Preliminary assessment of pre-launch operations and logistics for a suborbital vehicle

EPFL ROCKET TEAM

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Abstract

This report presents a comprehensive, standards-driven framework for planning and executing pre-launch operations and logistics for the EPFL Rocket Team's suborbital "Spaceshot" mission. Motivated by the need to move beyond ad-hoc practices as the team pursues a 100 km Kármán-line flight by 2030, the project first benchmarks best practices across NASA, ESA, commercial launch providers and high-reliability industries to identify critical gaps in the team's current approach.

Building on this state-of-the-art review, a modular methodology grounded in ECSS lifecycle phases and the team's own Systems Engineering Handbook is defined. Key steps include gap analysis, role definition, deliverable prioritisation and tool selection, all aimed at embedding logistics considerations from Phase A (Feasibility) through Phase E (launch operations).

The work produces 24 inter-linked deliverables—ranging from a Logistics Management Plan and Packaging Plan to a Compliance Framework, Training Matrix, cost-estimator script and countdown procedures—that together constitute a reusable "operations toolkit" for future campaigns. Each document or template is mapped to specific roles (e.g., Launch Logistics Lead, Chief Compliance Officer) and integrated into the existing systems-engineering document architecture to ensure traceability and long-term maintainability.

Project takeaways confirm that rigorous operations planning can be scaled to a student context without sacrificing agility, elevating logistics to a mission-enabling discipline on par with propulsion or avionics. The report also highlights open challenges—including cultural adoption, role saturation and continuous feedback loops—that must be addressed to translate documented integration into lived practice. Overall, the deliverables lay the foundation for a future Operations Handbook and position the EPFL Rocket Team to conduct safe, compliant and cost-effective launch campaigns as it advances toward orbital-class ambitions.

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Contents

Acronyms

ADR European Agreement concerning the International Carriage of Dangerous Goods by Road

ADN European Agreement concerning the International Carriage of Dangerous Goods by Inland Waterways

ATA Admission Temporaire / Temporary Admission carnet

AWB Air Waybill

CCO Chief Compliance Officer

CDR Critical Design Review

CFAR Compliance Framework Assessment and Rating

CFO Chief Financial Officer

CFR Code of Federal Regulations (49 CFR) *or* Cost and Freight (Incoterm)

CIF Cost, Insurance and Freight (Incoterm)

CIP Carriage and Insurance Paid to (Incoterm)

CMR Convention on the Contract for the International Carriage of Goods by Road

CO2 Carbon Dioxide

CRR Comms Readiness Review

CSO Chief Safety Officer

DAF Delivered At Frontier (legacy Incoterm)

DDP Delivered Duty Paid (Incoterm)

DES Delivered Ex Ship (legacy Incoterm)

DPU Delivered at Place Unloaded (Incoterm 2020)

ECSS European Co-operation for Space Standardisation

EIA Environmental Impact Assessment

EPFL École Polytechnique Fédérale de Lausanne

ERT EPFL Rocket Team

ESA European Space Agency

ESR Environmental and Safety Report

EXW Ex Works (Incoterm)

FAA Federal Aviation Administration

FAS Free Alongside Ship (Incoterm)

FOB Free on Board (Incoterm)

FIR Flight Information Region

FMEA Failure Mode and Effects Analysis

FRR Flight Readiness Review

GNC Guidance, Navigation and Control

GSE Ground Support Equipment

HL Head of Logistics

HSSE Health, Safety, Security and Environment

IATA International Air Transport Association

ICAO International Civil Aviation Organization

ICC International Chamber of Commerce

ICS Incident Command System

ISO International Organization for Standardization

ITAR International Traffic in Arms Regulations

KPI Key Performance Indicator

LCR Logistics Campaign Report

LLL Launch Logistics Lead

LMP Logistics Management Plan

LTE Long-Term Evolution (4G)

LRCI Launch-Readiness Compliance Index

MDR Mission Design Review

NASA National Aeronautics and Space Administration

NOTAM Notice to Airmen

OJT On-the-Job Training

ORR Operations Readiness Review

PDF Portable Document Format

PMBOK Project Management Body of Knowledge

PMI Project Management Institute

POR Preliminary Operations Review

PRR Preliminary Requirements Review

RAM Responsibility Assignment Matrix

RACI Responsible, Accountable, Consulted, Informed

RAS Risk Assessment Study

RFQ Request for Quotation

RSSI Received Signal-Strength Indicator

SE Systems Engineer

SEP Systems Engineering Plan

SH Spaceshot (sub-orbital launch vehicle class)

SOP Standard Operating Procedure

SOTA State of the Art

TCO Transport Coordination Officer

TMA Training Manager

TMP Training Master Plan

TNA Training Needs Analysis

TPL Transport Packaging Lead

TRR Test Readiness Review

UHF Ultra-High Frequency

UN United Nations

UPS Uninterruptible Power Supply

VHF Very-High Frequency

VoIP Voice over Internet Protocol

VP Vice Presidency

WBS Work Breakdown Structure

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List of Figures

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1 Foreword

1.1 Acknowledgments

I would like to express my sincere gratitude to **Mr. Mathieu Udriot** for his invaluable guidance, support, and encouragement throughout the course of this project. I also wish to thank **the EPFL Rocket Team** and **the EPFL Space Center** for providing the resources and environment necessary for this work. Special thanks to **Antoine Marchand, Michael Fuser, Ryan Svoboda** as well as the rest of the EPFL Rocket Team Systems Engineering team for their constructive feedback, collaboration, and assistance. Finally, I am grateful to my family and friends for their continuous support and motivation during this endeavor.

1.2 Motivation and Objectives

The EPFL Rocket Team's goal is to fly a rocket that will reach the Kármán line by 2030. Due to the inherent constraints of this spaceshot (SH) mission, the launch is expected to happen at a dedicated launch site in Europe. Because of this, many constraints will affect the operations of the team before reaching the launch day[1].

1.2.1 Goal of the Project

This project shall delve into what the specific constraints are and how they will affect the team. A particular care shall be put into examining how those constraints vary from one launch site to another. The end goal of the project is to craft a detailed pre-launch operations (packing for transport, unpacking at launch site, integration and on-site testing) and logistics (transport and supply chain) plan on a per-launchsite basis. This plan shall encompass multiple aspects: personnel, equipment, timeline and consumables with their respective dependencies, required preparation, lead time and schedules. The exact scope shall be defined at the start of the project with the agreement of the supervisor. The role of the project is also to derive good practices and deliverable templates that can be integrated seamlessly with the current team approach of systems engineering and project management. This shall be based on relevant European and NASA standards while ensuring that the approach is suitable for the team both from an efficiency and thoroughness standpoint[2].

1.2.2 Scope of This Document

This document serves as the basis for future developments at the EPFL Rocket Team in the field of launch logistics and operations. In particular, with regards to the Spaceshot Project, the precise extent of this scope will become clearer in subsequent sections.

[1] Extracted from the project description, see section 8.1.
[2] Extracted from the project description, see section 8.1.

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2 Introduction

This chapter introduces the EPFL Rocket Team, its historical context, and the rationale for developing a logistics and operations framework enabling launching suborbital missions as part of the Spaceshot initiative.

2.1 Space Launch Operations and Logistics

Space launch operations and logistics are, quite plainly, the backbone of any space mission—without them, no spacecraft would ever leave the ground. While propulsion systems, payload technologies, and orbital mechanics often dominate discussions about spaceflight, none of these innovations matter if the systems themselves cannot be safely, legally, and efficiently brought to the launch pad. In practice, launch operations encompass a wide range of preparatory activities: integrating hardware, coordinating with launch sites, managing fueling procedures, ensuring range safety, and validating environmental constraints. Meanwhile, logistics ties it all together—transporting rocket components across continents, complying with customs regulations for hazardous materials, securing test infrastructure, and synchronizing timelines across multiple stakeholders and agencies.

