trade Off</a></li></ul>
<a href="#">Safety</a>	Safety shall be considered at all levels of the project.	Project	<ul style="list-style-type: none"><li><a href="#">Preliminary Study</a></li></ul>
<a href="#">Safety and Hazard Analysis</a>	A safety and hazard analysis shall be conducted for the selected system concept.	Project	<ul style="list-style-type: none"><li><a href="#">Safety</a></li></ul>
<a href="#">Safety Criteria</a>	Safety shall be included as a criterion in the trade-off analysis for system concept selection.	Project	<ul style="list-style-type: none"><li><a href="#">Safety</a></li><li><a href="#">Trade Off</a></li></ul>
<a href="#">Safety Metric</a>	Safety metric(s) shall be established during the project.	Project	<ul style="list-style-type: none"><li><a href="#">Trade Off</a></li></ul>
<a href="#">Selected System Description</a>	Once a system concept has been selected, its design shall be further developed.	Project	<ul style="list-style-type: none"><li><a href="#">Preliminary Study</a></li></ul>
<a href="#">State of The Art</a>	A state of the art analysis shall be performed to generate potential system concepts.	Project	<ul style="list-style-type: none"><li><a href="#">System Concepts Considered</a></li></ul>
<a href="#">Student Organisation Constraints</a>	Constraints related to the student organisation shall be identified and documented.	Project	<ul style="list-style-type: none"><li><a href="#">Trade Off</a></li></ul>
<a href="#">System Concepts Considered</a>	The study shall begin with a broad scope to consider a wide range of system concepts.	Project	<ul style="list-style-type: none"><li><a href="#">Preliminary Study</a></li></ul>
<a href="#">System Modelling</a>	A preliminary sizing and performance measurement model shall be prepared for the chosen system concept.	Project	<ul style="list-style-type: none"><li><a href="#">Expected Performance</a></li><li><a href="#">Trade Off</a></li></ul>
<a href="#">Technical and Program Recommendations</a>	Technical and Program recommendations for future work shall be provided.	Project	<ul style="list-style-type: none"><li><a href="#">Recommendation for Future Work</a></li><li><a href="#">Work Package</a></li><li><a href="#">Work Breakdown Structure</a></li></ul>
<a href="#">Technical Constraints</a>	The system's technical constraints shall be compliant with those imposed on other, already developed, space-shot systems.	Technical	<ul style="list-style-type: none"><li><a href="#">Recovery System for Sounding Rocket</a></li></ul>
<a href="#">Technical Needs</a>	All of the system's technical needs shall be established during the project.	Project	<ul style="list-style-type: none"><li><a href="#">Preliminary Study</a></li></ul>
<a href="#">Test Launch Opportunity</a>	It is planned to have a launch opportunity with an apogee of 30km in 2026. The launch opportunity should be considered when planning for system verification.	Project	<ul style="list-style-type: none"><li><a href="#">Student Organisation Constraints</a></li></ul>
<a href="#">Time Constraint</a>	The system concept selection shall take into account time constraints, ensuring that the expected development timeline is compatible with the overall rocket team schedule.	Project	<ul style="list-style-type: none"><li><a href="#">Student Organisation Constraints</a></li><li><a href="#">Trade Off</a></li></ul>
<a href="#">Trade Off</a>	The best system concept shall be selected through a trade-off analysis.	Project	<ul style="list-style-type: none"><li><a href="#">System Concepts Considered</a></li></ul>

# Project Requirements

File (318)	Text	Domain	Source	Due	Parent statement
DDF Applicable Documents	"The DDF shall contain the list of applicable and reference documents, used in support to the generation of the document. "	Project	ECSS-E-ST-10C Rev.1	PRR	<ul style="list-style-type: none"><li>Technology Matrix</li></ul>
DDF Applicable Documents References	"The DDF shall include the reference to the following applicable documents: 1. Business agreement 2. System engineering plan (as defined in ECSS-E-ST-10 Annex D) 3. Coordinate system document (as defined in ECSS-E-ST-10-09 Annex A) 4. Technical requirements specification (TS) 5. Product assurance plan 6. Configuration management plan (as defined in ECSS-M-ST-40) 7. Configuration status report (as defined in ECSS-M-ST-40)."	Project	ECSS-E-ST-10C Rev.1	PRR	<ul style="list-style-type: none"><li>Design Definition File</li></ul>
DDF Design Deviations Summary	"The DDF shall list and summarize all deviations of the design with respect to the technical specifications and constraints induced by the system or product design definition."	Project	ECSS-E-ST-10C Rev.1	PRR	<ul style="list-style-type: none"><li>Design Definition File</li></ul>
DDF Engineering Data Repository	"The DDF shall contain the information on the system or product engineering data repository that contains the complete set of design parameters, or a reference to it."	Project	ECSS-E-ST-10C Rev.1	PRR	<ul style="list-style-type: none"><li>Design Definition File</li></ul>
DDF Function Tree Reference	"The DDF shall contain or refer to the system or product function tree, the latter conforming to ECSS-E-ST-10 Annex H."	Project	ECSS-E-ST-10C Rev.1	PRR	<ul style="list-style-type: none"><li>Design Definition File</li></ul>
DDF Functional Architecture Description	"The DDF shall contain the description of the functional architecture of the system or product i.e. the arrangement of functions, their sub-functions and interfaces (internal and external), and the performance requirements to satisfy the requirements of the TS."	Project	ECSS-E-ST-10C Rev.1	PRR	<ul style="list-style-type: none"><li>Design Definition File</li></ul>
DDF Functional Chains Description	"The DDF shall describe the functional chains that contribute to the realization of the functional requirements of the TS and their contributing functions, consider the different operational modes and states, and indicate the selected physical implementation for each of the functions."	Project	ECSS-E-ST-10C Rev.1	PRR	<ul style="list-style-type: none"><li>Design Definition File</li></ul>
DDF Budget Allocation and Margins	"The DDF shall present the budget allocation of the technical parameters of the system and provide the actual status of the system margins, and deviations. "	Project	ECSS-E-ST-10C Rev.1	PRR	<ul style="list-style-type: none"><li>Design Definition File</li></ul>
DDF Design Documentation Reference	"The DDF shall contain the description of the system or product design documentation, based on the product tree (as defined in ECSS-M-ST-10) and also include, or refer to, the specifications tree (as defined in ECSS-E-ST-10 Annex J)."	Project	ECSS-E-ST-10C Rev.1	PRR	<ul style="list-style-type: none"><li>Design Definition File</li></ul>
DDF Functional Data Flow Description	"The DDF shall present the data and their flow interchanged between the different functions, the conditions for control, and the execution sequencing for the different operational modes and states."	Project	ECSS-E-ST-10C Rev.1	PRR	<ul style="list-style-type: none"><li>Design Definition File</li></ul>
DDF Higher & Lower Level References	"The DDF shall refer to DDFs of next higher and lower level products."	Project	ECSS-E-ST-10C Rev.1	PRR	<ul style="list-style-type: none"><li>Design Definition File</li></ul>
DDF Maintenance Constraints	"The DDF shall present the constraints induced by the system or product design definition on the maintenance activities and procedures e.g. operational allowable envelopes, accessibility, tooling, support materials, parts availability, and deliveries."	Project	ECSS-E-ST-10C Rev.1	PRR	<ul style="list-style-type: none"><li>Design Definition File</li></ul>
DDF Operational Constraints	"The DDF shall present the constraints induced by the system or product design definition on the implementation of the operations e.g. operational allowable envelopes, restrictions on operating modes, and exclusion zones."	Project	ECSS-E-ST-10C Rev.1	PRR	<ul style="list-style-type: none"><li>Design Definition File</li></ul>
DDF Physical Architecture Description	"The DDF shall contain the description of physical architecture of the system or product i.e. the arrangement of elements, their decomposition, interfaces (internal and external), and physical constraints, which form the basis of a system or product design to satisfy the functional architecture and the technical requirements."	Project	ECSS-E-ST-10C Rev.1	PRR	<ul style="list-style-type: none"><li>Design Definition File</li></ul>
DDF Product Lifecycle Description	"The DDF shall contain a brief description of the product and of the main technical requirements throughout its life cycle phases (e.g. launch, deployed, operations, end-of-life)."	Project	ECSS-E-ST-10C Rev.1	PRR	<ul style="list-style-type: none"><li>Design Definition File</li></ul>
DDF Product Tree Reference	"The DDF shall contain or refer to the product tree of the system or product, as defined in ECSS-M-ST-10 Annex B."	Project	ECSS-E-ST-10C Rev.1	PRR	<ul style="list-style-type: none"><li>Design Definition File</li></ul>
DDF Interface Characteristics Description	"The DDF shall describe the physical and functional characteristics of the internal and external interfaces of the system and refer to the relevant IRD and ICD, conforming to Annex A of ECSS-E-ST-10-24."	Project	ECSS-E-ST-10C Rev.1	PRR	<ul style="list-style-type: none"><li>Design Definition File</li></ul>
DDF Production Constraints	"The DDF shall present the constraints induced by the system or product design definition on the production activities e.g. operational allowable envelopes, restrictions on assembling sequences, procedures and testing modes, exclusion zones, manufacturing environmental conditions, and conditions for procurement."	Project	ECSS-E-ST-10C Rev.1	PRR	<ul style="list-style-type: none"><li>Design Definition File</li></ul>
DDF Purpose and Objective	"The DDF shall contain a description of the purpose, objective and the reason prompting its preparation (e.g. programme or project reference and phase). "	Project	ECSS-E-ST-10C Rev.1	PRR	<ul style="list-style-type: none"><li>Technology Matrix</li></ul>
DDF Specification Tree Reference	"The DDF shall contain or refer to the specification tree of the system or product, the latter conforming to Annex J."	Project	ECSS-E-ST-10C Rev.1	PRR	<ul style="list-style-type: none"><li>Design Definition File</li></ul>
DDF System Drawings and Configuration	"The DDF shall provide 1. the nomenclature of the system or product, 2. the overall system or product drawings, 3. for each element of the system, the description of the different constituents of the physical architecture, 4. the characteristics of the respective elements, 5. their configuration management identifier (e.g. hardware part number, software version number, drawings number, electrical schematics numbers)."	Project	ECSS-E-ST-10C Rev.1	PRR	<ul style="list-style-type: none"><li>Design Definition File</li></ul>
DDF Technical Budget Reference	"The DDF shall contain or refer to the system or product technical budget, the latter conforming to Annex I."	Project	ECSS-E-ST-10C Rev.1	PRR	<ul style="list-style-type: none"><li>Design Definition File</li></ul>
DDF Technical Documentation Reference	"The DDF shall reference any documentation containing detailed technical descriptions and associated matrices to ensure overall consistency and completeness."	Project	ECSS-E-ST-10C Rev.1	PRR	<ul style="list-style-type: none"><li>Design Definition File</li></ul>
DDF Technical Requirements Specification	"The DDF of a system shall contain at least the technical requirements specifications of the elements in which the system is broken down "	Project	ECSS-E-ST-10C Rev.1	PRR	<ul style="list-style-type: none"><li>Design Definition File</li></ul>
DDF Transportation and Storage Constraints	"The DDF shall present the constraints induced by the system or product design definition on the transportation activities and during the periods of storage of the product e.g. allowable envelopes, restrictions on transportation and storage, exclusion zones, packaging, shock levels, temperature environments, humidity, cleanliness, regulations, and dangerous materials."	Project	ECSS-E-ST-10C Rev.1	PRR	<ul style="list-style-type: none"><li>Design Definition File</li></ul>
DJF Applicable Documents	"The DJF shall list the applicable and reference documents in support to its generation."	Project	ECSS-E-ST-10C Rev.1	MDR	<ul style="list-style-type: none"><li>Design Justification File</li></ul>
DJF Acceptance Verification Status	"The DJF shall cover the system and all disciplines relevant to the product, addressing all acceptance verification activities in line with the system verification Plan (VP)."	Project	ECSS-E-ST-10C Rev.1	PRR	<ul style="list-style-type: none"><li>Design Justification File</li></ul>