As the space industry undergoes a rapid transformation—from a government-dominated domain to a diversified and increasingly commercial sector—these operational and logistical considerations have become more critical than ever. The growing frequency of launches, driven by small satellite constellations, lunar missions, and space tourism, has introduced new challenges in scheduling, resource allocation, and risk mitigation. Reusability, another game-changing trend, introduces not only engineering complexities but also unprecedented logistical demands: tracking, recovering, refurbishing, and redeploying stages within tight operational windows. Moreover, with the proliferation of international spaceports and the rise of mobile launch platforms, the complexity of cross-border regulatory frameworks and intermodal transport chains has grown significantly.

In this context, space launch operations and logistics have evolved from background enablers into strategic levers for mission success, cost control, and competitive advantage. The ability to deliver launch-ready hardware on time, to the right place, and under the right conditions is no longer a given—it's a differentiating factor in an increasingly crowded space race.

2.2 The EPFL Rocket Team

The EPFL Rocket Team is a student-led initiative founded in 2016 with the mission of designing, building, and launching high-performance sounding rockets. Over the years, the team has grown into a structured organization of over 200 students from various academic backgrounds organized into project teams as well as systems and subsystems. Figure 1 illustrates the interactions between the team's various projects.

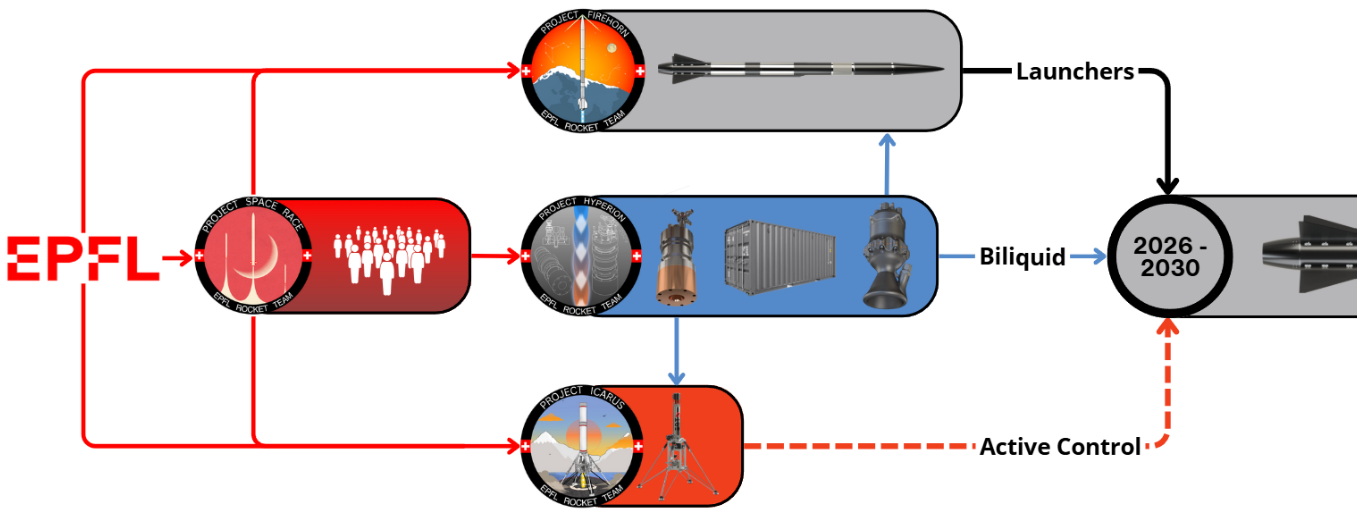

Figure 1: Engineering systems interaction flows within the EPFL Rocket Team

Previous missions include:

- **Bella Lui I (2020)** – First SRAD propulsion system, designed to fly at the Spaceport America Cup in the "SRAD 10K" category.
- **Bella Lui II (2021)** – Expanded on Bella Lui I, won the EuRoC Overall award, and placed second at the Spaceport America Cup.
- **Wildhorn (2022)** – The first supersonic rocket built by the team, which flew at over 9 km and won the EuRoC Best Flight prize.
- **Nordend (2023)** – A 3 km SRAD bi-liquid rocket that reached an apogee of 350 m on a ballistic trajectory.

Current efforts focus on progressively more ambitious goals. The most immediate is the 2025 launch of **Firehorn**, a sounding rocket targeting a 9 km apogee while being structurally designed for 30 km. A second iteration is expected to fly in 2028 to the full 30 km target. The long-term ambition is the **Spaceshot Mission**, which aims to reach the Kármán line (100 km) by 2030.

2.2.1 The Spaceshot Mission

The Spaceshot mission represents the most ambitious and technically demanding undertaking ever envisioned by the EPFL Rocket Team. Its primary goal is to demonstrate the capability of a student team to design, build, and launch a suborbital rocket reaching the edge of space—crossing the 100 km Kármán line and enabling meaningful in-flight experimentation in near-space conditions.

The mission operates at the intersection of aerospace engineering, research, and education, and aims to set a new standard for what student-led initiatives can achieve. Its scope extends beyond the launch vehicle itself: the Spaceshot is designed as a platform, a proving ground for advanced technologies, scientific payloads, and high-impact collaborations. It offers a rare opportunity to carry a functional payload through vacuum and reentry, creating valuable data and operational experience for all stakeholders involved. Whether the payload is developed internally—by teams such as H-PC—or externally, through partnerships with academic labs or industrial sponsors, the mission architecture is explicitly designed to accommodate high-value, research-grade experiments. In doing so, Spaceshot not only raises the bar for student rocketry, but also positions EPFL and the

Rocket Team as credible contributors to the growing ecosystem of reusable, suborbital, science-capable launch platforms. This mission is not just about reaching space—it is about expanding access to it.

2.2.2 The Role of Operations and Logistics within the Team

Operations and logistics have emerged as a cornerstone of mission success within the EPFL Rocket Team, gaining increasing importance as the team shifts from local experimental launches to complex international campaigns. Historically handled informally or reactively, these disciplines now demand structured processes to ensure safety, reliability, and repeatability.

As the team scales toward ambitious objectives—such as the 2030 Spaceshot mission—new requirements arise: cross-border transport of hazardous materials, high-stakes scheduling with external partners, compliance with export regulations, and environmental accountability. These challenges can no longer be addressed ad hoc. Instead, they necessitate the development of a robust, forward-looking operational framework that complements the technical systems engineering work already underway.

Anchored in the ECSS-based methodology presented in the team's Systems Engineering Handbook [94], this evolving framework formalizes how logistics, packaging, compliance, communications, and post-flight analysis are integrated into the mission lifecycle. It provides a structured foundation not only for executing current missions, but also for onboarding future members, interfacing with external stakeholders, and ensuring that critical operational knowledge is not lost between cohorts. As launch complexity increases, so must the rigour of the systems that support it—making operations and logistics a strategic function rather than a support role.

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3 Methodology

3.1 Guiding Principles

The development of the logistics and operations framework for the Spaceshot initiative was grounded in a systems-engineering-centric philosophy. The objective was not only to create a functional set of deliverables but to establish a scalable, reusable, and standards-aligned methodology that integrates into the broader EPFL Rocket Team Systems Engineering Framework. This section outlines the high-level principles that guided its structure and implementation.

3.1.1 Standards-Based Foundation

A key premise of the methodology was to align with established space systems standards wherever applicable. The following frameworks were used as primary references:

- **ECSS (European Cooperation for Space Standardization):** Provided the lifecycle model (Phases 0–F), document requirements definitions (DRDs), and process expectations for operations and product assurance.
- **NASA Systems Engineering Handbook and Launch Control Procedure Standards:** Offered guidance on role definitions, decision workflows, and operations documentation.
- **MIL-STD and ICS templates:** Used selectively to define communication discipline, net-control structures, and emergency protocols.

These standards were adapted—rather than adopted wholesale—to fit the constraints of a student-led environment, balancing rigor with feasibility.

3.1.2 Modularity and Traceability

The framework was designed to be modular: each component (template, tool or document) was developed as an independent functional unit that could be applied, validated or replaced without disrupting the overall structure. This approach allows for:

- Selective reuse across different missions and projects
- Simplified onboarding and role delegation
- Transparent mapping between deliverables and the operational problems they address

Functional traceability was prioritized over chronological structure, ensuring that each artefact is clearly tied to a use-case or logistical need.