File (318)	Text	Domain	Source	Due	Parent statement
<a href="#">DJF Acceptance Verification Implementation</a>	"The DJF shall present the implementation of the acceptance verification and the status thereof, addressing the detailed definition of acceptance activities (e.g. inspection, test, analysis), including the detailed definition of the tests, the prediction of expected test results, test success criteria, and test specifications."	Project	ECSS-E-ST-10C Rev.1	PRR	• <a href="#">Design Justification File</a>
<a href="#">DJF Architectural Element Justification</a>	"The DJF shall also provide the justification for the choice of architectural elements at the next lower level, or lower levels in case of system critical elements."	Project	ECSS-E-ST-10C Rev.1	PRR	• <a href="#">Design Justification File</a>
<a href="#">DJF Design Definition Reference Documents List</a>	"The applicable document list shall contain the reference to the relevant product specifications, and the relevant DDF and system engineering plan."	Project	ECSS-E-ST-10C Rev.1	MDR	• <a href="#">Design Justification File</a>
<a href="#">DJF Design Justification Status</a>	"The DJF shall present status of the design justification in response to requirements, with emphasis on the driving requirements that have a big impact on the system design, production and maintainability (see also K.2.1<8.2.4>a.)"	Project	ECSS-E-ST-10C Rev.1	PRR	• <a href="#">Design Justification File</a>
<a href="#">DJF Development Activities and Design Drivers</a>	"The DJF shall present the development activities (e.g. assessments, analyses, tests, and trade-offs) and the design drivers, which lead to and justify the design as defined in the DDF, in line with the development approach identified in the SEP."	Project	ECSS-E-ST-10C Rev.1	PRR	• <a href="#">Design Justification File</a>
<a href="#">DJF Discipline-Specific Information</a>	"For the system and each discipline, following information shall be produced: 1. Activity inputs, such as requirements, operational modes, assumptions, analysis cases, boundary conditions, model descriptions and limitations. 2. Activity results, such as (a) raw results, (b) evaluation of results, (c) evaluation of margins with respect to the technical requirements contained in the TS, (d) identification of any marginal areas. 3. Activity synthesis, such as (a) evidence of compliance to the technical requirements contained in the TS, (b) list of technical requirements which have not been met, including proposed actions, (c) list of all critical points, and how criticalities have been or are intended to be resolved, (d) identification of aspects of the design, which are not yet justified, and assessment of inherent risks."	Project	ECSS-E-ST-10C Rev.1	PRR	• <a href="#">Design Justification File</a>
<a href="#">DJF Expected Product Description</a>	"The DJF shall contain a description of the expected product, its intended mission, architecture and design, and the functioning principles on which it is based."	Project	ECSS-E-ST-10C Rev.1	PRR	• <a href="#">Design Justification File</a>
<a href="#">DJF Justification Across Engineering Disciplines</a>	"The justification shall concern all the engineering disciplines contributing to design and development of the product (including its operational modes and scenarios)."	Project	ECSS-E-ST-10C Rev.1	PRR	• <a href="#">Design Justification File</a>
<a href="#">DJF Justification of Non-Originating Functional Block Requirements</a>	"Where requirements assigned to functional blocks do not have their origin within any of the customer preliminary technical specifications, these requirements shall be justified. "	Project	ECSS-E-ST-10C Rev.1	PRR	• <a href="#">Design Justification File</a>
<a href="#">DJF Justification of Non-Originating Upper-Level Requirements</a>	"Where requirements do not have their origin within any of the upper level technical specifications, these shall be justified. "	Project	ECSS-E-ST-10C Rev.1	PRR	• <a href="#">Design Justification File</a>
<a href="#">DJF Lower-Level DJF Status</a>	"The DJF shall include the status of DJF of lower level products."	Project	ECSS-E-ST-10C Rev.1	PRR	• <a href="#">Design Justification File</a>
<a href="#">DJF Manufacturing Process Aspects</a>	"The DJF shall include a requirement status log, addressing design relevant aspects of manufacturing processes, and recording their characteristics in regard to qualification."	Project	ECSS-E-ST-10C Rev.1	PRR	• <a href="#">Design Justification File</a>
<a href="#">DJF Model Validation Evidence</a>	"The DJF shall contain all evidence (e.g. analyses, test results, and model descriptions and correlations) regarding the suitability and validation of all models used for the analysis of the system."	Project	ECSS-E-ST-10C Rev.1	PRR	• <a href="#">Design Justification File</a>
<a href="#">DJF Lower-Level DJF References</a>	"The DJF shall include or refer to the DJF of lower level elements of the product."	Project	ECSS-E-ST-10C Rev.1	PRR	• <a href="#">Design Justification File</a>
<a href="#">DJF Maintenance Constraints Justification</a>	"The DJF shall present the justification of constraints induced by the system or product design definition on the maintenance activities and procedures e.g. operational allowable envelopes, accessibility, tooling, support materials, parts availability, and deliveries. "	Project	ECSS-E-ST-10C Rev.1	PRR	• <a href="#">Design Justification File</a>
<a href="#">DJF Operational Constraints Justification</a>	"The DJF shall present the justification of constraints induced by the system or product design definition on the implementation of the operations e.g. operational allowable envelopes, restrictions on operating modes, and exclusion zones."	Project	ECSS-E-ST-10C Rev.1	PRR	• <a href="#">Design Justification File</a>
<a href="#">DJF Production Constraints Justification</a>	"The DJF shall present the justification of constraints induced by the system or product design definition on the production activities e.g. operational allowable envelopes, restrictions on assembling sequences, procedures and testing modes, exclusion zones, manufacturing environmental conditions, and conditions for procurement."	Project	ECSS-E-ST-10C Rev.1	PRR	• <a href="#">Design Justification File</a>
<a href="#">DJF Purpose and Objective</a>	"The DJF shall contain a description of the purpose, objective, content and the reason prompting its preparation."	Project	ECSS-E-ST-10C Rev.1	PRR	• <a href="#">Design Justification File</a>
<a href="#">DJF Qualification Evidence</a>	"The DJF shall present the evidence of the qualification of the design in conformance to the applicable technical requirements and proper qualification margins. "	Project	ECSS-E-ST-10C Rev.1	PRR	• <a href="#">Design Justification File</a>
<a href="#">DJF Qualification Plan Implementation</a>	"The DJF shall present the implementation of the qualification plan and the status thereof, addressing the detailed definition of qualification activities (e.g. analysis, test, ROD, and inspection), including the detailed definition of the tests, the prediction of expected test results, test success criteria, test specifications, and model validations."	Project	ECSS-E-ST-10C Rev.1	PRR	• <a href="#">Design Justification File</a>
<a href="#">DJF Qualification and Acceptance Criteria</a>	"The DJF shall define the requirement criteria levels for qualification and acceptance verification of the product."	Project	ECSS-E-ST-10C Rev.1	PRR	• <a href="#">Design Justification File</a>
<a href="#">DJF Reference Documents List</a>	"The reference document list shall contain the reference to: 1. Trade-Off-Reports, as defined Annex L. 2. Analysis Reports (e.g. requirements allocation analysis, functional analysis). 3. Requirements Traceability Matrix, as defined in Annex N (with link to analysis). 4. Verification Control Document 5. All verification documentation, such as: (a) Analysis Reports (e.g. reports w.r.t. qualification aspects) (b) Test Reports (c) ROD Reports (d) Inspection Reports (e) Verification Reports"	Project	ECSS-E-ST-10C Rev.1	MDR	• <a href="#">Design Justification File</a>
<a href="#">DJF Requirement Allocation to Functional Blocks</a>	"The DJF shall contain the demonstration that all requirements of the preliminary technical requirements specification are allocated to functional blocks of the system functional architecture."	Project	ECSS-E-ST-10C Rev.1	PRR	• <a href="#">Design Justification File</a>
<a href="#">DJF Requirement Status Log</a>	"The DJF shall include a requirement status log addressing each requirement in turn, and including the 1. reference to relevant elements of the verification plan,	Project	ECSS-E-ST-10C Rev.1	PRR	• <a href="#">Design Justification File</a>



File (318)	Text	Domain	Source	Due	Parent statement
	<p>2. synthesis of the justifications acquired, calling up references to the supporting activities and evidence (e.g. Technical Notes listed in section K.2.1&lt;4&gt;),</p> <p>3. list of justifications to be acquired and related activities,</p> <p>4. conclusion / action flag."</p>				
<a href="#">DJF Requirements Traceability Matrix Reference</a>	"The DJF shall reference the requirements traceability matrix, e.g. w.r.t. building up the justification of a considered system top level requirements in terms of the various elements contributing to it, including where relevant contribution from other disciplines (e.g. pointing as a function of thermal, structures, and AOCS)."	Project	ECSS-E-ST-10C Rev.1	MDR	<ul style="list-style-type: none"> <li><a href="#">Design Justification File</a></li> </ul>
<a href="#">DJF System Design Conformance</a>	"The DJF shall contain the demonstration that the system design conforms to the requirements of the technical specification, and identify products which are reused (e.g. COTS)."	Project	ECSS-E-ST-10C Rev.1	PRR	<ul style="list-style-type: none"> <li><a href="#">Design Justification File</a></li> </ul>
<a href="#">DJF System Qualification Synthesis</a>	<p>"The DJF shall present an overall system qualification status synthesis, including:</p> <ol style="list-style-type: none"> <li>the list of requirements which have not been met (e.g. nonconformances), including proposed actions,</li> <li>the list of all critical points, and how criticalities have been or are intended to be resolved,</li> <li>the identification of requirements which have not been justified yet, and associated risks analysis, with emphasis on those that can have an impact at system level."</li> </ol>	Project	ECSS-E-ST-10C Rev.1	PRR	<ul style="list-style-type: none"> <li><a href="#">Design Justification File</a></li> </ul>
<a href="#">DJF System and Discipline Coverage</a>	"The DJF shall cover the system and all disciplines relevant to the product in all its operational modes and scenarios, addressing all applicable technical requirements and proper qualification margins. "	Project	ECSS-E-ST-10C Rev.1	PRR	<ul style="list-style-type: none"> <li><a href="#">Design Justification File</a></li> </ul>
<a href="#">DJF Technical Budgets and Margins</a>	"The DJF shall present a synthesis of all technical budgets and margins for specific parameters according to the functional and physical architectures."	Project	ECSS-E-ST-10C Rev.1	PRR	<ul style="list-style-type: none"> <li><a href="#">Design Justification File</a></li> </ul>
<a href="#">DJF Transportation and Storage Constraints Justification</a>	"The DJF shall present the justification of constraints induced by the system or product design definition on the transportation activities and during the periods of storage of the product e.g. allowable envelopes, restrictions on transportation and storage, exclusion zones, packaging, shock levels, temperature environments, humidity, cleanliness, regulations, and dangerous materials."	Project	ECSS-E-ST-10C Rev.1	PRR	<ul style="list-style-type: none"> <li><a href="#">Design Justification File</a></li> </ul>
<a href="#">DJF Verification Document References</a>	<p>"The DJF shall integrate or refer to the documents that conform to the:</p> <ol style="list-style-type: none"> <li>ECSS-E-ST-10 Annex L, Trade-Off-Report - DRD</li> <li>ECSS-E-ST-10 Annex Q, Analysis Report - DRD</li> <li>ECSS-E-ST-10 Annex O, Requirement Justification File - DRD</li> <li>ECSS-E-ST-10 Annex N, Requirements Traceability Matrix - DRD</li> <li>ECSS-E-ST-10-02 Annex B, Verification Control Document - DRD</li> <li>ECSS-E-ST-10-02 Annex C, Test Report - DRD</li> <li>ECSS-E-ST-10-02 Annex D, Review Of Design Report - DRD</li> <li>ECSS-E-ST-10-02 Annex E, Inspection Report - DRD</li> <li>ECSS-E-ST-10-02 Annex F, Verification Report - DRD"</li> </ol>	Project	ECSS-E-ST-10C Rev.1	PRR	<ul style="list-style-type: none"> <li><a href="#">Design Justification File</a></li> </ul>
<a href="#">DJF Verification Plan Reference</a>	"The DJF shall integrate or refer to the document that conforms to the verification plan DRD defined in ECSS-E-ST-10-02 Annex A."	Project	ECSS-E-ST-10C Rev.1	PRR	<ul style="list-style-type: none"> <li><a href="#">Design Justification File</a></li> </ul>
<a href="#">Deliverables</a>	A list of deliverables required for the Mission Definition Review and Project Requirements Review shall be documented in the Systems Engineering Plan.	Project		-	<ul style="list-style-type: none"> <li><a href="#">Deliverables per Review</a></li> <li><a href="#">System Engineering Plan</a></li> </ul>
<a href="#">Development Complexity Criterion</a>	Development complexity shall be minimised and used as a key criterion in the comparison of potential technologies and system architectures.	Project		-	<ul style="list-style-type: none"> <li><a href="#">Development Complexity</a></li> </ul>
<a href="#">ECSS Compliance Matrix</a>	An ECSS conformance matrix shall be prepared for all ECSS requirements related to documentation written during the project.	Project		MDR	<ul style="list-style-type: none"> <li><a href="#">ECSS Compliance</a></li> <li><a href="#">Launch Site Documentation</a></li> </ul>
<a href="#">Design Definition File</a>	A Design Definition File shall be prepared.	Project	ECSS-E-ST-10C	PRR	<ul style="list-style-type: none"> <li><a href="#">Selected System Description</a></li> </ul>
<a href="#">Design Justification File</a>	A Design Justification File (DJF) shall be prepared.	Project	ECSS-E-ST-10C	MDR	<ul style="list-style-type: none"> <li><a href="#">Selected System Description</a></li> </ul>
<a href="#">Estimated Budget</a>	An estimated budget range for the chosen system concept shall be established and documented in the Design Definition File (DDF).	Project		-	<ul style="list-style-type: none"> <li><a href="#">Estimated Monetary Range</a></li> <li><a href="#">Design Definition File</a></li> </ul>
<a href="#">FMECA Acronyms and Definitions</a>	"The FMEA/FMECA report shall list of acronyms, abbreviations and definitions of special terms used."	Project	ECSS-Q-ST-30-02C	PRR	<ul style="list-style-type: none"> <li><a href="#">Failure Modes and Effects Criticality Analysis</a></li> </ul>
<a href="#">FMECA Applicable Documents</a>	"The FMEA/FMECA report shall list the applicable and reference documents, including design reference, analyses performed by lower level suppliers, used in the preparation of the FMEA/FMECA."	Project	ECSS-Q-ST-30-02C	PRR	<ul style="list-style-type: none"> <li><a href="#">Failure Modes and Effects Criticality Analysis</a></li> </ul>
<a href="#">FMECA Block Diagrams and Schematics</a>	<p>"The FMEA/FMECA report shall include block diagrams and schematics to assist in describing the product, provide schematic diagrams, functional block diagrams and reliability block diagrams (RBDs) to a level consistent with the depth of the analysis and with design maturity.</p> <p>NOTE Functional tree is also useful to describe functional relationships."</p>	Project	ECSS-Q-ST-30-02C	PRR	<ul style="list-style-type: none"> <li><a href="#">Failure Modes and Effects Criticality Analysis</a></li> </ul>
<a href="#">FMECA Customer Approval of Rules</a>	<p>"All rules and assumptions shall be approved by the customer.</p> <p>NOTE For information a list of failure modes for EEE parts is provided in Annex G."</p>	Project	ECSS-Q-ST-30-02C	PRR	<ul style="list-style-type: none"> <li><a href="#">Failure Modes and Effects Criticality Analysis</a></li> </ul>
<a href="#">FMECA Design Status Reference</a>	<p>"The FMEA/FMECA report shall provide the definition of the status of the design of the product under analysis by reference to a configuration document.</p> <p>NOTE For example, CIDL."</p>	Project	ECSS-Q-ST-30-02C	PRR	<ul style="list-style-type: none"> <li><a href="#">Failure Modes and Effects Criticality Analysis</a></li> </ul>
<a href="#">FMECA Design Maturity</a>	"If the design is not mature enough to provide this document, then the design shall be defined by reference to reports used to perform the analysis."	Project	ECSS-Q-ST-30-02C	PRR	<ul style="list-style-type: none"> <li><a href="#">Failure Modes and Effects Criticality Analysis</a></li> </ul>
<a href="#">FMECA Critical Items List</a>	"The FMEA/FMECA report shall provide a list of all the critical items identified (as per 4.3 or 5.3, respectively) including item identification and cross-reference with FMEA/FMECA worksheets."	Project	ECSS-Q-ST-30-02C	PRR	<ul style="list-style-type: none"> <li><a href="#">Failure Modes and Effects Criticality Analysis</a></li> </ul>
<a href="#">FMECA FDIR Policy and Criteria</a>	<p>"The FMEA/FMECA report shall describe the FDIR policy and criteria including reference to relevant documents and to detection reference.</p> <p>NOTE The detection reference includes telemetry, housekeeping data, and health check."</p>	Project	ECSS-Q-ST-30-02C	PRR	<ul style="list-style-type: none"> <li><a href="#">Failure Modes and Effects Criticality Analysis</a></li> </ul>
<a href="#">FMECA Failure Effects and Severity Classification</a>	"The FMEA/FMECA report shall provide a list of the failure effects leading to consequences classified in severity category 1, 2 and 3 and identify all relevant failure modes including item identification and cross-reference with FMEA/FMECA worksheets."	Project	ECSS-Q-ST-30-02C	PRR	<ul style="list-style-type: none"> <li><a href="#">Failure Modes and Effects Criticality Analysis</a></li> </ul>