3.1.3 Systemic Integration

The methodology was conceived to interface directly with the EPFL Rocket Team's documentation and decision-making infrastructure. Rather than creating standalone outputs, all deliverables were designed to integrate into:

- The **Systems Engineering Handbook (SEH)**, either as a new "Operations" section or a separate "Operations Handbook"
- Mission-specific **Systems Engineering Plans (SEPs)** by function

- Active platforms including Wiki.js and the team's shared drive

Classification by operational function (e.g., coordination, compliance, execution) further supports long-term coherence within the broader systems architecture.

3.1.4 Practical Usability and Stakeholder Alignment

Beyond technical correctness, the framework emphasizes usability. Development choices were shaped by regular feedback loops with other systems engineers, operational contributors, and the Spaceshot team. This ensured that:

- Templates and tools are easy to access, fill, and deploy
- Terminology and structure match existing workflows
- Documentation reflects the practical realities of student-led missions

The outcome is a methodology that is not only robust but accessible to future team members with varying levels of experience.

3.1.5 Academic Rigor and Engineering Integrity

The methodology was developed with the standards of an engineering thesis in mind. It demonstrates:

- Research-grade source integration and comparative benchmarking
- Context-aware judgment in adapting industry frameworks
- Documentation of reasoning, trade-offs, and validation logic

This ensures its dual relevance—as an academic contribution in its own right, and as a foundational system for operational use within the EPFL Rocket Team.

3.2 Overall Project Structure

The development of the logistics and operations framework followed a structured, phase-based timeline over the course of a semester. Each work package was framed to produce actionable outputs at well-defined decision points, following a cadence aligned with the EPFL Rocket Team's academic calendar, internal systems engineering processes and Spaceshot mission interfaces. This approach ensured continuous integration, early stakeholder validation and sustained relevance to the team's operational needs.

3.2.1 Timeline and Planning Logic

The project unfolded over a 14-week semester, mapped to an initial high-level planning document that delineated key focus areas per week. The timeline can be grouped into three main macro-phases:

Phase	Weeks	Objective
Exploration & Scoping	W0–W4	Benchmark existing practices, identify team-specific gaps and define a realistic but ambitious project scope in collaboration with the project supervisor.

Phase	Weeks	Objective
Development & Integration	W5–W10	Generate all operational templates, documentation structures, decision frameworks and automation tools. Integrate progressively with the Systems Engineering Handbook.
Finalization & Application	W10–W12	Consolidate outputs into a coherent framework, validate their applicability through reviews and discussions and finalize the public handover to the team's documentation infrastructure.

Each phase concluded with a formal or informal milestone, serving as internal gate reviews or external integration points.

3.2.2 Milestone-Driven Progression

The methodology adopted a milestone-driven structure reflecting classical systems engineering planning. These milestones ensured traceability of progress and alignment with mission needs. Major checkpoints included:

- **State-of-the-Art Review Completion (W3)** – Delivery of a benchmark analysis across ESA, NASA, MIL and industry sources.
- **Scope Consolidation (W4)** – Formal validation of deliverable perimeter following stakeholder consultation.
- **Midterm Presentation and Spaceshot Interface Meeting (W7)** – Structured internal review evaluating feasibility and stakeholder relevance. Presentation and alignment with the broader Spaceshot mission system team.
- **Final Presentation and Delivery (W14)** – Formal review of the developed framework, with emphasis on systemic applicability to launch operations and readiness for long-term team adoption.
- **Report Submission (W16)** – Submission of the present report for review and grading, a standalone document encapsulating the process and the expanded framework itself.

Each milestone was complemented by feedback sessions with peers, system engineers or operations specialists, fostering continuous improvement and preventing divergence from mission-critical goals.

3.2.3 Cross-Linking with Team Lifecycle and Systems Plan

Although executed over a single semester, the methodology was explicitly designed to interface with the longer-term systems engineering lifecycle used by the EPFL Rocket Team. This cross-linking was realized through:

- Alignment with the team's internal **Systems Engineering Handbook (SEH)[94]**, which serves as the long-term repository for engineering process documentation.
- Creation of deliverables mapped to **ECSS project phases**, particularly Phases D (qualification & integration) and E (preparation & launch operations).
- Use of **interoperable media formats** such as Markdown, LaTeX, Python scripts and Google Sheets to match the team's documentation platforms.

Rather than producing one-off outputs, every deliverable was embedded in active team structures, enabling modular reuse, onboarding of future contributors and progressive enrichment of the team's operational knowledge base. As such, this methodology lays the structural foundation for a future, standalone Operations Handbook—extending the SEH into mission execution domains.

3.3 Methodological Steps

The methodology developed for this project was structured into discrete, purpose-driven stages. Each step was tailored to produce a specific type of knowledge, structural artefact or system mechanism needed to support a robust and scalable logistics framework. The process was informed by best practices in systems engineering and operations research, while remaining context-aware to the constraints and dynamics of student-led space projects.

3.3.1 State-of-the-Art Review

The first methodological step consisted in benchmarking institutional, commercial and academic practices in space launch logistics and operations. Sources included the European Cooperation for Space Standardization (ECSS), NASA's Systems Engineering Handbook, MIL-STD documentation, FAA regulations, as well as internal records from previous EPFL Rocket Team campaigns.

Rather than serving purely as a literature review, this step was treated as an **applied comparative analysis**, aiming to answer:

- Which elements of a full-scale launch operations framework are relevant or adaptable to a student-led structure?
- Where does the EPFL Rocket Team currently stand with respect to those elements?

Each identified standard or source was mapped to a subset of recurring operational needs: communication, packaging, scheduling, compliance, documentation, etc. The output of this phase was a structured gap assessment, forming the foundation for the next stages.

3.3.2 Framework Definition and Gap Analysis

Following the comparative phase, the next step consisted in formalizing the scope and logic of the operational framework itself. This was accomplished by:

- Identifying missing or under-specified **Document Requirements Definitions (DRDs)** relevant to logistics and operations
- Proposing new operational **roles** (e.g., Launch Logistics Lead, Transport Packaging Lead) to fulfill unaddressed coordination needs
- Classifying the framework into functional clusters to define clear ownership and enable modular evolution over time

This step was carried out in collaboration with the project supervisor and in alignment with the EPFL Rocket Team's Systems Engineering Handbook. The goal was to build a forward-compatible backbone that would remain relevant across multiple projects and launches.

3.3.3 Deliverable Definition and Prioritization

Once the framework architecture was defined, the next step involved translating functional requirements into tangible outputs. The deliverables were selected and prioritized based on the following criteria:

- Relevance to the team's historical pain points and upcoming launch challenges
- Alignment with ECSS Phases D–E and typical mission planning constraints

- Expected reusability and long-term integration potential

Figure 2 shows the current deliverables list as presented in the current SE handbook[94].

				0	A	B		C	D		E		F
	Deliverable Name	ABV.	Type	MDR	PRR	SRR	PDR	CDR	QR	AR	FRR	LRR	MCR
System	Mission Statement and Description	MSD	Definition										
	Stakeholder Value Network	SVN	Definition										
	State Of The Art	SOTA	Definition										
	External Forces Identification	EFI	Definition										
	Outcomes of Interest	OOI	Definition										
	Functional Analysis	FUA	Definition										
	Systems Engineering Plan	SEP	Planning										
	Technical Requirements Specifications	TS	Requirements										
	Costs Budgets	CBU	Tracking										
	Risk Assessment	RAS	Tracking										
	Concept of Operations	COP	Planning										
	Timeline	TIM	Planning										
	System Trade-Offs	SYT	Design										
	System Decomposition	SYD	Design										
	Block Diagram	BDI	Interface										
	Design Structure Matrix	DSM	Interface										
	System Overview	SYO	Tracking										
	Documentation Plan	DOP	Planning										
	Interface Control Document	ICD	Interface										
	System Sizing	SYS	Tracking										
	Technology Readiness Assessment	TRA	Tracking										
	Safety Plan	SAP	Planning										
	Manufacturing Assembly Integration and Verification Diagram	MAIV	Planning										
	Operation Plan	OPP	Planning										
	Mission Report	MRE	Closure										
	Review Item Discrepancy	RID	Feedback										
Subsystem	Design Justification File	DJF	Design										
	Design Definition File	DDF	Design										
	Technical Drawing	TD	Manufacturing										
	Finite Element Analysis Report	FEAR	Design										
	Software Design Definition	SDD	Design										
	Software User Manual	SUM	Operations										
	Manufacturing Procedure	MAP	Manufacturing										
	Assembly Procedure	ASP	Manufacturing										
	Test Specifications and Procedure	TSP	Verification										
	Test Report	TRP	Verification										
	Operation Procedure	OP	Operations										
	Non Conformance Report	NCR	Closure										

Figure 2: Phase-Mapped Deliverables List

This phase relied on a **consolidated scoping logic**—a collaborative prioritization map developed with the project supervisor to ensure that each deliverable addressed a clearly identified operational gap.