File (318)	Text	Domain	Source	Due	Parent statement
<a href="#">FMECA Failure Mode Adjustments</a>	"The list of failure modes of each part may be amended or additional modes included, depending on specific applications."	Project	ECSS-Q-ST-30-02C	PRR	<ul style="list-style-type: none"> <li><a href="#">Failure Modes and Effects Criticality Analysis</a></li> </ul>
<a href="#">FMECA Ground Rules and Assumptions</a>	"The FMEA/FMECA report shall include the description of the ground rules adopted for the analysis (including list of items omitted from the analysis) and all the assumptions made regarding mission phases and times, operational modes, environmental conditions, failure modes and failure criteria. NOTE This list is not conclusive."	Project	ECSS-Q-ST-30-02C	PRR	<ul style="list-style-type: none"> <li><a href="#">Failure Modes and Effects Criticality Analysis</a></li> </ul>
<a href="#">FMECA Hardware-Software Partitioning</a>	"The FMEA/FMECA report shall include a functional partition in the design between hardware and software, including a reference to the corresponding HSIA shall be addressed."	Project	ECSS-Q-ST-30-02C	PRR	<ul style="list-style-type: none"> <li><a href="#">Failure Modes and Effects Criticality Analysis</a></li> </ul>
<a href="#">FMECA Identification Numbering</a>	"An appropriate identification number shall be used to provide consistent identification and complete visibility of the relationship between each block and the applicable failure modes."	Project	ECSS-Q-ST-30-02C	PRR	<ul style="list-style-type: none"> <li><a href="#">Failure Modes and Effects Criticality Analysis</a></li> </ul>
<a href="#">FMECA Incomplete Design Identification</a>	"Description and listing of any incomplete design areas shall be identified."	Project	ECSS-Q-ST-30-02C	PRR	<ul style="list-style-type: none"> <li><a href="#">Failure Modes and Effects Criticality Analysis</a></li> </ul>
<a href="#">FMECA Objectives</a>	"The FMEA/FMECA report shall provide concise statements on the objectives of the analysis including definition of the level of the analysis."	Project	ECSS-Q-ST-30-02C	PRR	<ul style="list-style-type: none"> <li><a href="#">Failure Modes and Effects Criticality Analysis</a></li> </ul>
<a href="#">FMECA Product Function Description</a>	"The FMEA/FMECA report shall include narrative description of the product functions to provide an understanding of the analysis."	Project	ECSS-Q-ST-30-02C	PRR	<ul style="list-style-type: none"> <li><a href="#">Failure Modes and Effects Criticality Analysis</a></li> </ul>
<a href="#">FMECA Recommendations Status Reference</a>	"The FMEA/FMECA report shall make reference to the document providing the status of the recommendations."	Project	ECSS-Q-ST-30-02C	PRR	<ul style="list-style-type: none"> <li><a href="#">Failure Modes and Effects Criticality Analysis</a></li> </ul>
<a href="#">FMECA Report Identification</a>	"The FMEA/FMECA report shall include the title of the analysis and reference number, issue, revision and date, supplier sign-off date, and the names and signatures of the analyst(s) and the approval authority."	Project	ECSS-Q-ST-30-02C	PRR	<ul style="list-style-type: none"> <li><a href="#">Failure Modes and Effects Criticality Analysis</a></li> </ul>
<a href="#">FMECA Results and Recommendations</a>	"The FMEA/FMECA report shall provide results and recommendations based upon the detailed analysis presented by the FMEA/FMECA worksheets."	Project	ECSS-Q-ST-30-02C	PRR	<ul style="list-style-type: none"> <li><a href="#">Failure Modes and Effects Criticality Analysis</a></li> </ul>
<a href="#">FMECA Worksheets Inclusion</a>	"The FMEA/FMECA report shall include the FMEA/FMECA worksheets in conformance with Annex B/Annex C, respectively."	Project	ECSS-Q-ST-30-02C	PRR	<ul style="list-style-type: none"> <li><a href="#">Failure Modes and Effects Criticality Analysis</a></li> </ul>
<a href="#">Function Tree Applicable Documents</a>	"The function tree document shall contain the list of applicable and reference documents, used in support to the generation of the document."	Project	ECSS-E-ST-10C Rev.1	PRR	<ul style="list-style-type: none"> <li><a href="#">Function Tree</a></li> </ul>
<a href="#">Failure Modes and Effects Criticality Analysis</a>	A Failure Modes and Effects Criticality Analysis shall be prepared.	Project	ECSS-Q-ST-30-02C	PRR	<ul style="list-style-type: none"> <li><a href="#">Safety and Hazard Analysis</a></li> </ul>
<a href="#">Function Tree Consistency with Other Functional Descriptions</a>	"The function tree shall be coherent with other functional descriptions of the system or product (e.g. functional architecture, functional block diagram)."	Project	ECSS-E-ST-10C Rev.1	PRR	<ul style="list-style-type: none"> <li><a href="#">Function Tree</a></li> </ul>
<a href="#">Function Tree Functional Breakdown Representation</a>	"The function tree document shall provide the complete list of functions that the system or product shall perform, and contain a graphical representation where the main specified function(s) (i.e. at the top level of the tree) is/are decomposed into lower level functions."	Project	ECSS-E-ST-10C Rev.1	PRR	<ul style="list-style-type: none"> <li><a href="#">Function Tree</a></li> </ul>
<a href="#">Function Tree Project and User Needs Description</a>	"The function tree document shall contain a brief description of the project and of the key user's needs."	Project	ECSS-E-ST-10C Rev.1	PRR	<ul style="list-style-type: none"> <li><a href="#">Function Tree</a></li> </ul>
<a href="#">Function Tree Purpose and Objective</a>	"The function tree document shall contain a description of the purpose, objective and the reason prompting its preparation."	Project	ECSS-E-ST-10C Rev.1	PRR	<ul style="list-style-type: none"> <li><a href="#">Function Tree</a></li> </ul>
<a href="#">Function Tree Recurrent Product Identification</a>	"When recurrent products from previous space projects are used, the product's functions shall be identified in the tree structure, and addition, every necessary function by the system or product that is not under the supplier's responsibility identified in the tree structure."	Project	ECSS-E-ST-10C Rev.1	PRR	<ul style="list-style-type: none"> <li><a href="#">Function Tree</a></li> </ul>
<a href="#">Function Tree</a>	A Function Tree shall be prepared.	Project	ECSS-E-ST-10C	PRR	<ul style="list-style-type: none"> <li><a href="#">Design Definition File</a></li> <li><a href="#">Selected System Description</a></li> </ul>
<a href="#">IRD Compliance with ECSS-E-ST-10-06</a>	"Interface Requirements shall be specified in accordance with ECSS-E-ST-10-06."	Project	ECSS-E-ST-10-24C Rev.1	PRR	<ul style="list-style-type: none"> <li><a href="#">Interface Requirements Document</a></li> </ul>
<a href="#">IRD Applicability to Interface Ends</a>	"The IRD shall specify for each requirement the applicability to each interface end."	Project	ECSS-E-ST-10-24C Rev.1	PRR	<ul style="list-style-type: none"> <li><a href="#">Interface Requirements Document</a></li> </ul>
<a href="#">IRD Consistency Check with Other Specifications</a>	"It shall be confirmed that the IRD does not include duplicate or conflicting requirements already specified in another Technical requirements specification applicable to any interface end. "	Project	ECSS-E-ST-10-24C Rev.1	PRR	<ul style="list-style-type: none"> <li><a href="#">Interface Requirements Document</a></li> </ul>
<a href="#">IRD Existing Interface End Requirements</a>	"In case of an existing interface end design, the interface requirements shall address: <ol style="list-style-type: none"> <li>1. interface plane definition,</li> <li>2. interface behaviour definition,</li> <li>3. data affecting the interface definition."</li> </ol>	Project	ECSS-E-ST-10-24C Rev.1	PRR	<ul style="list-style-type: none"> <li><a href="#">Interface Requirements Document</a></li> </ul>
<a href="#">IRD Glossary and Terminology</a>	"The applicable dictionary or glossary and the meaning of specific terms or abbreviation utilized in IRD shall be defined."	Project	ECSS-E-ST-10-24C Rev.1	PRR	<ul style="list-style-type: none"> <li><a href="#">Interface Requirements Document</a></li> </ul>
<a href="#">IRD Applicability of Requirements to Interface Ends</a>	"In addition to the general requirements defined in ECSS-E-ST-10-06, for each interface requirement the applicability to each interface end shall be specified."	Project	ECSS-E-ST-10-24C Rev.1	PRR	<ul style="list-style-type: none"> <li><a href="#">Interface Requirements Document</a></li> </ul>
<a href="#">IRD Applicable Documents</a>	"The IRD shall list the applicable and reference documents in support to the generation of the document."	Project	ECSS-E-ST-10-24C Rev.1	PRR	<ul style="list-style-type: none"> <li><a href="#">Interface Requirements Document</a></li> </ul>
<a href="#">IRD Interface End Requirements</a>	"The IRD shall specify the requirements of an interface, for all identified interface ends."	Project	ECSS-E-ST-10-24C Rev.1	PRR	<ul style="list-style-type: none"> <li><a href="#">Interface Requirements Document</a></li> </ul>
<a href="#">IRD Grouping of Multiple Interfaces</a>	"In case the IRD addresses more than one interface, the interface requirements shall be grouped either by interface end pair, by nature of interface, or by contractual party."	Project	ECSS-E-ST-10-24C Rev.1	PRR	<ul style="list-style-type: none"> <li><a href="#">Interface Requirements Document</a></li> </ul>

File (318)	Text	Domain	Source	Due	Parent statement
<a href="#">IRD Integration with Technical Requirements Specification</a>	"The content of the IRD may be merged with the content of the technical requirements specification (as defined in ECSS-E-ST-10-06 Annex A) of the product."	Project	ECSS-E-ST-10-24C Rev.1	PRR	• <a href="#">Interface Requirements Document</a>
<a href="#">IRD Interface Requirements Definition</a>	"The IRD shall define the physical, functional, procedural and operational interface requirements between two or more items in the product tree and ensure hardware and software compatibility."	Project	ECSS-E-ST-10-24C Rev.1	PRR	• <a href="#">Interface Requirements Document</a>
<a href="#">IRD Interface Specification Details</a>	"For each interface, the following aspects shall be addressed: 1. interface description using tables, figures, or drawings, 2. units of measure including scale of measure, 3. tolerances or required accuracies, 4. in case of using non-SI quantities or units, conversions and conventions, 5. interface plane specification, 6. coordinate system specification, in case of interfaces involving geometric aspects, 7. interface behaviour specification, including limitation of use."	Project	ECSS-E-ST-10-24C Rev.1	PRR	• <a href="#">Interface Requirements Document</a>
<a href="#">IRD Purpose and Objective</a>	"The IRD shall contain a description of the purpose, objective, content and the reason prompting its preparation."	Project	ECSS-E-ST-10-24C Rev.1	PRR	• <a href="#">Interface Requirements Document</a>
<a href="#">IRD Reference Documents List</a>	"The IRD shall include the following references: 1. Product tree (as defined in ECSS-M-ST-10 Annex B), 2. Specification tree (as defined in ECSS-E-ST-10), 3. Coordinate system document (as defined in ECSS-E-ST-10-09) 4. References to requirements specified in other Technical requirement specifications or Standards which are applicable for a particular Interface."	Project	ECSS-E-ST-10-24C Rev.1	PRR	• <a href="#">Interface Requirements Document</a>
<a href="#">IRD Reference Interface Data List Usage</a>	"Interface requirements shall be built starting from the Reference Interface Data List of Annex E and adding all data necessary to specify the interface. "	Project	ECSS-E-ST-10-24C Rev.1	PRR	• <a href="#">Interface Requirements Document</a>
<a href="#">IRD Relationship to Other Documents</a>	"The relationship and precedence of the IRD to other project documents shall be clearly defined. "	Project	ECSS-E-ST-10-24C Rev.1	PRR	• <a href="#">Interface Requirements Document</a>
<a href="#">IRD Verification Requirements</a>	"Each interface requirements shall be accompanied by its verification requirements."	Project	ECSS-E-ST-10-24C Rev.1	PRR	• <a href="#">Interface Requirements Document</a>
<a href="#">IRD Verification Responsibility Definition</a>	"For each verification requirement as defined in A.2.1<4>c., the verification responsibility shall be defined."	Project	ECSS-E-ST-10-24C Rev.1	PRR	• <a href="#">Interface Requirements Document</a>
<a href="#">Interface Requirements Document</a>	An Interface Requirements Document shall be prepared.	Project	ECSS-E-ST-10C	PRR	• <a href="#">Interface Identification</a>
<a href="#">Individual and Project Risk Appraisal</a>	"The assessment report shall give an appraisal of identified individual risks and the overall project risk."	Project	ECSS-M-ST-80C	PRR	• <a href="#">Risk Assessment Report</a>
<a href="#">Launch Site</a>	The recovery system shall be compatible with the requirements set in the Esrange Safety Manual ( <a href="https://sscspc.com/wp-content/uploads/Esrange-Safety-Manual.pdf">https://sscspc.com/wp-content/uploads/Esrange-Safety-Manual.pdf</a> )	Project	-	-	• <a href="#">Launch Site Compatibility</a> • <a href="#">Safety Metric</a> • <a href="#">Safety Goal</a>
<a href="#">MDD Concept Strengths and Weaknesses</a>	"The MDD shall provide the list of identified risk related to the concept, including as a minimum technology, contingencies handling, and programmatic aspects."	Project	ECSS-E-ST-10C Rev.1	PRR	• <a href="#">Mission Definition Document</a>
<a href="#">MDD Identified Risks</a>	"The MDD shall provide the 1. assessment against the current preliminary technical requirements specification requirements, and 2. identification of non-compliances, and their impact on the current preliminary technical requirements specification."	Project	ECSS-E-ST-10C Rev.1	PRR	• <a href="#">Mission Definition Document</a>
<a href="#">MDD Preliminary Requirements Summary</a>	"The MDD shall provide a summary of the preliminary technical requirements specification objectives and list the design driving requirements, derived from the current initial specification."	Project	ECSS-E-ST-10C Rev.1	MDR	• <a href="#">Mission Definition Document</a>
<a href="#">MDD Purpose and Objective</a>	"The MDD shall contain a description of the purpose, objective, content and the reason prompting its preparation (e.g. logic, organization, process or procedure)."	Project	ECSS-E-ST-10C Rev.1	MDR	• <a href="#">Mission Definition Document</a>
<a href="#">MDD Requirements Assessment</a>	"<<deleted and moved as item 4 into requirement B.2.1<4>a>>"	Project	ECSS-E-ST-10C Rev.1	MDR	• <a href="#">Mission Definition Document</a>
<a href="#">MDD System Trade-Off Report</a>	"The MDD shall summarize the strengths and weaknesses of the concept."	Project	ECSS-E-ST-10C Rev.1	MDR	• <a href="#">Mission Definition Document</a>
<a href="#">MDD Applicable Documents</a>	"The MDD shall list the applicable and reference documents in support to the generation of the document, and include, as a minimum, the current preliminary technical requirements specification."	Project	ECSS-E-ST-10C Rev.1	MDR	• <a href="#">Mission Definition Document</a>
<a href="#">MDD Concept Overview</a>	"The MDD shall provide: 1. Overview of the concept 2. Mission analysis 3. System description, element by element 4. Description of how the system works in each mission phase (a) Performance drivers (b) Constraints (c) Main events (d) Operations scenarios"	Project	ECSS-E-ST-10C Rev.1	PRR	• <a href="#">Mission Definition Document</a>
<a href="#">MOCD Input Constraints</a>	"The MOCD shall provide all the essential input information that drives or constrains the operations concepts."	Project	ECSS-E-ST-70C	PRR	• <a href="#">Mission Operations Concept Document</a>
<a href="#">MOCD Ground Segment Constraints</a>	"The MOCD shall identify any constraints relating to the design of the ground segment or its operation, including: 1. the re-use of existing ground segment elements or infrastructure; 2. the use of remote facilities for operation or maintenance of part of the space or ground segments, such as experimenter-provided control facilities or industry-provided facilities for software maintenance; 3. the use of customer furnished items developed as part of the space segment programme and to be re-used for operations."	Project	ECSS-E-ST-70C	PRR	• <a href="#">Mission Operations Concept Document</a>
<a href="#">MOCD Mission Data Generation and Delivery</a>	"The MOCD shall describe the concept for the generation, archiving and delivery of mission products to the end-users in a timely manner, including: 1. data transmission between ground entities; 2. data processing on ground; NOTE For example, generation of mission products. 3. data delivery to the end-user; 4. data archiving, cataloguing and retrieval;	Project	ECSS-E-ST-70C	PRR	• <a href="#">Mission Operations Concept Document</a>

File (318)	Text	Domain	Source	Due	Parent statement
MOCD Mission End-User Categories	5. feedback to mission planning; NOTE For example, to report achieved versus planned data acquisition." "The MOCD shall identify all distinct categories of mission end-user and describe the data products, services, associated availability and delivery requirements."	Project	ECSS-E-ST-70C	PRR	• <a href="#">Mission Operations Concept Document</a>
MOCD Mission Operations Concepts	"The MOCD shall describe the mission operations concepts for each distinct mission phase, according to the top-level breakdown of operations processes as defined in C.2.1<5.2> to <5.6>. NOTE It is recognized that not all these processes are applicable for each mission phase and the corresponding process can therefore be omitted. For example, mission exploitation processes are not normally undertaken during the LEOP. Also: · there can be additional mission-specific operations processes; · the concept for realizing a given process can be the same for several mission phases, in which case it is not repeated, but it is defined once and referenced as needed."	Project	ECSS-E-ST-70C	PRR	• <a href="#">Mission Operations Concept Document</a>
MOCD Mission Relationship with Other Programs	"The MOCD shall describe the relationship of the mission with other missions or programmes, including: 1. membership of a family of missions of the same or similar design or based on the same spacecraft platform; 2. membership of a multi-national or coordinated multi-mission programme; 3. agreements for the ground segment to support other concurrent missions or programmes or to process data from other missions."	Project	ECSS-E-ST-70C	PRR	• <a href="#">Mission Operations Concept Document</a>
MOCD Mission Scope and Objectives	"The MOCD shall describe the scope of the mission, its objectives and the top-level requirements on its operations. NOTE This information is derived from the mission analysis report and the customer requirements document."	Project	ECSS-E-ST-70C	PRR	• <a href="#">Mission Operations Concept Document</a>
MOCD Operational Capabilities and Trade-offs	"The MOCD shall also identify: 1. Reuse of existing operational capabilities and services. NOTE For example, there can be a mission requirement to re-use specific existing infrastructure, possibly modified or extended for the mission; 2. Areas where existing operational capabilities cannot satisfy the concept, i.e. new developments are needed; 3. Areas where trade-offs are needed. NOTE For example, if it is not obvious whether to realize a given operational process by ground-based automation or manually by an operator."	Project	ECSS-E-ST-70C	PRR	• <a href="#">Mission Operations Concept Document</a>
MOCD Operational Interfaces	"The MOCD shall describe the operational interfaces with other agencies, companies or other third parties."	Project	ECSS-E-ST-70C	PRR	• <a href="#">Mission Operations Concept Document</a>
MOCD Operations Performance Monitoring	"The MOCD shall describe the concept for evaluating the success of executed operations and for monitoring the performance of the space segment, including: 1. data analysis processes (trend analysis, forecasts); 2. monitoring of resource availability and utilization with provision of feedback to the planning processes described earlier; 3. report production (automated report production, routine operations reporting, anomaly reporting)."	Project	ECSS-E-ST-70C	PRR	• <a href="#">Mission Operations Concept Document</a>
MOCD Applicable Documents	"The MOCD shall list the applicable and reference documents in support of the generation of the document."	Project	ECSS-E-ST-70C	PRR	• <a href="#">Mission Operations Concept Document</a>
MOCD Execution of Scheduled Operations	"The MOCD shall describe the concept for the implementation of scheduled operations for the space and ground segment, including: 1. schedule execution; 2. procedure execution; 3. manual commanding; 4. command pre-transmission validation and uplink management; 5. command verification; 6. schedule and command history archiving; 7. space and ground segment health monitoring; 8. failure detection, isolation and recovery (FDIR)."	Project	ECSS-E-ST-70C	PRR	• <a href="#">Mission Operations Concept Document</a>
MOCD Operations Realization	"The MOCD shall identify how to realize the operations processes with the ground systems and operations personnel."	Project	ECSS-E-ST-70C	PRR	• <a href="#">Mission Operations Concept Document</a>
MOCD Other Support Activities	"The MOCD shall describe the concepts for all other activities performed in support of operations that are not covered by any of the above categories, including: 1. orbit and attitude determination and maintenance; 2. orbital and geometric events prediction; 3. ground station coverage predictions; 4. monitoring and control database maintenance; 5. ground software maintenance; 6. on-board software maintenance."	Project	ECSS-E-ST-70C	PRR	• <a href="#">Mission Operations Concept Document</a>
MOCD Planning and Scheduling Concept	"The MOCD shall describe the concept for the planning and scheduling of space and ground segment operations, including: 1. user request management; 2. space segment routine operations; 3. ground segment maintenance requests; 4. constraints management; 5. resources management (space and ground); 6. conflict resolution; 7. space segment operations scheduling; 8. ground segment operations scheduling."	Project	ECSS-E-ST-70C	PRR	• <a href="#">Mission Operations Concept Document</a>
MOCD Purpose and Objective	"The introduction shall describe the purpose and objective of the MOCD."	Project	ECSS-E-ST-70C	PRR	• <a href="#">Mission Operations Concept Document</a>
MOCD Space Segment Characteristics	"The MOCD shall describe the capabilities and characteristics of the space segment platform, payload(s) and the space link subnet, including: 1. on-board autonomous functions; 2. the mechanisms for on-board generation, storage and downlink of mission data products; 3. the end-user services to be provided. NOTE The objective is to capture all the salient operational characteristics that are needed for the analysis of the operations processes."	Project	ECSS-E-ST-70C	PRR	• <a href="#">Mission Operations Concept Document</a>
Mission Definition Document	A Mission Description Document (MDD) shall be prepared.	Project	ECSS-E-ST-10C	MDR	• <a href="#">Selected System Description</a>
Mission Operations Concept Document	A preliminary Mission Operations Concept Document for the system shall be provided.	Project	ECSS-E-ST-70C	PRR	• <a href="#">Selected System Description</a>
Maximum Budget	The maximum allowable budget for the final recovery system shall be 10'000 CHF.	Project	2025_FINANCES	-	• <a href="#">Monetary Budget</a>
Preliminary Technical Requirements Specifications	A Preliminary Technical Requirements Specifications shall be prepared.	Project	ECSS-E-ST-10-06	MDR	• <a href="#">Test Launch Opportunity</a> • <a href="#">Facility Constraint</a>



File (318)	Text	Domain	Source	Due	Parent statement
					<ul style="list-style-type: none"> <li>Selected System Description</li> <li>Safety Goal</li> <li>Launch Site Compatibility</li> <li>Student Organisation Constraints</li> <li>Technical Needs</li> <li>Technical Constraints</li> <li>Launch Site Compatibility</li> </ul>
<a href="#">Product Tree Applicable Documents</a>	"The product tree shall list the applicable and reference documents used in support of the generation of the document."	Project	ECSS-M-ST-10C Rev. 1	PRR	<ul style="list-style-type: none"> <li><a href="#">Product Tree</a></li> </ul>
<a href="#">Preliminary Technical Requirements Specification for Next Lower Level</a>	A Preliminary Technical Requirements Specification for Next Lower Level shall be prepared.	Project	ECSS-E-ST-10C	PRR	<ul style="list-style-type: none"> <li><a href="#">Design Definition File</a></li> </ul>
<a href="#">Product Tree Breakdown Structure</a>	"The product tree shall provide the breakdown of lower level products constituting the deliverable product."	Project	ECSS-M-ST-10C Rev. 1	PRR	<ul style="list-style-type: none"> <li><a href="#">Product Tree</a></li> </ul>
<a href="#">Product Tree Configuration Item Identification</a>	"Each product item selected as configuration item shall be identified in the product tree."	Project	ECSS-M-ST-10C Rev. 1	PRR	<ul style="list-style-type: none"> <li><a href="#">Product Tree</a></li> </ul>
<a href="#">Product Tree Item Information</a>	"For each item identified in the product tree, the following information shall be provided: 1. identification code; 2. item name; 3. item supplier; 4. applicable specification."	Project	ECSS-M-ST-10C Rev. 1	PRR	<ul style="list-style-type: none"> <li><a href="#">Product Tree</a></li> </ul>
<a href="#">Product Tree Presentation Format</a>	"The product tree shall be presented either as a graphical diagram or an indented structure where the product (i.e. at the top level of the tree) is decomposed into lower level products."	Project	ECSS-M-ST-10C Rev. 1	PRR	<ul style="list-style-type: none"> <li><a href="#">Product Tree</a></li> </ul>
<a href="#">Product Tree Purpose and Objective</a>	"The product tree shall contain a description of the purpose, objective and the reason prompting its preparation (e.g. program or project reference and phase)."	Project	ECSS-M-ST-10C Rev. 1	PRR	<ul style="list-style-type: none"> <li><a href="#">Product Tree</a></li> </ul>
<a href="#">Product Tree Recurrent Product Identification</a>	"When recurrent products from previous space projects are used, they shall be identified in the tree structure."	Project	ECSS-M-ST-10C Rev. 1	PRR	<ul style="list-style-type: none"> <li><a href="#">Product Tree</a></li> </ul>
<a href="#">Product Tree</a>	A Product Tree shall be prepared.	Project	ECSS-E-ST-10C	PRR	<ul style="list-style-type: none"> <li><a href="#">Design Definition File</a></li> </ul>
<a href="#">RJF Applicable Documents</a>	"The RJF shall list the applicable and reference documents in support to the generation of the document."	Project	ECSS-E-ST-10C Rev.1	MDR	<ul style="list-style-type: none"> <li><a href="#">Requirement Justification File</a></li> </ul>
<a href="#">RJF COTS Compliance Matrix</a>	"For COTS, the RJF shall contain a compliance matrix between the technical specification/characteristics of the COTS and the technical requirement expressed by the TS."	Project	ECSS-E-ST-10C Rev.1	MDR	<ul style="list-style-type: none"> <li><a href="#">Requirement Justification File</a></li> </ul>
<a href="#">RJF Concept Selection Rationale</a>	"The RJF shall present the rationale for the selection of a concept for the technical requirements specification."	Project	ECSS-E-ST-10C Rev.1	MDR	<ul style="list-style-type: none"> <li><a href="#">Requirement Justification File</a></li> </ul>
<a href="#">RJF Environmental Constraints Justification</a>	"The RJF shall present and justify the different environments and constraints for each life profile situations for the concept presented in the technical requirements specification."	Project	ECSS-E-ST-10C Rev.1	PRR	<ul style="list-style-type: none"> <li><a href="#">Requirement Justification File</a></li> </ul>
<a href="#">RJF Inclusion in DJF</a>	"The RJF may be part of the design justification file (DJF) (as defined in ECSS-E-ST-10 Annex K)."	Project	ECSS-E-ST-10C Rev.1	MDR	<ul style="list-style-type: none"> <li><a href="#">Requirement Justification File</a></li> </ul>
<a href="#">RJF Life Profile Situations Justification</a>	"The RJF shall present and justify the life profile situations for the concept presented in the technical requirements specification."	Project	ECSS-E-ST-10C Rev.1	MDR	<ul style="list-style-type: none"> <li><a href="#">Requirement Justification File</a></li> </ul>
<a href="#">RJF Purpose and Objective</a>	"The RJF shall contain a description of the purpose, objective, content and the reason prompting its preparation."	Project	ECSS-E-ST-10C Rev.1	MDR	<ul style="list-style-type: none"> <li><a href="#">Requirement Justification File</a></li> </ul>
<a href="#">RJF Requirement Justification Details</a>	"For each technical requirement the following information shall be provided: 1. the justification of the requirement (i.e. justified source), 2. the Entity or owner responsible for the requirement, 3. if one technical requirement is induced by several sources, the reason of the specified performance, 4. the justification of the quantified performance (such as the range, the approach used to determine the level, e.g. measure, estimation), 5. the justification of the selected verification method."	Project	ECSS-E-ST-10C Rev.1	MDR	<ul style="list-style-type: none"> <li><a href="#">Requirement Justification File</a></li> </ul>
<a href="#">RJF Requirement Traceability</a>	"The RJF shall present the requirement traceability between the technical requirements of the TS, and their justified source."	Project	ECSS-E-ST-10C Rev.1	MDR	<ul style="list-style-type: none"> <li><a href="#">Requirement Justification File</a></li> </ul>
<a href="#">RJF Technical Requirements List</a>	"The RJF shall list all the technical requirements, and their identifier, expressed by the corresponding TS as they are organized in these documents. "	Project	ECSS-E-ST-10C Rev.1	MDR	<ul style="list-style-type: none"> <li><a href="#">Requirement Justification File</a></li> </ul>
<a href="#">RJF Technical Requirements Specification Reference</a>	"The RJF shall include the reference to the technical requirements specification."	Project	ECSS-E-ST-10C Rev.1	MDR	<ul style="list-style-type: none"> <li><a href="#">Requirement Justification File</a></li> </ul>
<a href="#">Requirement Justification File</a>	A Requirement Justification File shall be prepared.	Project	ECSS-E-ST-10C	MDR	<ul style="list-style-type: none"> <li><a href="#">Design Justification File</a></li> </ul>
<a href="#">Risk Assessment Applicable Documents</a>	"The risk assessment report shall contain the list of applicable and reference documents, used to support the generation of the document."	Project	ECSS-M-ST-80C	PRR	<ul style="list-style-type: none"> <li><a href="#">Risk Assessment Report</a></li> </ul>
<a href="#">Risk Assessment Conclusions</a>	"The assessment report shall describe the conclusions drawn from the identification and assessment, including any statements for future assessments and follow-up actions."	Project	ECSS-M-ST-80C	PRR	<ul style="list-style-type: none"> <li><a href="#">Risk Assessment Report</a></li> </ul>
<a href="#">Risk Assessment Method Justification</a>	"The assessment report shall describe the basics of the identification and assessment method (e.g. interviewing method), including the justification for the method(s) selected."	Project	ECSS-M-ST-80C	PRR	<ul style="list-style-type: none"> <li><a href="#">Risk Assessment Report</a></li> </ul>
<a href="#">Risk Assessment Process Summary</a>	"The assessment report shall briefly describe what was done during the identification and assessment exercise."	Project	ECSS-M-ST-80C	PRR	<ul style="list-style-type: none"> <li><a href="#">Risk Assessment Report</a></li> </ul>
<a href="#">Risk Assessment Report Contents</a>	"The assessment report shall contain the following information: 1. risk register (see ECSS-M-ST-80, Annex D); 2. ranked risk log; 3. rating scheme; 4. overall risk rating; 5. other analysis."	Project	ECSS-M-ST-80C	PRR	<ul style="list-style-type: none"> <li><a href="#">Risk Assessment Report</a></li> </ul>
<a href="#">Risk Assessment Report Introduction</a>	"The assessment report shall introduce the following items: 1. The purpose and objective of the risk assessment report; 2. A brief description of what was done during the identification and assessment"	Project	ECSS-M-ST-80C	PRR	<ul style="list-style-type: none"> <li><a href="#">Risk Assessment Report</a></li> </ul>