3.3.4 Integration with Systems Plan and Document Architecture

Because the EPFL Rocket Team operates with a growing, Wiki.js-based documentation ecosystem, integration was a core methodological concern. The new framework was designed to plug directly into:

- The **Systems Engineering Handbook (SEH)**, either as a new "Operations" section or as a standalone "Operations Handbook"

- The team's **shared drive architecture** for role-based templates and editable spreadsheets
- The mission-specific **Systems Engineering Plans (SEPs)** through functional referencing

To support this, each document was classified not just by its ECSS phase, but also by its **operational function** (e.g., decision-making, execution, coordination, safety). This ensured both structural and thematic consistency with existing documentation layers.

3.3.5 Decision Frameworks

One methodological innovation was the introduction of structured decision-making templates to support logistics planning. These were based on a **weighted sum trade-off method**, guided by the following principles:

- Each criterion must be justified and scored independently
- Quantitative inputs (e.g., carbon footprint, customs cost) must be evidenced
- Qualitative inputs must be explained and transparently sourced

Where applicable, the trade-offs were cross-referenced with the team's risk management system. In the case of Incoterms-based planning, the framework also captured financial responsibility boundaries and compliance exposure.

This component adds systemic repeatability to decisions that were previously made informally or reactively. The templates are intentionally modular and lightweight, allowing multiple decisions to be evaluated independently without loss of consistency.

3.3.6 Automation and Tooling

To maximize operational value, a small set of tools were developed in parallel with the documentation effort. The most prominent of these is the **Python-based logistics cost estimator**, which allows users to:

- Input basic cargo parameters (mass, value, destination, transport mode)
- Select applicable Incoterms
- Receive a breakdown of estimated cost, emissions and uncertainties

The code is provided as a copy-pastable CLI script, embedded within the team's Wiki.js platform and fully commented for transparency. This low-infrastructure model was chosen deliberately, as it ensures accessibility and reduces future maintenance cost.

Complementary tools, such as Google Sheets-based trackers with conditional formatting, were also built to support training matrices, milestone scheduling and compliance progress.

Each tool was designed around three principles:

1. **Minimal input burden** — to avoid rejection during real mission use
2. **High transparency** — all calculations are documented or visible
3. **Modular extensibility** — each tool can evolve independently

Together, these tools enhance the practical deployability of the framework while reinforcing the systemic logic developed throughout the methodology.

3.4 Conclusion

The methodology presented in this chapter fulfilled its dual objective: to deliver a technically robust, standards-aligned framework tailored to the operational realities of student-led suborbital launches and to demonstrate academic rigour in systems engineering practice. Through modularity, functional traceability and stakeholder-centred design, it offers enduring value to the EPFL Rocket Team—both as a reusable foundation and as a living structure for future mission scaling. From an academic standpoint, the work reflects methodological integrity, critical synthesis and actionable innovation grounded in real-world constraints.

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4 Deliverables

4.1 Introduction

Having established a solid methodological foundation, this chapter transitions from theoretical constructs to tangible outputs. The following deliverables were developed as part of the project to operationalize the logistics and operations framework for suborbital-class launch campaigns. Each document or template is grounded in the standards, stakeholder analysis, and systemic rigor described in earlier chapters. Together, they form a comprehensive toolkit for real-world mission planning, enabling consistency, traceability, and scalability across future campaigns.

4.2 Disclaimer

The following deliverables were developed throughout the project, they are presented here in a slightly different format in an effort to make this present report self-contained. They are intended, however to be used through the EPFL Rocket Team Wiki and Google Drive platforms and this present version may hence lack some usability features implemented in their original format.

Generative Artificial Intelligence (AI) and Large Language Models (LLM) were used in the crafting of those deliverables where the author's skills were insufficient. The contents were nonetheless fact-checked thoroughly and held up to the highest of standards.

4.3 State-of-the-Art Review: Pre-Launch Operations and Logistics Methodologies

This document establishes a comprehensive review of current processes and methods applied to the planning and scheduling for suborbital-class vehicle launch operations.

4.3.1 Introduction

Pre-launch operations and logistics encompass all activities from the completion of a space system's assembly and testing up to the moment of liftoff. These activities are critical in ensuring mission success, especially for high-reliability projects where failure is not an option. Developing a robust methodology for pre-launch operations requires understanding best practices from the space industry and analogous high-value sectors. This review compiles insights from industry reports, academic research, standards and manuals [41] to inform a methodology suitable for the EPFL Rocket Team's goal of reaching the Kármán line by 2030. The focus is on **process and methodology** rather than performance metrics, though key metrics are noted where they illustrate why certain frameworks or tools are preferred.

4.3.2 Defining Pre-Launch Operations and Logistics

Pre-launch operations refer to the final phase of a space mission's ground activities, including final assembly integration, testing, fueling, countdown rehearsals, range safety checks, launch vehicle and payload mating and the launch countdown itself. **Logistics** involves the coordination of resources and materiel: transporting the launch vehicle and payload to the launch site, handling ground support equipment, managing facilities and ensuring all required personnel and supplies are in place.
These operations typically begin weeks to months before launch day. For instance, U.S. launch ranges may begin formal pre-launch campaigns ~ 30 days before liftoff [51], while key operational requirements must often be finalized ~ 90 days prior. In Europe, Ariane 5 launch campaigns historically lasted about five weeks [7]. Timelines highlight the intense, time-bound nature of pre-launch logistics.

Key elements of pre-launch operations include:

- **Mission Planning and Scheduling:** Development of a detailed timeline of tasks, often as a Gantt or PERT/CPM schedule, identifying the **critical path** for launch [13].
- **Resource and Constraint Management:** Allocation of facilities, ground support equipment and commodities (propellants, gases). Scheduling must account for weather, range availability and launch commit criteria.
- **Procedures and Checklists:** High-reliability sectors rely on step-by-step operating procedures to minimize human error. NASA, ESA, SpaceX and others use comprehensive checklists with built-in hold points during the countdown [36].

Overall, pre-launch operations are about **coordination**—ensuring parallel work streams converge successfully at "T-0." Ariane 5 campaigns, for example, coordinate three parallel streams (launcher, satellite, spaceport) that merge ~ 12 days before launch [60].

4.3.3 Methodologies in Space Agency Launch Operations

4.3.3.1 NASA and International Best Practices

Major space agencies emphasize:

- **Phase-Gated Processes:** NASA's lifecycle (Phases A-E) places pre-launch in Phase D/E [5], governed by management requirements in NPR 7120.5 [35].
- **Readiness Reviews:** The **Flight Readiness Review (FRR)** and **Operations Readiness Review (ORR)** ensure all elements are "go" for launch [29].
- **Scheduling & Critical Path Management:** NASA mandates an **Integrated Master Schedule** detailing final hardware processing and rehearsals [13].
- **Mission Simulations & Rehearsals:** Full dress rehearsals validate procedures; ECSS similarly calls for an Operational Validation Plan [21].
- **Launch Commit Criteria & Flight Rules:** Formal go/no-go conditions govern terminal count.
- **Post-Launch Analysis:** NASA's Post-Launch Assessment Review captures lessons learned [11].

International agencies (Roscosmos, ISRO, JAXA) apply comparable gated reviews and checklist-driven countdowns.