File (318)	Text	Domain	Source	Due	Parent statement
	exercise, and its outcome; 3. Identification of organizations that contributed to the preparation of the document."				
<a href="#">Risk Conflict and Decision Highlights</a>	"The assessment report shall emphasize items of conflict and highlight the decisions that were taken for consideration in the overall assessment."	Project	ECSS-M-ST-80C	PRR	<ul style="list-style-type: none"> <li><a href="#">Risk Assessment Report</a></li> </ul>
<a href="#">Risk Consolidation Approach</a>	"The assessment report shall describe the consolidation approach for the overall risk assessment. "	Project	ECSS-M-ST-80C	PRR	<ul style="list-style-type: none"> <li><a href="#">Risk Assessment Report</a></li> </ul>
<a href="#">Risk Follow-Up Assessment</a>	"The assessment report shall describe results of the follow-up actions that were taken in comparison with earlier assessment(s)."	Project	ECSS-M-ST-80C	PRR	<ul style="list-style-type: none"> <li><a href="#">Risk Assessment Report</a></li> </ul>
<a href="#">Risk Identification Methodology</a>	"The assessment report shall describe how the risks in question were identified, which inputs, method, tool(s) were used, and which people were involved. "	Project	ECSS-M-ST-80C	PRR	<ul style="list-style-type: none"> <li><a href="#">Risk Assessment Report</a></li> </ul>
<a href="#">SEP Applicable Document References</a>	<p>"The SEP shall include the references to the following applicable documents:</p> <ol style="list-style-type: none"> <li>1. Business agreement</li> <li>2. Project management plan, as defined in ECSS-M-ST-10 Annex A</li> <li>3. Product assurance plan, as defined in ECSS-Q-ST-10 Annex A</li> <li>4. Configuration management plan, as defined in ECSS-M-ST-40 Annex A</li> <li>5. Production plan</li> <li>6. Mission operations plan, as defined in ECSS-E-ST-70 Annex G</li> <li>7. ILS plan."</li> </ol>	Project	ECSS-E-ST-10C Rev.1	PRR	<ul style="list-style-type: none"> <li><a href="#">System Engineering Plan</a></li> </ul>
<a href="#">SEP Applicable Documents</a>	"The SEP shall list the applicable and reference documents in support to the generation of the document."	Project	ECSS-E-ST-10C Rev.1	MDR	<ul style="list-style-type: none"> <li><a href="#">System Engineering Plan</a></li> </ul>
<a href="#">SEP Communication Engineering Process Control</a>	"The SEP shall define process and control to be put in place to meet requirements for control engineering, covering, amongst others, AOCs, robotics, rendez-vous and docking."	Project	ECSS-E-ST-10C Rev.1	PRR	<ul style="list-style-type: none"> <li><a href="#">System Engineering Plan</a></li> </ul>
<a href="#">SEP Coordinate System Reference</a>	"The SEP shall contain the Coordinate System Document (as defined in ECSS-E-ST-10-09 Annex A)."	Project	ECSS-E-ST-10C Rev.1	PRR	<ul style="list-style-type: none"> <li><a href="#">System Engineering Plan</a></li> </ul>
<a href="#">SEP Discipline-Specific Engineering Activities</a>	"The SEP shall define the process and control to be put in place to meet requirements for the thermal, structures, mechanisms, environmental control and life support, propulsion, pyrotechnics, mechanical parts, and materials functions and interfaces."	Project	ECSS-E-ST-10C Rev.1	PRR	<ul style="list-style-type: none"> <li><a href="#">System Engineering Plan</a></li> </ul>
<a href="#">SEP Electrical and Electronic Process Control</a>	"The SEP shall define process and control to be put in place to meet requirements for software engineering, covering, amongst others, flight and ground software, checkout software and simulation software."	Project	ECSS-E-ST-10C Rev.1	PRR	<ul style="list-style-type: none"> <li><a href="#">System Engineering Plan</a></li> </ul>
<a href="#">SEP Engineering Methods and Interactions</a>	<p>"In the case of a system incremental evolution, the SEP shall describe the design strategy for the:</p> <ol style="list-style-type: none"> <li>1. development of the initial release of the product,</li> <li>2. development, the verification of subsequent releases and their deployment,</li> <li>3. introduction of new technologies,</li> <li>4. tools and methods used for analysis,</li> <li>5. control of the evolutions for each release."</li> </ol>	Project	ECSS-E-ST-10C Rev.1	PRR	<ul style="list-style-type: none"> <li><a href="#">System Engineering Plan</a></li> </ul>
<a href="#">SEP Acquisition Strategy</a>	"The SEP shall list the critical issues identified at the beginning of the project phase(s) covered in the SEP (e.g. any specific issues, problems, critical subjects, which require dedicated attention, investigation, action and planning)."	Project	ECSS-E-ST-10C Rev.1	PRR	<ul style="list-style-type: none"> <li><a href="#">System Engineering Plan</a></li> </ul>
<a href="#">SEP External Means and Facilities</a>	"The SEP shall list the external means and facilities (e.g. equipment, software, and premises) made available by the customer or by any other entity external to the supplier that is responsible of this SEP, and, for each identified mean or facility, identify the applicable interface requirements (e.g. interface control documentation) as well as the authority in charge of it."	Project	ECSS-E-ST-10C Rev.1	PRR	<ul style="list-style-type: none"> <li><a href="#">System Engineering Plan</a></li> </ul>
<a href="#">SEP External and Internal Coordination</a>	"The SEP shall describe the system engineering process tailored to the specifics of the considered project, and identify all the system engineering tasks to be implemented from the starting conditions (e.g. kick-off) to the closing event (e.g. review), their relationship, and their interfaces with other actors of the project, and identify and describe any existing iteration within the process."	Project	ECSS-E-ST-10C Rev.1	MDR	<ul style="list-style-type: none"> <li><a href="#">System Engineering Plan</a></li> </ul>
<a href="#">Risk Assessment Report</a>	A preliminary Risk Assessment Report for the system shall be provided.	Project	ECSS-M-ST-80C	PRR	<ul style="list-style-type: none"> <li><a href="#">Preliminary Study</a></li> <li><a href="#">Risk Threshold</a></li> </ul>
<a href="#">SEP Human Factors and Environment Considerations</a>	"The SEP shall define process and control to be put in place to meet requirements for implementation of design selections relating to humans for any item with associated human interface, including computer based system and equipment."	Project	ECSS-E-ST-10C Rev.1	PRR	<ul style="list-style-type: none"> <li><a href="#">System Engineering Plan</a></li> </ul>
<a href="#">SEP Identified Issues and Risk Mitigation</a>	"The SEP shall describe any specific issues, problems requiring dedicated attention, investigations or actions during the current phase and identify risks, and risk mitigation measures."	Project	ECSS-E-ST-10C Rev.1	PRR	<ul style="list-style-type: none"> <li><a href="#">System Engineering Plan</a></li> </ul>
<a href="#">SEP Incremental Evolution Design Strategy</a>	<p>"The SEP shall contain the following:</p> <ol style="list-style-type: none"> <li>1. Definition of the entities participating in the system engineering activities and the corresponding functions according to the project management plan.</li> <li>2. Identification of key engineering roles and responsibilities (e.g. system engineers, disciplines engineers, and technical managers).</li> <li>3. Description of the co-operative work amongst the different teams participating in the system design."</li> </ol>	Project	ECSS-E-ST-10C Rev.1	PRR	<ul style="list-style-type: none"> <li><a href="#">System Engineering Plan</a></li> </ul>
<a href="#">SEP Incremental System Development</a>	<p>"The SEP shall detail the incremental development of the system:</p> <ol style="list-style-type: none"> <li>1. progressive implementation of system functionalities,</li> <li>2. identification of possible successive versions,</li> <li>3. objectives and strategy for the implementation of the successive versions."</li> </ol>	Project	ECSS-E-ST-10C Rev.1	PRR	<ul style="list-style-type: none"> <li><a href="#">System Engineering Plan</a></li> </ul>
<a href="#">SEP Internal Means and Facilities</a>	"The SEP shall list the internal means and facilities (e.g. equipment, software, and premises) made available by the organization in charge of the development of the system or product."	Project	ECSS-E-ST-10C Rev.1	PRR	<ul style="list-style-type: none"> <li><a href="#">System Engineering Plan</a></li> </ul>
<a href="#">SEP Logistics and Maintenance Process Control</a>	"The SEP shall define the process and control to be put in place to meet requirements for human activities and environments associated with space systems. "	Project	ECSS-E-ST-10C Rev.1	PRR	<ul style="list-style-type: none"> <li><a href="#">System Engineering Plan</a></li> </ul>
<a href="#">SEP Mechanical and Structural Process Control</a>	"The SEP shall define the process and control to be put in place to meet requirements for electrical and electronic engineering, covering all electrical and electronic aspects of the relevant space product, including functions such as power generation, storage, conversion and distribution, and optical, avionics and microwave domains, electromagnetic compatibility, and electrical interfaces. "	Project	ECSS-E-ST-10C Rev.1	PRR	<ul style="list-style-type: none"> <li><a href="#">System Engineering Plan</a></li> </ul>
<a href="#">SEP Model Philosophy and Margin Policy</a>	<p>"The SEP shall also describe</p> <ol style="list-style-type: none"> <li>1. the method(s) and process(es) considered for the engineering activities (e.g. concurrent engineering, value analysis, or iteration cycle),</li> <li>2. the interrelation between the different engineering disciplines and other project activities (e.g. production, quality assurance, and operations and logistics),</li> <li>3. the interaction with other actors (e.g. customer and suppliers),</li> <li>4. the consistency and coherency of simultaneous activities (e.g. performed in parallel),</li> <li>5. which and how, control activities are implemented,</li> </ol>	Project	ECSS-E-ST-10C Rev.1	MDR	<ul style="list-style-type: none"> <li><a href="#">System Engineering Plan</a></li> </ul>

File (318)	Text	Domain	Source	Due	Parent statement
	6. Assessment of potential COTS usage"				
SEP Natural Environment Process Control	"The SEP shall define the process and control to be put in place to meet requirements for the approach, methods, procedures, organization and resources to be implemented to ensure proper technical interfaces between system engineering and production. "	Project	ECSS-E-ST-10C Rev.1	PRR	<ul style="list-style-type: none"> <li>System Engineering Plan</li> </ul>
SEP Project Milestones and Phases	"The SEP shall provide dates of milestones or the duration of phases and the critical path according to the project master schedule."	Project	ECSS-E-ST-10C Rev.1	MDR	<ul style="list-style-type: none"> <li>System Engineering Plan</li> <li>Deliverables per Review</li> <li>Review Plan</li> </ul>
SEP Project Overview and Constraints	<p>"The SEP shall contain the following description of:</p> <ol style="list-style-type: none"> <li>1. The project objective and the main elements that characterize the user's need.</li> <li>2. The objective of the system or product as established by the TS (as defined in the ECSS-E-ST-10-06 Annex A).</li> <li>3. The main elements of the system architecture (i.e. first level elements of the architecture adopted for the system and identification of their reuse constraints).</li> <li>4. The principal characteristics of the project lifecycle and the incremental development of the system (e.g. successive versions, progressive implementation of the functions of the system).</li> <li>5. The main elements supporting the project lifecycle (e.g. ground support equipment, and facilities).</li> <li>6. The organizational constraints impacting system engineering activities (e.g. the external and internal industrial organization (e.g. contractors, partners, suppliers, own company) constraints).</li> <li>7. The list of the critical issues identified at the beginning of the project phase(s).</li> <li>8. The list of national and international regulations.</li> <li>9. The capacity for verification and validation of the product, taking into account the means available, e.g. for tests, analysis, or simulation."</li> </ol>	Project	ECSS-E-ST-10C Rev.1	MDR	<ul style="list-style-type: none"> <li>System Engineering Plan</li> </ul>
SEP Project Schedule and Critical Path	"The SEP shall describe the strategy for acquisition of the items of the system or products defined in the product tree (e.g. make or buy, product line, incremental development)."	Project	ECSS-E-ST-10C Rev.1	PRR	<ul style="list-style-type: none"> <li>System Engineering Plan</li> <li>Review Plan</li> </ul>
SEP Purpose and Objective	"The SEP shall contain a description of the purpose, objective, content and the reason prompting its preparation (e.g. programme or project reference and phase)."	Project	ECSS-E-ST-10C Rev.1	MDR	<ul style="list-style-type: none"> <li>System Engineering Plan</li> </ul>
SEP Related System Engineering Plans	<p>"The SEP shall identify the other plans relevant to system engineering function activity belonging to the following categories:</p> <ol style="list-style-type: none"> <li>1. Programmatic plans</li> <li>2. Verification plans</li> <li>3. Engineering discipline plans</li> <li>4. Operations plans"</li> </ol>	Project	ECSS-E-ST-10C Rev.1	PRR	<ul style="list-style-type: none"> <li>System Engineering Plan</li> </ul>
SEP Requirements Traceability and Compliance	"In relation to requirements traceability and demonstration of verification (compliance with requirements, VCD), the specific methods and tools shall be described (including interfaces to next lower level suppliers), and reuse of elements (e.g. COTS) identified."	Project	ECSS-E-ST-10C Rev.1	PRR	<ul style="list-style-type: none"> <li>System Engineering Plan</li> </ul>
SEP Software Engineering Process Control	"The SEP shall define process and control to be put in place to meet requirements for communication engineering, covering, amongst others, spacecraft-to-ground, spacecraft-to-spacecraft, ground-to-ground and on-board communications links. "	Project	ECSS-E-ST-10C Rev.1	PRR	<ul style="list-style-type: none"> <li>System Engineering Plan</li> </ul>
SEP Space Segment Operations Process Control	"The SEP shall define the process and control to be put in place to meet requirements for ground and in-orbit logistics and maintenance, addressing, amongst others, technical activities, related engineering standards, methods and analyses to be performed to ensure that the development of space systems (i.e. manned and unmanned) properly takes into account and integrates the supportability and support aspects for the whole life cycle."	Project	ECSS-E-ST-10C Rev.1	PRR	<ul style="list-style-type: none"> <li>System Engineering Plan</li> </ul>
SEP System Engineering Constraints and Interactions	"The SEP shall describe the constraints and the interactions impacting the system engineering activities derived from the analysis of the plans identified as relevant in D.2.1<5.2>b."	Project	ECSS-E-ST-10C Rev.1	PRR	<ul style="list-style-type: none"> <li>System Engineering Plan</li> </ul>
SEP System Engineering Implementation	<p>"The SEP shall provide an implementation and schedule of the system engineering activities and identify for the considered phase(s), as a minimum:</p> <ol style="list-style-type: none"> <li>1. the main project milestones driving the system engineering process,</li> <li>2. the phase(s) of the project lifecycle and the main reviews in accordance to project management plan."</li> </ol>	Project	ECSS-E-ST-10C Rev.1	MDR	<ul style="list-style-type: none"> <li>System Engineering Plan</li> </ul>
SEP System Engineering Inputs	<p>"The SEP shall list the driving inputs for the system engineering activities described and defined by the:</p> <ol style="list-style-type: none"> <li>1. business agreement,</li> <li>2. outputs from previous phase(s) or expected under the heading of activities which are not controlled within the context of this SEP (e.g. data provided by the customer, data coming from other projects, upstream or predevelopment studies, product lines),</li> <li>3. project management plan, product assurance plan, risk management plan, and configuration and documentation management plans."</li> </ol>	Project	ECSS-E-ST-10C Rev.1	MDR	<ul style="list-style-type: none"> <li>System Engineering Plan</li> </ul>
SEP System Engineering Outputs	"The SEP shall list the specified system engineering outputs as defined in ECSS-E-ST-10 clause 6 for the specific project phase(s) covered in the SEP."	Project	ECSS-E-ST-10C Rev.1	PRR	<ul style="list-style-type: none"> <li>System Engineering Plan</li> </ul>
SEP System Engineering Process Tailoring	"For each task, the input information and their origin, the document(s) delivered (i.e. expected output) and their destination, the system engineering function(s) performed and the contribution of other actors shall be identified."	Project	ECSS-E-ST-10C Rev.1	MDR	<ul style="list-style-type: none"> <li>System Engineering Plan</li> </ul>
SEP System Engineering Roles and Responsibilities	"The SEP shall describe the external and internal coordination in line with the project management plan."	Project	ECSS-E-ST-10C Rev.1	PRR	<ul style="list-style-type: none"> <li>System Engineering Plan</li> </ul>
SEP System Engineering Strategy	<p>"The SEP shall describe the following:</p> <ol style="list-style-type: none"> <li>1. The strategy for the system engineering activities in line with the guidelines addressed by the management plan. In particular, identifying intermediate technical events for each phase in compliance with the master program schedule.</li> <li>2. The system design activities, with their objectives and major outputs according to the phase.</li> <li>3. The major engineering activities for each intermediate technical events, showing their mutual interactions and their relationships with the principal milestones (i.e. internal or contractual) of the project.</li> <li>4. The model philosophy (as defined in ECSS-E-ST-10-02 clause 4.2.5) in terms of number and characterization of models, from system to the requested lower level, necessary to achieve a high confidence in the product verification.</li> <li>5. The margin policy according to project phase, product category and maturity level."</li> </ol>	Project	ECSS-E-ST-10C Rev.1	MDR	<ul style="list-style-type: none"> <li>System Engineering Plan</li> </ul>
SEP System Engineering Sub-Plans	"When the SEP includes sub-plans covering parts of system engineering activities, these sub-plans shall be annexed to the SEP."	Project	ECSS-E-ST-10C Rev.1	PRR	<ul style="list-style-type: none"> <li>System Engineering Plan</li> </ul>
SEP System Engineering and Production	"The SEP shall define the process and control to be put in place to meet requirements of operations of the space segment, covering, amongst others:	Project	ECSS-E-ST-10C Rev.1	PRR	<ul style="list-style-type: none"> <li>System Engineering Plan</li> </ul>

File (318)	Text	Domain	Source	Due	Parent statement
Integration	<ol style="list-style-type: none"> <li>mission operation definition and preparation,</li> <li>mission and trajectory analysis, and</li> <li>operability analysis (e.g. autonomy, operational scenario, nominal and non-nominal modes, failure detection isolation and recovery)."</li> </ol>				
SEP Task Inputs, Outputs, and Interfaces	"The SEP shall address the following activities that concern the different engineering disciplines, recalling the relevant applicable standards and ancillary dedicated plans that are considered integral part of this SEP."	Project	ECSS-E-ST-10C Rev.1	PRR	<ul style="list-style-type: none"> <li>System Engineering Plan</li> </ul>
SEP Units System Definition	"The SEP shall define the units system to be used in the project."	Project	ECSS-E-ST-10C Rev.1	PRR	<ul style="list-style-type: none"> <li>System Engineering Plan</li> </ul>
SEP Work Breakdown Structure Definition	"The SEP shall define and describe the work package(s) for the relevant engineering tasks, which are maintained in the work breakdown structure."	Project	ECSS-E-ST-10C Rev.1	PRR	<ul style="list-style-type: none"> <li>System Engineering Plan</li> </ul>
SEP Control Engineering Process Control	"The SEP shall define the process and control to be put in place to meet requirements specifying natural environment for all space regimes (e.g. debris regulations, or planetary contamination protection) and general models and rules for determining the local induced environment"	Project	ECSS-E-ST-10C Rev.1	PRR	<ul style="list-style-type: none"> <li>System Engineering Plan</li> </ul>
SEP Engineering Tools and Methods	"The SEP shall list and briefly describe the methods, tools, and data models that the system engineering team uses in performing their tasks."	Project	ECSS-E-ST-10C Rev.1	PRR	<ul style="list-style-type: none"> <li>System Engineering Plan</li> </ul>
SEP Future System Engineering Activities	"The SEP shall introduce the system engineering activities, to be conducted during subsequent phase(s) of the project, and as a minimum, list any identified critical issue and risk to be mitigated during the subsequent phase(s)."	Project	ECSS-E-ST-10C Rev.1	PRR	<ul style="list-style-type: none"> <li>System Engineering Plan</li> </ul>
Sections Recovered	The preliminary study shall establish at least two potential architectures: one architecture which allows for total recovery and one architecture which allows for recovering only the Nosecone.	Project		-	<ul style="list-style-type: none"> <li>Descoping Options</li> </ul>
System Concept Discipline Trade-Offs	"Where relevant, specific e.g. discipline trade-off's shall be performed, contributing to the system trade-off, each one being reported in a document conforming to ECSS-E-ST-10 Annex L."	Project	ECSS-E-ST-10C Rev.1	MDR	<ul style="list-style-type: none"> <li>System Concept Report</li> </ul>
System Concept Report Scope	"This report shall address all technical (e.g. engineering disciplines), programmatic and related aspects relevant to the system."	Project	ECSS-E-ST-10C Rev.1	MDR	<ul style="list-style-type: none"> <li>System Concept Report</li> </ul>
System Concept Report	A System Concept Report shall be prepared.	Project	ECSS-E-ST-10C	MDR	<ul style="list-style-type: none"> <li>System Concepts Considered</li> <li>Design Justification File</li> <li>State of The Art</li> <li>Descoping Options</li> </ul>
System Engineering Plan	A System Engineering Plan shall be prepared.	Project	ECSS-E-ST-10C	MDR	<ul style="list-style-type: none"> <li>Technical and Program Recommendations</li> </ul>
System Schedule Constraint	The entire recovery system shall be fully developed and verified by the year 2030.	Project		-	<ul style="list-style-type: none"> <li>Time Constraint</li> </ul>
System Concept Report as Trade-Off Report	"The system concept report shall be an instantiation of the trade-off report at system level in Phase 0 and Phase A of a project, conforming to ECSS-E-ST-10 Annex L."	Project	ECSS-E-ST-10C Rev.1	MDR	<ul style="list-style-type: none"> <li>System Concept Report</li> </ul>
TP Engineering Roles and Responsibilities	<p>"The TP shall contain the following:</p> <ol style="list-style-type: none"> <li>definition of the entities participating in the engineering activities and the corresponding functions according to the SEP;</li> <li>identification of key engineering roles and responsibilities for each technology or technological element."</li> </ol>	Project	ECSS-E-ST-10C Rev.1	PRR	<ul style="list-style-type: none"> <li>Technology Plan</li> </ul>
TP External and Internal Interfaces	"The TP shall describe the external and internal interfaces in conformance to the SEP."	Project	ECSS-E-ST-10C Rev.1	PRR	<ul style="list-style-type: none"> <li>Technology Plan</li> </ul>
TP Future Technology Activities	"The TP shall introduce the related activities, to be conducted during all phase(s) of the project."	Project	ECSS-E-ST-10C Rev.1	PRR	<ul style="list-style-type: none"> <li>Technology Plan</li> </ul>
TP Purpose and Objective	"The TP shall contain a description of the purpose, objective, content and the reason prompting its preparation (e.g. programme or project reference and phase)."	Project	ECSS-E-ST-10C Rev.1	PRR	<ul style="list-style-type: none"> <li>System Engineering Plan</li> </ul>
TP SEP Integration	"The content of the TP may be merged with the content of the SEP."	Project	ECSS-E-ST-10C Rev.1	PRR	<ul style="list-style-type: none"> <li>Technology Plan</li> </ul>
TP Summary of Project Aspects	<p>"The TP shall contain a summary of the main aspects of:</p> <ol style="list-style-type: none"> <li>project objectives and constraints (i.e. section &lt;3.1&gt; of ECSS-E-ST-10, Annex D "SEP DRD");</li> <li>product evolution logic (i.e. section &lt;3.2&gt; of ECSS-E-ST-10, Annex D "SEP DRD");</li> <li>project phase(s), reviews and planning (i.e. section &lt;3.3&gt; of ECSS-E-ST-10, Annex D "SEP DRD");</li> <li>Procurement approach (i.e. section &lt;3.4&gt; of ECSS-E-ST-10, Annex D "SEP DRD")"</li> </ol>	Project	ECSS-E-ST-10C Rev.1	PRR	<ul style="list-style-type: none"> <li>System Engineering Plan</li> </ul>
TP System Function Input Requirements	<p>"For each system function, the TP input shall be:</p> <ol style="list-style-type: none"> <li>technical requirements,</li> <li>the selected technology or technological element and its TRL,</li> <li>the list of the identified project risks and critical aspects, and</li> <li>the schedule for Engineering activities."</li> </ol>	Project	ECSS-E-ST-10C Rev.1	PRR	<ul style="list-style-type: none"> <li>Technology Plan</li> </ul>
TP TRSL Reporting and Evaluation	<p>"The TP shall include the TRSL by using the template in Figure E-1, and listing:</p> <ol style="list-style-type: none"> <li>the critical function, with reference to the Function tree,</li> <li>the name of the technology or element(s) implementing such a function,</li> <li>current declared and verified TRL, as defined in ECSS-E-AS-11,</li> <li>reference to the TRA report confirming the declared TRL,</li> <li>date of the report,</li> <li>key points to support TRL declared in column [3],</li> <li>forward plan for TRL evaluation, indicating the target TRL, the phase or date at which such target TRL is expected, and status of the planning to achieve the target TRL,</li> <li>during phases A &amp; B, indication whether or not the technology/element is a candidate for the CIL."</li> </ol>	Project	ECSS-E-ST-10C Rev.1	PRR	<ul style="list-style-type: none"> <li>Technology Plan</li> <li>Technology Readiness Status List</li> </ul>
TP Technical Milestones and Interactions	"The TP shall identify technical milestones, showing their interactions and relationships with the SEP milestones."	Project	ECSS-E-ST-10C Rev.1	PRR	<ul style="list-style-type: none"> <li>Technology Plan</li> </ul>
TP Technology Acquisition Strategy	"The TP shall establish and describe the necessary activities to complete the acquisition of each technology or technological element, including verification strategies and methods, and the link to product assurance aspects."	Project	ECSS-E-ST-10C Rev.1	PRR	<ul style="list-style-type: none"> <li>Technology Plan</li> </ul>
TP Technology Development Activities	"The TP shall describe the technology development activities, their required or possible interrelations and timings, as necessary for the satisfactory acquisition of the technologies and procurement of the technological elements."	Project	ECSS-E-ST-10C Rev.1	PRR	<ul style="list-style-type: none"> <li>Technology Plan</li> </ul>
TP Technology Feasibility Assessment	"The TP expected output shall be an answer concerning the possibility for using the identified or needed technology to perform a function."	Project	ECSS-E-ST-10C Rev.1	PRR	<ul style="list-style-type: none"> <li>Technology Plan</li> </ul>