4.3.3.2 European Standards and ECSS Guidelines

The **European Cooperation for Space Standardization (ECSS)** codifies pre-launch best practices:

- **Lifecycle Phases & Reviews:** Phase D for integration/test and Phase E for operations/launch [33].
- **Ground Segment & Operations Engineering:** Early operations involvement and mandatory documentation [21].
- **Project Planning & Implementation:** Detailed DRDs and master schedules [3].
- **Product Assurance & Safety:** Compliance with ECSS-Q series for configuration control and hazard reporting [28].
- **Launch Campaign Execution:** Coordination among launcher, payload and range infrastructure [60].

4.3.3.3 Commercial Launch Provider Innovations

Companies such as **SpaceX** have introduced:

- **Automated Countdown Sequencers** that compress timelines to ~ 1 hour [36].
- **Rapid Reuse and Turnaround** philosophies, supported by integrated digital workflows.

4.3.4 Comparable High-Reliability Industry Processes

4.3.4.1 Military Aerospace and Nuclear Sector

High-reliability sectors demonstrate:

- **Strict Procedure Compliance:** Missile launches and nuclear operations apply two-person rules and multiple sign-offs [4].
- **Safety Culture:** Operators empowered to halt operations; lessons learned feed continuous improvement [12].
- **Independent Review:** External "red teams" provide unbiased assessments [14].

4.3.4.2 High-Value Manufacturing (Semiconductor, Pharma)

Shared attributes include automation, configuration management and simulation-driven validation.

4.3.5 Digital Tools and Software for Pre-Launch Scheduling and Logistics

Key enablers are:

- **Integrated Scheduling Software** (Primavera, MS Project) for critical-path control [27].
- **Constraint-Checking Simulations** such as NASA's STAR to detect resource conflicts [17].
- **Automated Countdown Systems** and real-time data logging [36].

4.3.6 Best Practices and Constraints Shaping Pre-Launch Methodology

1. **Early Planning & Integration:** Begin logistics months in advance and integrate operations into design [3].
2. **Structured Reviews:** ORR and FRR with formal entrance criteria [29].
3. **Parallel Stream Management:** Use a master schedule with integration milestones [13].
4. **Risk Management:** Maintain a risk register and mitigation strategies [12].
5. **Training & Human Factors:** Conduct rehearsals and anomaly simulations [4].
6. **Lessons Learned Loop:** Post-launch debriefs and continuous improvement [11].

4.3.7 Toward a Methodology for the EPFL Rocket Team's Kármán Line Mission

Recommended actions include adopting a phase-based plan [33], maintaining a master schedule, leveraging digital aids and formalizing safety best practices informed by ECSS and NASA guidelines [21, 35]. Early coordination with external entities (ranges, regulators) and continuous improvement after each test will underpin mission reliability.

4.3.8 Conclusion

Pre-launch operations and logistics are **highly coordinated, multi-disciplinary** endeavors. Decades of experience from NASA, ESA, commercial providers and high-reliability industries underscore the importance of structured procedures, rigorous reviews, critical-path scheduling, robust safety cultures and digital toolchains. By implementing these best practices, the EPFL Rocket Team can manage the complexities of a student-led but high-stakes mission and maintain a validated launch plan en route to the Kármán line target by 2030.

4.4 State-of-the-Art Review: Pre-Launch Operations and Logistics Practices

4.4.1 Introduction

Space launch operations and logistics encompass all activities from **final vehicle integration** through **launch execution**. In mission-phase terms, this corresponds to **late Phase D** into **Phase E** (focusing on pre-launch final assembly, transport to launch site, on-site preparation, fueling, countdown and T-0 events). This review explores **concrete practices** of major government space agencies, private-sector launch companies, sounding-rocket operators and student rocket teams. Particular attention is paid to **student teams** in Europe and the United States, whose lessons directly inform the EPFL Rocket Team's upcoming Spaceshot mission. Although smaller in scale, student launches mirror professional methodologies and therefore offer valuable insights for lean, resource-constrained campaigns.

4.4.2 Launch Operations in Major Space Agencies

4.4.2.1 NASA (USA)

NASA launch operations are **highly structured**, with long countdowns and large teams. The Space Shuttle, for instance, was integrated in the Vehicle Assembly Building (VAB), then *rolled out* to Pad 39 via crawler-transporter. Countdowns spanned days (starting at T-43 h over three real days). Cryogenic fueling of the External Tank ($\sim$2 million L) began about eight hours before liftoff, overseen by a large staff in the Launch Control Center[6]. Although costly, this process enabled on-pad repairs if anomalies arose.

4.4.2.2 ESA (Europe)

The European Space Agency—primarily via Arianespace at the Guiana Space Centre—uses a **multi-week launch campaign** (e.g. $\sim$5 weeks for Ariane 5). The launcher is stacked in an assembly building, the payload integrated $\sim$12 days before launch and the complete stack rolls to the pad one day prior. Cryogenic stages are fueled a few hours before T-0, with parallel launcher, payload and range streams converging near launch day[7].

4.4.2.3 Roscosmos (Russia)

Russian logistics emphasize **horizontal integration**: Soyuz rockets are assembled in a hangar, rolled out by rail and raised vertical at the pad about two days before launch. Kerosene and liquid-oxygen fueling starts at roughly T-3 h, after which automated sequencers handle engine ignition[62]. Centuries of Soyuz flights have refined this short, efficient campaign.

4.4.2.4 CNSA, ISRO and JAXA

China's Long March family alternates between vertical and horizontal integration; countdowns last $\sim$24 h. ISRO's PSLV/GSLV flows include $\sim$30-h countdowns at Satish Dhawan. Japan's H-IIA involves multi-day rollout from assembly to pad at Tanegashima[16]. All employ NASA/ESA-level rigor, tailored to varying infrastructure and budgets.

4.4.3 Launch Operations in Private Space Companies

4.4.3.1 United Launch Alliance (ULA)

ULA merges **legacy government** processes with commercial efficiency. Atlas V, Delta IV Heavy and Vulcan are integrated vertically, rolled out one day beforehand and fueled over 2-3 h, using extensive checklists and built-in holds[43]. Mission success trumps cost.

4.4.3.2 SpaceX

SpaceX prioritizes **fast turnaround**, horizontal integration and heavy automation. Falcon 9 can be fully fueled just 35 min before T-0 with densified LOX and RP-1, while the Autonomous Flight-Safety System reduces reliance on range personnel[36]. A lean team, booster reuse and simplified pad infrastructure enable a weekly cadence.

4.4.3.3 Blue Origin

The **New Shepard** suborbital system employs a quick-turnaround model with a small crew. For orbital **New Glenn**, Blue Origin is building new Florida infrastructure for reusable vertical integration[76].

4.4.3.4 Rocket Lab

The compact **Electron** launcher is integrated horizontally and erected via a simple transporter/erector at the private New Zealand range. Countdown runs 2-3 h, with containerised GSE and LOX/RP-1 fueling[87].

4.4.3.5 Emerging Start-ups

Firefly's Alpha, ABL's RS1 and Astra's Rocket leverage "**mobile launch**" concepts: containerised GSE, minimal pad infrastructure and automated safety systems[56, 84].

4.4.4 Sounding-Rocket Operations

Professional sounding-rocket providers such as NASA's Wallops Program and DLR/MORABA conduct **modular, short campaigns**. Portable rails or towers, small teams and minimal GSE enable agile timelines measured in days[50]. The approach resembles student operations but with more professional resources.

4.4.5 Operations & Logistics in Student Rocket Teams

4.4.5.1 Overview

Student teams face constrained budgets and volunteer labour yet emulate professional processes: checklists, readiness reviews and range coordination. They typically manage transport, on-site integration and launch execution with minimal staff.

4.4.5.2 USC Rocket Propulsion Laboratory (USA)

First undergraduate team to surpass the Kármán line ($\sim$104 km with "Traveler IV"). Operated at Spaceport America with a custom tower and $\sim$40 students on-site, relying on thorough rehearsals and iterative design[82].

4.4.5.3 Delft Aerospace Rocket Engineering (DARE, NL)

Stratos hybrids (>20 km) required custom crates, multi-day trucking to INTA Spain and portable launch towers; emphasis on dress rehearsals and FTS compliance[69].