File (318)	Text	Domain	Source	Due	Parent statement
<a href="#">TP Technology Model Philosophy</a>	"The TP shall define the model philosophy for each technology or technological element, based on an assessment on the maturity status and on the criticality of the technology with respect to functions' requirements."	Project	ECSS-E-ST-10C Rev.1	PRR	• <a href="#">Technology Plan</a>
<a href="#">TP Technology Risk Mitigation</a>	"The TP shall describe, for any identified technology risk and related critical aspects for the project, the specific actions taken for risk mitigation based on identified technology readiness level (TRL)."	Project	ECSS-E-ST-10C Rev.1	PRR	• <a href="#">Technology Plan</a>
<a href="#">TS Applicable Documents</a>	"The TS shall list the applicable and reference documents in support of the generation of the document."	Project	ECSS-E-ST-10-06C	MDR	• <a href="#">Preliminary Technical Requirements Specifications</a>
<a href="#">TS Environmental Constraints</a>	"The TS shall describe the different environments and constraints for each situation in the life profile that the product is expected to encounter."	Project	ECSS-E-ST-10-06C	MDR	• <a href="#">Preliminary Technical Requirements Specifications</a>
<a href="#">TS Higher Tier System Context</a>	"If the TS defines a product that is a component of a higher tier system, the TS shall recall the related needs of that larger system and shall describe the identified interfaces between that system and the product."	Project	ECSS-E-ST-10-06C	MDR	• <a href="#">Preliminary Technical Requirements Specifications</a>
<a href="#">TS Product Independence Statement</a>	"If the product is independent and totally self-contained, i.e. able to match the final user's need, it should be so stated here. "	Project	ECSS-E-ST-10-06C	MDR	• <a href="#">Preliminary Technical Requirements Specifications</a>
<a href="#">TS Product Life Profile</a>	"The TS shall list and describe the different chronological situations of the product's life profile."	Project	ECSS-E-ST-10-06C	MDR	• <a href="#">Preliminary Technical Requirements Specifications</a>
<a href="#">TS Product Perspective</a>	"The TS shall put the product into perspective with other related products. "	Project	ECSS-E-ST-10-06C	MDR	• <a href="#">Preliminary Technical Requirements Specifications</a>
<a href="#">TS Purpose and Objective</a>	"The TS shall contain a description of the purpose, objective, content and the reason prompting its preparation."	Project	ECSS-E-ST-10-06C	MDR	• <a href="#">Preliminary Technical Requirements Specifications</a>
<a href="#">TS Technical Requirements Expression Standard</a>	"The technical requirements shall be expressed according to ECSS-E-ST-10-06 clauses 7 and 8."	Project	ECSS-E-ST-10-06C	MDR	• <a href="#">Preliminary Technical Requirements Specifications</a>
<a href="#">TS Technical Requirements List</a>	"The TS shall list all the technical requirements necessary for the product to satisfy the user's needs."	Project	ECSS-E-ST-10-06C	MDR	• <a href="#">Preliminary Technical Requirements Specifications</a>
<a href="#">TS User Needs Background</a>	"The TS shall present the main elements that characterize the user's need for developing the product as a background for those requirements that are defined in detail in the dedicated section."	Project	ECSS-E-ST-10-06C	MDR	• <a href="#">Preliminary Technical Requirements Specifications</a>
<a href="#">Technical Budget Applicable Documents</a>	"The technical budget shall list the applicable and reference documents in support to the generation of the document."	Project	ECSS-E-ST-10C Rev.1	PRR	• <a href="#">Technical Budget</a>
<a href="#">Technical Budget Conclusion and Risk Identification</a>	"The technical budget shall contain a conclusion that identifies the key engineering parameters having a negative margin, and identify for each of those: 1. the impact on the technical requirements and the associated risk for the project, and 2. the specific program to conform to the specified value and for project risk mitigation."	Project	ECSS-E-ST-10C Rev.1	PRR	• <a href="#">Technical Budget</a>
<a href="#">Technical Budget Key Engineering Parameters</a>	"The technical budget shall: 1. list the selected key engineering parameters (those specified by the customer and those selected by the supplier), 2. present the reason for their selection, 3. identify for each key engineering parameters the stages of maturity of the design. 4. present the related margin policy for these parameters."	Project	ECSS-E-ST-10C Rev.1	PRR	• <a href="#">Technical Budget</a>
<a href="#">Technical Budget Parameter Values and Margins</a>	"For each key engineering parameter, the technical budget shall: 1. provide the specified value of the parameter, 2. provide the supplier's margin resulting of the allocation of the parameter to the lower level products, 3. provide the specified values with the reference to the relevant technical requirement of the lower level products, 4. propose a specific program to conform to the specified value in case of nonconformance, 5. contain a chart of parameter history that presents the evolution of the parameter's value at the different design maturity steps for which the evaluation of the parameter is performed, 6. list the documentation sources (e.g. analysis report and verification report)."	Project	ECSS-E-ST-10C Rev.1	PRR	• <a href="#">Technical Budget</a>
<a href="#">Technical Budget Purpose and Objective</a>	"The technical budget shall contain a description of the purpose, objective, content and the reason prompting its preparation."	Project	ECSS-E-ST-10C Rev.1	PRR	• <a href="#">Technical Budget</a>
<a href="#">Technical Budget</a>	A Technical Budget shall be prepared.	Project	ECSS-E-ST-10C	PRR	• <a href="#">Design Definition File</a> • <a href="#">Technical Constraints</a>
<a href="#">Technical Constraint Compliance</a>	The recovery system shall be compliant with the technical constraints imposed in: • Mechanical structure of a spaceshot rocket – Claude Allenspach • 2025_SH_GS_SLRS_TS	Project		-	• <a href="#">Technical Constraints</a>
<a href="#">TP Applicable Documents</a>	"The TP shall list the applicable and reference documents in support to the generation of the document and include the reference to the following applicable documents: 1. SEP 2. Technology matrix (as defined in ECSS-E-ST-10, Annex F) 3. Function tree 4. Specification tree."	Project	ECSS-E-ST-10C Rev.1	PRR	• <a href="#">System Engineering Plan</a>
<a href="#">Technology Matrix Applicable Documents</a>	"The technology matrix shall list the applicable and reference documents in support to the generation of the document and include the reference to the following applicable documents: 1. Specification tree 2. Preliminary technical requirements specifications 3. Function tree."	Project	ECSS-E-ST-10C Rev.1	PRR	• <a href="#">Technology Plan</a>
<a href="#">Technology Matrix Purpose and Objective</a>	"The technology matrix shall contain a description of the purpose, objective, content and the reason prompting its preparation."	Project	ECSS-E-ST-10C Rev.1	PRR	• <a href="#">Technology Plan</a>
<a href="#">Technology Matrix System Functions and TS</a>	"The technology matrix shall list the system technical requirements/functions and for each, a potential technology or technological element."	Project	ECSS-E-ST-10C Rev.1	PRR	• <a href="#">Technology Matrix</a>
<a href="#">Technology Matrix Technology Identification</a>	"For each technology or technological element, the following information shall be listed:	Project	ECSS-E-ST-10C Rev.1	PRR	• <a href="#">Technology Matrix</a>

File (318)	Text	Domain	Source	Due	Parent statement
	<ol style="list-style-type: none"> <li>index of technology readiness and maturity as defined in Table 4-2 of ECSS-E-AS-11;</li> <li>proof of company's maturity concerning the knowledge and expertise of the technology, including a description of the necessary technology acquisition activities;</li> <li>identification of potential risks, e.g. technology availability, programmatic and financial aspects."</li> </ol>				
Technology Matrix Technology Readiness and Maturity	"The technology matrix shall propose a ranking of the potential technology or technological element for each system requirement/ function."	Project	ECSS-E-ST-10C Rev.1	PRR	<ul style="list-style-type: none"> <li>Technology Matrix</li> </ul>
Technology Matrix Technology Risk Assessment	"The technology matrix shall provide, for each system requirement/function, the selected technology or technological element, a list of the identified project risks and critical aspects, and an identified back-up technological solution."	Project	ECSS-E-ST-10C Rev.1	PRR	<ul style="list-style-type: none"> <li>Technology Matrix</li> </ul>
Technology Matrix	A Technology Matrix shall be prepared.	Project	ECSS-E-ST-10C	PRR	<ul style="list-style-type: none"> <li>System Engineering Plan</li> </ul>
Technology Plan	A Technology Plan shall be prepared.	Project	ECSS-E-ST-10C	PRR	<ul style="list-style-type: none"> <li>System Engineering Plan</li> </ul>
Technology Readiness Status List	A Technology Readiness Status List shall be prepared.	Project	ECSS-E-ST-10C	MDR	<ul style="list-style-type: none"> <li>System Engineering Plan</li> <li>Existing Technologies</li> </ul>
TS Product Concept and Architecture	"The technical specification shall describe the concept, the expected product architecture and the functioning principles on which it is based."	Project	ECSS-E-ST-10-06C	MDR	<ul style="list-style-type: none"> <li>Preliminary Technical Requirements Specifications</li> </ul>
Trade off reports	A Trade Off Report shall be prepared for each trade off regarding system concept selection performed.	Project	ECSS-E-ST-10C	MDR	<ul style="list-style-type: none"> <li>Trade Off</li> <li>Design Justification File</li> <li>Dependability Metric</li> <li>Development Complexity</li> <li>Safety Metric</li> <li>Safety Criteria</li> <li>State of The Art</li> <li>Performance Metrics</li> <li>System Modelling</li> <li>Student Organisation Constraints</li> </ul>
Trade-Off Report Alternative Design Exploration	"The research of possible alternative design solutions should not preclude the identification of design solutions which are not currently mature enough, but which can be potential design solution for future similar applications."	Project	ECSS-E-ST-10C Rev.1	MDR	<ul style="list-style-type: none"> <li>Trade off reports</li> </ul>
Trade-Off Report Alternative Design Solutions	"The trade-off report shall present every different alternative design solutions proposed by the organization in charge of the development of the system or product, the proposals from the customer and supplier if any, and emphasize the technical description that is correlated to the criteria of evaluation. "	Project	ECSS-E-ST-10C Rev.1	MDR	<ul style="list-style-type: none"> <li>Trade off reports</li> </ul>
Trade-Off Report Alternative Solution Evaluations	"The system trade-off report shall present the result of the evaluation of every identified alternative design solution with regard to the key technical requirements."	Project	ECSS-E-ST-10C Rev.1	MDR	<ul style="list-style-type: none"> <li>Trade off reports</li> </ul>
Trade-Off Report Applicable Documents	<p>"The trade-off report shall list the applicable and reference documents in support to the generation of the document and include the reference to the following applicable documents:</p> <ol style="list-style-type: none"> <li>Mission description document, if relevant</li> <li>Technical requirements specification</li> <li>System engineering plan</li> <li>Project phasing and planning requirement document."</li> </ol>	Project	ECSS-E-ST-10C Rev.1	MDR	<ul style="list-style-type: none"> <li>Trade off reports</li> </ul>
Trade-Off Report Design Solution Characterization	"The trade-off report shall characterize each alternative design solution in terms of technology status or maturity, performances capability, and risks."	Project	ECSS-E-ST-10C Rev.1	MDR	<ul style="list-style-type: none"> <li>Trade off reports</li> </ul>
Trade-Off Report Design Solution Classification	"Based on the proposed scheme for weighting the evaluation criteria, the trade-off report shall provide a classification of the different alternative design solutions."	Project	ECSS-E-ST-10C Rev.1	MDR	<ul style="list-style-type: none"> <li>Trade off reports</li> </ul>
Trade-Off Report Evaluation Criteria and Justification	"The trade-off report shall list the selected evaluation criteria and precise the justification for selecting those criteria, and provide the weighting of criteria and their justifications."	Project	ECSS-E-ST-10C Rev.1	MDR	<ul style="list-style-type: none"> <li>Trade off reports</li> </ul>
Trade-Off Report Evaluation Responsibility and Weighting Agreement	"The trade-off report shall identify the entity responsible for the evaluation of the design solutions for any criteria, as well as the source and agreement regarding weighting factors (e.g. with management)."	Project	ECSS-E-ST-10C Rev.1	MDR	<ul style="list-style-type: none"> <li>Trade off reports</li> </ul>
Trade-Off Report Evaluation Table	"The trade-off report shall present, in a table, the result of the evaluation per criteria."	Project	ECSS-E-ST-10C Rev.1	MDR	<ul style="list-style-type: none"> <li>Trade off reports</li> </ul>
Trade-Off Report Information Sources	"The system trade-off report shall identify and present the sources of information used to identify the possible design solution, e.g. R&D results, lessons learned, or similar applications."	Project	ECSS-E-ST-10C Rev.1	MDR	<ul style="list-style-type: none"> <li>Trade off reports</li> </ul>
Trade-Off Report Key Technical Requirements	"The trade-off report shall list the key technical requirements from the TS (as defined in ECSS-E-ST-10-06) to be satisfied by the possible alternative design solutions to conform to the needs or requirements of the user."	Project	ECSS-E-ST-10C Rev.1	MDR	<ul style="list-style-type: none"> <li>Trade off reports</li> </ul>
Trade-Off Report Pros and Cons Assessment	<p>"For each alternative design solution the following shall be performed:</p> <ol style="list-style-type: none"> <li>assessment of all the key technical requirements / evaluation criteria,</li> <li>presentation of the pros and cons of the design solution, and</li> <li>identification of the technical and programmatic risks."</li> </ol>	Project	ECSS-E-ST-10C Rev.1	PRR	<ul style="list-style-type: none"> <li>Trade off reports</li> </ul>
Trade-Off Report Purpose and Context	"The trade-off report shall contain a brief description of the purpose of the trade-off study and its context (e.g. logic, organization, process or procedure)."	Project	ECSS-E-ST-10C Rev.1	MDR	<ul style="list-style-type: none"> <li>Trade off reports</li> </ul>
Trade-Off Report Purpose and Objective	"The trade-off report shall contain a description of the purpose, objective, content and the reason prompting its preparation."	Project	ECSS-E-ST-10C Rev.1	MDR	<ul style="list-style-type: none"> <li>Trade off reports</li> </ul>
Trade-Off Report Recommended Solution and Justification	"The trade-off report shall recommend one solution and explain the reason for this choice (e.g. evaluation criteria where the selected solution take advantage), and precise the condition for the application of the recommended solution."	Project	ECSS-E-ST-10C Rev.1	MDR	<ul style="list-style-type: none"> <li>Trade off reports</li> </ul>
Trade-Off Report Risk Assessment and Mitigation	"The trade-off report shall present the identified technical and programmatic risks induced by the choice of the recommended solution, and any additional activity necessary to be performed for risk mitigation."	Project	ECSS-E-ST-10C Rev.1	MDR	<ul style="list-style-type: none"> <li>Trade off reports</li> </ul>
Trade-Off Report Sensitivity Analysis	"The trade-off report shall provide the result of a sensitivity analysis of the criteria that provide advantage to the solution ranked first, e.g. when changing the weighting of the evaluation criteria. "	Project	ECSS-E-ST-10C Rev.1	MDR	<ul style="list-style-type: none"> <li>Trade off reports</li> </ul>
Test Opportunity	The potential 2026 launch opportunity targeting a 30 km apogee shall, if used for verification, be documented in the system verification plan.	Project		-	<ul style="list-style-type: none"> <li>Test Launch Opportunity</li> </ul>