4.4.5.4 HyEnD (DE)

Hybrid “HEROS” (32 km) and “N2ORTH” (64 km) campaigns at Esrange involved large rails, extensive GSE and rapid iteration between attempts[71].

4.4.5.5 EPFL Rocket Team (CH)

Having won EuRoC and now targeting a space-shot, the EPFL Rocket Team faces advanced logistics: taller towers, FTS implementation and shipping large motors[85]. Lessons from earlier Bella Lui and Nordend campaigns reinforce the need for structured ops.

4.4.6 Launch Infrastructure & GSE Comparison

Aspect	Govt Agencies	Private Companies	Student Teams
Pad/Infrastructure	Large fixed pads, flame trenches, VABs	Strongbacks, containerised GSE, minimal towers	Portable rails/towers, often homemade
Transport	Crawlers, rail transport (Soyuz)	Trucks, horizontal integration	Rental trucks, modular crates
Fueling & GSE	High-capacity cryo farms, automated umbilicals	Container-based or streamlined fueling	Manual or partially automated fueling
Automation	Extensive software + large teams	Automated countdown/AFSS	Mixed manual checks
Personnel	Hundreds to thousands	Dozens to 100	10-30 volunteers
Budget	$100M+ per campaign	$1-100M	$10k-100k per project

4.4.7 Best Practices & Key Takeaways

1. **Extensive rehearsals**: full dress runs catch surprises early.
2. **Logistics focus**: detailed packing and spares avoid show-stoppers.
3. **Simplified infrastructure**: horizontal integration and portable towers cut complexity.
4. **Selective automation**: off-the-shelf electronics replicate big-agency checkouts.
5. **Safety first**: FTS, two-person verification, rigorous checklists.
6. **Adaptability**: plans for scrubs, weather holds and rapid repairs.
7. **Knowledge transfer**: thorough documentation mitigates student turnover.
8. **Metrics & iteration**: capture data, analyse and improve—mirroring SpaceX’s agile model.

4.4.8 Conclusion

Concrete practices for **space-launch operations and logistics** vary widely—from NASA's massive pads and multi-day counts to SpaceX's rapid, automated flows and student teams' improvised yet disciplined campaigns—but all share foundational traits: rigorous procedures, resource management and robust safety culture. For the EPFL Rocket Team, adopting professional reviews, partial automation, comprehensive rehearsals and disciplined logistics will be critical to achieving a successful student space-shot by 2030.

4.5 Atlantic Spaceport Consortium vs. Esrange Spaceport: Sounding-Rocket Launch Capabilities

4.5.1 Available Infrastructure

Figure 3: Mobile launch of the *GAMA* rocket at Santa Maria[89]

Atlantic Spaceport Consortium (Santa Maria, Azores)

- **Launch Pads & Facilities** - ASC presently employs a *mobile launch platform* for sounding rockets. Two back-to-back GAMA flights in September 2024 proved basic operability[89]. A permanent pad is planned, but the portable system provides rapid re-configuration.
- **Integration & Processing** - Secure storage and small clean-room areas are available in repurposed airport hangars[90]. A dedicated *Mission Control Centre* complements basic payload preparation spaces.

- **Fueling & Ground Support** - Solid-propellant rockets require minimal on-site fueling infrastructure; ASC nevertheless offers logistics for propellants and gases[92]. Custom MGSE can be adapted to multiple vehicle geometries[90].
- **Telemetry & Tracking** - The island hosts ESA's S-band ground station at Montes das Flores[58], supplemented by local radar and GPS trackers. The wide Atlantic down-range corridor eases range-safety constraints.
- **Rapid Launch Turnaround** - The portable pad enabled consecutive-day launches in 2024[89]. Rocket supply rather than pad reuse currently limits cadence.

Figure 4: Esrange sounding-rocket pads and integration facilities[67]

Esrange Spaceport (Kiruna, Sweden)

- **Launch Pads & Facilities** - A mature complex with six fixed pads dedicated to sounding rockets such as MAXUS and MRL[68]. Over 500 flights have been conducted since 1966[67]. Ongoing "New Esrange" upgrades add liquid-propellant and reusability capabilities under dedicated cryogenic-safety governance[30].
- **Integration & Payload Processing** - A 795 m^2 integration hall[64] supports horizontal or vertical build-up. Multi-stage vehicles are assembled entirely on-site, with refurbishment capability between flights[67].
- **Fueling & Propellant Infrastructure** - Solid motors are stored in magazines, while hybrids/liquids use a purpose-built test stand[37]. Cryogens are managed per stringent safety instructions[30].
- **Telemetry, Tracking & Range Safety** - Multiple C-band radars and S-band links[68], optical tracking and a range-safety FTS approval process[44]. The 5 200 km^2 impact area[63] supports high-altitude missions up to 700 km.

- **Rapid Campaigns** - Parallel pad availability allows consecutive launches within hours, provided weather and hardware readiness align[67].

4.5.2 Environmental Conditions

Santa Maria Island (Azores)

- **Weather Patterns** - Temperate oceanic climate with 13-26 ℃ range; wetter October-April[81].
- **Wind & Atmospheric Conditions** - Influenced by the Azores High; summer stability versus winter frontal systems.
- **Seasonal Launch Feasibility** - Year-round launches feasible, though Atlantic storms (Aug-Nov) may induce scrubs[70].
- **Geographical Factors** - $36.95°$ N, sea-level island surrounded by open ocean; multiple azimuths with debris into the Atlantic[91].
- **Environmental Considerations** - Pristine ecosystem demands stringent debris-recovery and spill-mitigation protocols[70].

Kiruna - Esrange (Swedish Lapland)

- **Weather Patterns** - Sub-arctic climate: 25 ℃ winters, mild 15-20 ℃ summers[73].
- **Light Conditions** - Polar day/night at $67.9°$ N affects scheduling and human factors[72].
- **Seasonal Launch Feasibility** - Year-round operations; winter requires heated equipment and snow handling[67].
- **Geographical Setting** - A 5 200 km^2 restricted impact area supports safe debris fall[63].
- **Ecological Factors** - Arctic wilderness and reindeer herding necessitate robust environmental management[83].

4.5.3 Regulatory & Compliance Factors

Atlantic Spaceport Consortium (Portugal)

- **Governing Regulations** - Portuguese Space Act revisions (2019-2023)[79]. Licensing by ANACOM/PT Space; each launch requires authorisation.
- **Safety & Liability** - Mandatory launch insurance[59]. Flight-safety analyses address oceanic debris.
- **Airspace & Maritime Coordination** - Santa Maria FIR managed by NAV Portugal with NOTAM/NAVAREA closures[80].

Esrange Spaceport (Sweden)

- **Governing Regulations** - Swedish Space Act exempts suborbital launches[1]. SSC self-regulates via internal safety policy[66].
- **Range Safety** - Launches follow Esrange Safety Manual[66]; cryogenic and FTS operations approved by dedicated processes[30, 44].
- **Permitting Simplicity** - No mission-by-mission license required, streamlining frequent campaigns[67].

4.5.4 Operational Considerations

Atlantic Spaceport Consortium

- **Site Accessibility** - Santa Maria Airport (3 048 m runway)[77] plus a small port. All facilities within minutes' drive.
- **Local Support** - Limited industry; most specialised hardware imported[92].
- **Cost & Sustainability** - Mobile infrastructure lowers range fees; island shipping adds cost. Supportive regional policies may offset fees.

Esrange Spaceport

- **Site Accessibility** - Kiruna Airport, rail and roads; SSC owns snow-clearing and recovery fleet.
- **Experienced Workforce** - Decades of heritage, rapid troubleshooting, and in-house meteorology[67].
- **User Guidance** - New operators benefit from the comprehensive Esrange User's Handbook series[46, 47, 48, 49, 45].

4.5.5 Overall Comparison & Key Findings

1. **Infrastructure Heritage** - Esrange: established, multi-pad complex[67]. ASC: emerging, mobile-pad flexibility[90].
2. **Environmental Factors** - Azores: mild maritime[81]. Kiruna: sub-arctic extremes[73].
3. **Regulatory Environment** - Portugal: formal per-mission licensing[79]. Sweden: streamlined suborbital oversight[1].
4. **Operational Support** - Esrange: lodging, workshops and rapid relaunch[67]. ASC: lower overhead but island-logistics complexity[92].
5. **Use-Case Alignment** - Esrange for advanced, multi-stage or high-altitude flights; ASC for flexible, lower-mass tests requiring oceanic impact zones.

4.5.6 Conclusion

Esrange Spaceport offers a turnkey, heritage-rich environment suited to complex campaigns requiring proven safety processes. The *Atlantic Spaceport Consortium* presents a cost-competitive, mild-climate alternative with oceanic drop zones and rapid pad re-configuration. Mission planners should weigh infrastructure maturity, regulatory timelines and environmental constraints when selecting a launch site.

4.6 Operations and Logistics Planning Scope

With the state-of-the-art reviewed, we now turn to the overarching scope that guided the planning and structuring of the deliverables. This document ensures all operational and logistical elements are addressed comprehensively and coherently.

4.6.1 Scope Breakdown Overview

Figure 5 illustrates the high-level Work-Breakdown Structure (WBS) that frames all pre-launch operations and logistics activities for the Spaceshot initiative. Existing deliverables are named outright and an external source or best example is provided in each section. New documents are named as such and colored per their expected type.

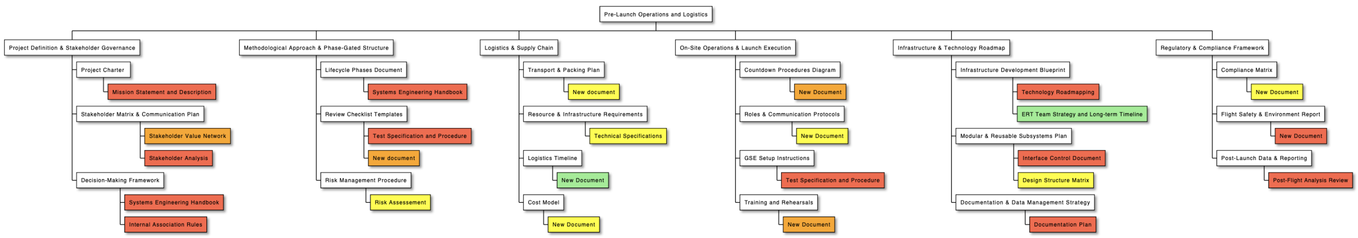

Figure 5: Top-level WBS for Operations and Logistics planning. Colour codes refer to deliverable types listed in the following table.

Table	Quantitative matrices, specification sheets or RACI charts.
Figure	Static diagrams or road-map graphics communicating long-term vision.
Diagram	Process-flow or countdown schematics supporting execution.
Text-based	Narrative documents or handbook chapters that frame policy and rationale.

4.6.2 Project Definition & Stakeholder Governance

4.6.2.1 Purpose

Establish the project vision, enumerate all internal and external stakeholders, and codify the decision-making rules that keep the programme aligned and traceable.

4.6.2.2 Key Deliverables

D1: Project Charter - succinct statement of objectives, boundaries and success criteria, modelled on the structure recommended in NASA NPR 7120.5[75].

D2: Stakeholder Matrix & Communication Plan - a RACI-style mapping of influence versus information needs, as promoted by PMI's PMBOK[39].

D3: Decision-Making Framework - criteria, voting rules and authority allocation documented in a Decision Log, following guidance from ECSS-M-ST-10C[3].

An extracted WBS for this branch is provided in Figure 6.

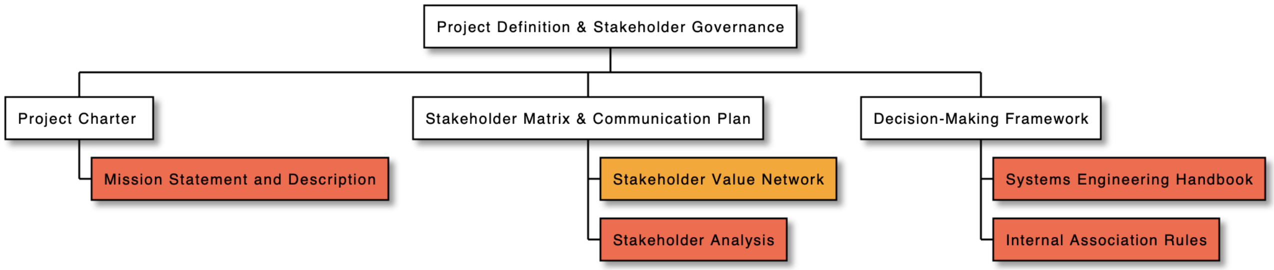

Figure 6: WBS branch for Project Definition & Stakeholder Governance.

4.6.3 Methodological Approach & Phase-Gated Structure

4.6.3.1 Purpose

Translate the NASA/ESA life-cycle (Phases A-E) into an academic-team context, embedding mandatory reviews and risk checkpoints.

4.6.3.2 Key Deliverables

M1: Lifecycle Phases & Review Gates - concise handbook defining ORR and FRR triggers, adapted from NASA Life-Cycle guidance[20].

M2: Review Checklist Templates - gate-specific checklists to eliminate omissions, based on ECSS-E-ST-70[21].

M3: Risk-Management Procedure - workflow for risk identification and mitigation consistent with NASA's Risk-Informed Decision-Making Handbook[26].

An extracted WBS for this branch is provided in Figure 7.

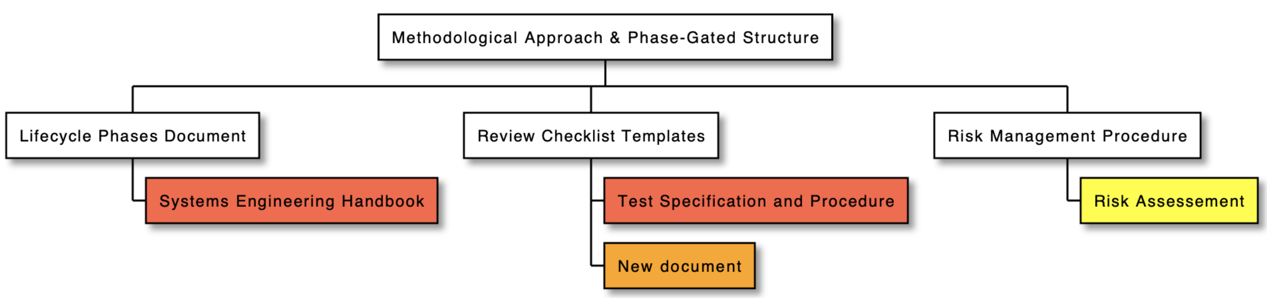

Figure 7: WBS branch for Methodological Approach & Phase-Gated Structure.

4.6.4 Logistics & Supply-Chain Management

4.6.4.1 Purpose

Manage the end-to-end flow of hardware, ground-support equipment and consumables, including resilience planning for spares and repairs.

4.6.4.2 Key Deliverables

L1: Transport & Packing Plan - containerisation, labelling and ADR/ICAO compliance, aligning with Arianespace logistics practice[8].

L2: Resource & Infrastructure Requirements - bill of on-site needs (cranes, forklifts, gas cylinders) derived from NASA integration standards[53].

L3: Logistics Timeline & Cost Model - Gantt and cost model combining PMI logistics methodology[40].

An extracted WBS for this branch is provided in Figure 8.

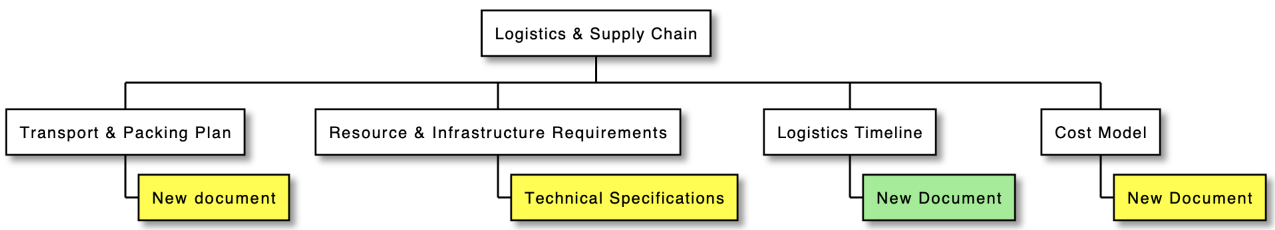

Figure 8: WBS branch for Logistics & Supply-Chain Management.