File (318)	Text	Domain	Source	Due	Parent statement
					<ul style="list-style-type: none"> <li><a href="#">Verification Plan</a></li> </ul>
<a href="#">VP Glossary and Terminology</a>	"The VP shall list the applicable dictionary or glossary and the meaning of specific terms or abbreviations utilized in the document."	Project	ECSS-E-ST-10-02C Rev.1	PRR	<ul style="list-style-type: none"> <li><a href="#">Verification Plan</a></li> </ul>
<a href="#">VP Open Issues and Constraints</a>	"Open issues, assumptions and constraints relevant to this document shall be stated and described."	Project	ECSS-E-ST-10-02C Rev.1	PRR	<ul style="list-style-type: none"> <li><a href="#">Verification Plan</a></li> </ul>
<a href="#">VP Applicable Documents</a>	"The VP shall list the applicable and reference documents in support to the generation of the document."	Project	ECSS-E-ST-10-02C Rev.1	PRR	<ul style="list-style-type: none"> <li><a href="#">Verification Plan</a></li> </ul>
<a href="#">VP Reference to AIT Plan</a>	"Analysis, review of design, inspection and test programmes should be detailed through dedicated activity sheets, or through reference to the AIT Plan. "	Project	ECSS-E-ST-10-02C Rev.1	PRR	<ul style="list-style-type: none"> <li><a href="#">Verification Plan</a></li> </ul>
<a href="#">VP Requirement Allocation to Verification Tasks</a>	"The allocation of the requirements to the specific verification tasks shall be given."	Project	ECSS-E-ST-10-02C Rev.1	PRR	<ul style="list-style-type: none"> <li><a href="#">Verification Plan</a></li> </ul>
<a href="#">VP Responsibility Assignment</a>	"It shall describe the responsibilities within the project team, the relation to product assurance, quality control and configuration control (including anomaly handling and change control) as well as the responsibility sharing with external partners. "	Project	ECSS-E-ST-10-02C Rev.1	PRR	<ul style="list-style-type: none"> <li><a href="#">Verification Plan</a></li> </ul>
<a href="#">VP Responsibility and Management Tools</a>	"The VP shall describe the responsibility and management tools applicable to the described verification process. "	Project	ECSS-E-ST-10-02C Rev.1	PRR	<ul style="list-style-type: none"> <li><a href="#">Verification Plan</a></li> </ul>
<a href="#">VP Review Planning and Responsibilities</a>	"The relevant reviews shall be planned and responsibilities described."	Project	ECSS-E-ST-10-02C Rev.1	PRR	<ul style="list-style-type: none"> <li><a href="#">Verification Plan</a></li> </ul>
<a href="#">VP Verification Activities and Planning</a>	"The VP shall document the verification activities and associated planning in the applicable verification stages. "	Project	ECSS-E-ST-10-02C Rev.1	PRR	<ul style="list-style-type: none"> <li><a href="#">Verification Plan</a></li> </ul>
<a href="#">VP Verification Concepts and Definitions</a>	"The VP shall describe the basic verification concepts and definitions (methods, levels and stages)."	Project	ECSS-E-ST-10-02C Rev.1	PRR	<ul style="list-style-type: none"> <li><a href="#">Verification Plan</a></li> </ul>
<a href="#">VP Verification Documents and Content</a>	"The VP shall list the involved verification documents and describe their content."	Project	ECSS-E-ST-10-02C Rev.1	PRR	<ul style="list-style-type: none"> <li><a href="#">Verification Plan</a></li> </ul>
<a href="#">VP Verification Methods and Levels</a>	"The VP shall describe the selected combination of the different verification methods at the applicable verification levels and stages, in general and for each requirement type/group (including software). "	Project	ECSS-E-ST-10-02C Rev.1	PRR	<ul style="list-style-type: none"> <li><a href="#">Verification Plan</a></li> </ul>
<a href="#">VP Verification Monitoring and Control</a>	"The VP shall describe the proposed methodology to be utilized for verification monitoring and control including the use of a verification data base."	Project	ECSS-E-ST-10-02C Rev.1	PRR	<ul style="list-style-type: none"> <li><a href="#">Verification Plan</a></li> </ul>
<a href="#">VP Verification Subject</a>	"The VP shall briefly describe the subject of the verification process."	Project	ECSS-E-ST-10-02C Rev.1	PRR	<ul style="list-style-type: none"> <li><a href="#">Verification Plan</a></li> </ul>
<a href="#">VP Verification Tools and Facilities</a>	"The VP shall describe high level definitions of the verification tools to be used, such as S/W facilities, special tools, simulators, analytical tools. "	Project	ECSS-E-ST-10-02C Rev.1	PRR	<ul style="list-style-type: none"> <li><a href="#">Verification Plan</a></li> </ul>
<a href="#">VP Combination with AIT Plan</a>	"The Verification Plan may be combined with the AIT Plan in one single AIV Plan."	Project	ECSS-E-ST-10-02C Rev.1	PRR	<ul style="list-style-type: none"> <li><a href="#">Verification Plan</a></li> </ul>
<a href="#">WBS Applicable Documents</a>	"The WBS shall list the applicable and reference documents used in support of the generation of the document."	Project	ECSS-M-ST-10C Rev. 1	PRR	<ul style="list-style-type: none"> <li><a href="#">Work Breakdown Structure</a></li> </ul>
<a href="#">WBS Coding Scheme</a>	"A coding scheme for WBS elements that represents the hierarchical structure when viewed in text format shall be used. "	Project	ECSS-M-ST-10C Rev. 1	PRR	<ul style="list-style-type: none"> <li><a href="#">Work Breakdown Structure</a></li> </ul>
<a href="#">WBS Control Work-Packages</a>	"The WBS shall identify all control work-packages."	Project	ECSS-M-ST-10C Rev. 1	PRR	<ul style="list-style-type: none"> <li><a href="#">Work Breakdown Structure</a></li> </ul>
<a href="#">WBS Presentation Format</a>	"The WBS shall be presented either as a graphical diagram or an indentured structure."	Project	ECSS-M-ST-10C Rev. 1	PRR	<ul style="list-style-type: none"> <li><a href="#">Work Breakdown Structure</a></li> </ul>
<a href="#">WBS Product Tree Breakdown</a>	"The WBS shall provide a logical and exhaustive breakdown of the product tree elements, that includes the customer's defined support functions (e.g. project management, engineering, product assurance support) necessary to produce the end item deliverables (development and flight models) and the necessary services as appropriate for the project."	Project	ECSS-M-ST-10C Rev. 1	PRR	<ul style="list-style-type: none"> <li><a href="#">Work Breakdown Structure</a></li> </ul>
<a href="#">WBS Purpose</a>	"The WBS shall contain a description of the purpose, objective and the reason prompting its preparation (e.g. program or project reference and phase)."	Project	ECSS-M-ST-10C Rev. 1	PRR	<ul style="list-style-type: none"> <li><a href="#">Work Breakdown Structure</a></li> </ul>
<a href="#">WBS Total Work Scope Coverage</a>	"All defined work-packages together shall cover the total work scope."	Project	ECSS-M-ST-10C Rev. 1	PRR	<ul style="list-style-type: none"> <li><a href="#">Work Breakdown Structure</a></li> </ul>
<a href="#">WBS Work-Package Breakdown</a>	"The control work-packages may be further broken down by the supplier in several more detailed work-packages."	Project	ECSS-M-ST-10C Rev. 1	PRR	<ul style="list-style-type: none"> <li><a href="#">Work Breakdown Structure</a></li> </ul>
<a href="#">WCA Document Content</a>	"The WCA document shall include: <ol style="list-style-type: none"> <li>assumptions applicable to the environmental condition,</li> <li>a list of the selected parts database with the worst case parameters,</li> <li>a description of the general methodology,</li> <li>an explanation of the numerical analysis technique,</li> <li>results and conclusion of the WCA."</li> </ol>	Project	ECSS-Q-ST-30C Rev.1	PRR	<ul style="list-style-type: none"> <li><a href="#">Worst Case Analysis</a></li> </ul>
<a href="#">WCA Linked Analyses</a>	"The WCA may be linked to other analyses such as: <ol style="list-style-type: none"> <li>Radiation analysis,</li> <li>Thermal analysis."</li> </ol>	Project	ECSS-Q-ST-30C Rev.1	PRR	<ul style="list-style-type: none"> <li><a href="#">Worst Case Analysis</a></li> </ul>
<a href="#">WP Description Elements</a>	"The WP description shall contain the following elements: <ol style="list-style-type: none"> <li>project name and project phase;</li> <li>WP title;</li> <li>unique identification of each WP and issue number</li> <li>supplier or entity in charge of the WP performance;</li> <li>WP manager's name and organization;</li> <li>supplier's country;</li> <li>product to which the tasks of the WP are allocated (link to the product tree);</li> <li>description of the objectives of the WP;</li> <li>description of the tasks;</li> <li>list of the inputs necessary to achieve the tasks;</li> <li>interfaces or links with other tasks or WP's;</li> <li>list of constraints, requirements, standards, and regulations;</li> <li>list of the expected outputs;</li> <li>list of deliverables;</li> <li>location of delivery;</li> <li>start event identification including date;</li> <li>end event identification including date;</li> <li>excluded tasks."</li> </ol>	Project	ECSS-M-ST-10C Rev. 1	PRR	<ul style="list-style-type: none"> <li><a href="#">Work Package</a></li> </ul>
<a href="#">Work Breakdown Structure</a>	A Work Breakdown Structure for the system shall be provided.	Project	ECSS-M-ST-10C	PRR	<ul style="list-style-type: none"> <li><a href="#">Recommendation for Future Work</a></li> </ul>
<a href="#">Work Package</a>	A description for the next work package regarding the system development shall be provided.	Project	ECSS-M-ST-10C	PRR	<ul style="list-style-type: none"> <li><a href="#">Recommendation for Future Work</a></li> </ul>

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<a href="#">Worst Case Analysis</a>	A Worst Case Analysis shall be prepared.	Project	ECSS-Q-HB-30-01A	PRR	<ul style="list-style-type: none"> <li>• <a href="#">Safety and Hazard Analysis</a></li> </ul>
<a href="#">VP Model Selection and Philosophy</a>	"The VP shall describe the selected models and the associated model philosophy, product matrix."	Project	ECSS-E-ST-10-02C Rev.1	PRR	<ul style="list-style-type: none"> <li>• <a href="#">Verification Plan</a></li> </ul>
<a href="#">VP Purpose and Objective</a>	"The VP shall contain a description of the purpose, objective, content and the reason prompting its preparation. "	Project	ECSS-E-ST-10-02C Rev.1	PRR	<ul style="list-style-type: none"> <li>• <a href="#">Verification Plan</a></li> </ul>
<a href="#">Verification Plan</a>	A Verification Plan shall be prepared.	Project	ECSS-E-ST-10-02C	PRR	<ul style="list-style-type: none"> <li>• <a href="#">System Engineering Plan</a></li> <li>• <a href="#">Technical and Program Recommendations</a></li> </ul>