4.6.5 On-Site Operations & Launch Execution

4.6.5.1 Purpose

Define safe, repeatable procedures for final assembly, fuelling, countdown and launch, including precise role allocation and communications discipline.

4.6.5.2 Key Deliverables

O1: Countdown & Operational Procedures Handbook - T-72 h to T-0 steps, adopting the Shuttle Countdown Manual structure[10].

O2: Roles & Communication Protocols - console assignments and net discipline, aligned with ECSS-E-ST-70-41A packet-utilisation rules[19].

O3: GSE Setup Instructions - fuelling and umbilical operations derived from ESA launch-campaign guidelines[42].

O4: Training & Rehearsal Plan - incremental rehearsal ladder inspired by Blackwell's small-sat mission-ops training model[15].

An extracted WBS for this branch is provided in Figure 9.

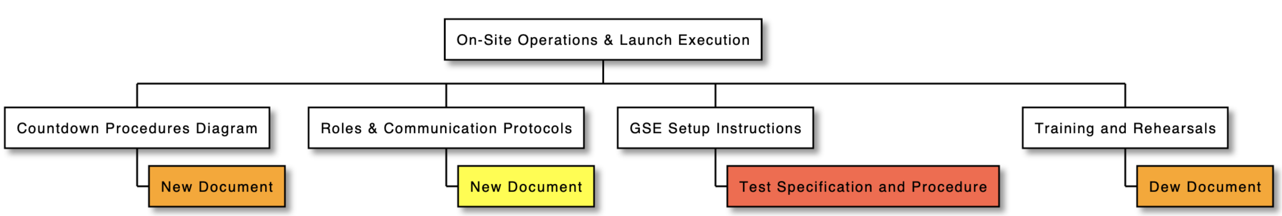

Figure 9: WBS branch for On-Site Operations & Launch Execution.

4.6.6 Infrastructure & Technology Road-map

4.6.6.1 Purpose

Provide a strategic view on facility upgrades, reusable subsystems and documentation architecture enabling future missions beyond the Spaceshot flight.

4.6.6.2 Key Deliverables

I1: Infrastructure Development Blueprint - phased upgrade plan aligned with ECSS-E-ST-20 system-engineering principles[25].

I2: Modular & Reusable Subsystems Plan - reusability strategy benchmarked against SpaceX white papers[34].

I3: Documentation & Data-Management Strategy - configuration-management schema compliant with NASA NPR 7120.7[54].

An extracted WBS for this branch is provided in Figure 10.

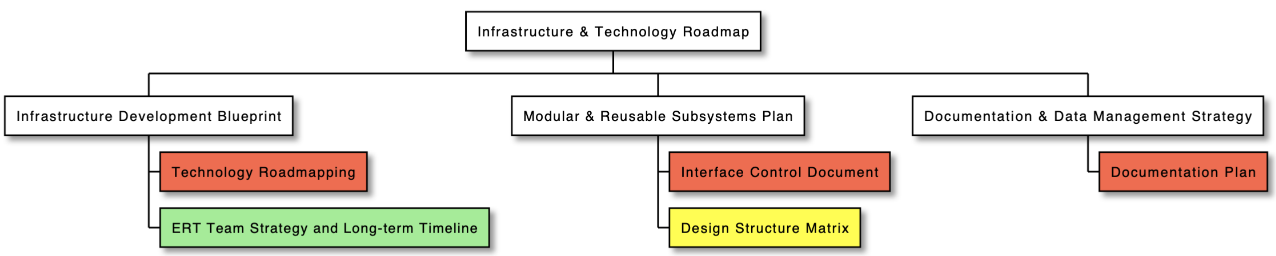

Figure 10: WBS branch for Infrastructure & Technology Road-map.

4.6.7 Regulatory & Compliance Framework

4.6.7.1 Purpose

Guarantee conformance with national space acts, range-safety policies and environmental obligations at the selected launch site(s).

4.6.7.2 Key Deliverables

C1: Compliance Matrix - side-by-side comparison of Portuguese[78] and Swedish[2] legislative requirements.

C2: Flight Safety & Environment Report - risk corridor and ecological-impact synthesis referencing Esrange safety standards[65].

C3: Post-Launch Data & Reporting Plan - PLAR-style template satisfying NASA post-launch assessment practices[11].

An extracted WBS for this branch is provided in Figure 11.

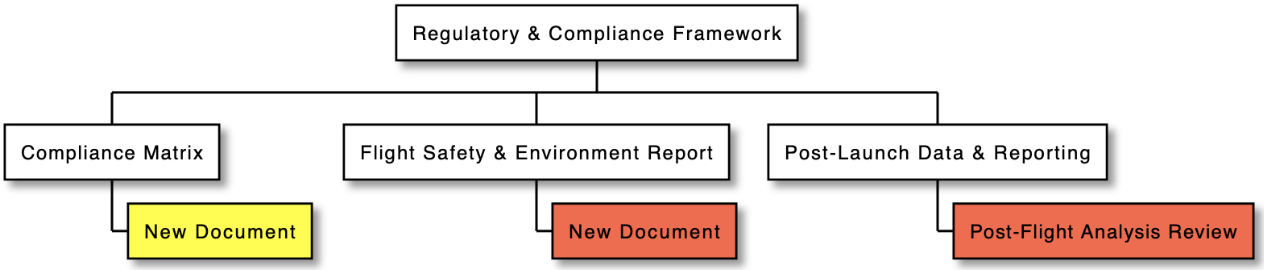

Figure 11: WBS branch for Regulatory & Compliance Framework.

4.6.8 Consolidated Deliverable Register

Deliverable	Type	Existing	Source / Standard
Project Charter	Text	Yes	NPR 7120.5[75]
Stakeholder Matrix & Comms Plan	Table	Yes	PMBOK[39]
Decision-Making Framework	Text	Yes	ECSS-M-ST-10C[3]
Lifecycle Phases & Review Gates	Text	Yes	NASA Life-Cycle[20]
Review Checklist Templates	Diagram	No	ECSS-E-ST-70[21]
Risk-Management Procedure	Table	Yes	NASA RIDM[26]
Transport & Packing Plan	Table	No	Ariane Logistics Manual[8]
Resource & Infrastructure Requirements	Table	Yes	NASA LV Integration[53]
Logistics Timeline & Cost Model	Figure	No	PMBOK Logistics[40]
Countdown Procedures Handbook	Diagram	No	Shuttle Countdown[10]
Roles & Communication Protocols	Table	No	ECSS-E-ST-70-41A[19]
GSE Setup Instructions	Text	Yes	ESA Launch Guidelines[42]
Training & Rehearsal Plan	Diagram	No	Blackwell [15]
Infrastructure Development Blueprint	Text	Yes	ECSS-E-ST-20[25]
Modular & Reusable Subsystems Plan	Table	Yes	SpaceX Reuse[34]
Documentation & Data-Management Strategy	Text	Yes	NPR 7120.7[54]
Compliance Matrix	Table	No	PT vs. SE Space Acts[78, 2]
Flight Safety & Environment Report	Text	No	Esrange Safety[65]
Post-Launch Data & Reporting Plan	Text	Yes	NASA PLAR[11]

4.7 Launch–Campaign Communication Procedure Guidelines

This key deliverable addresses intra-team communications. Ensuring clarity, authority, and fail-safes in voice and digital exchanges during the campaign is essential to mission safety and coordination.

4.7.1 Purpose & Scope

Provide a **repeatable, scalable, safety-centred framework** for *all* person-to-person voice or text communications during a Spaceshot sub-orbital launch campaign—from site set-up through recovery and demobilisation. Applies to every team member, contractor or partner who participates in operations.

4.7.2 Guiding Principles

#	Principle	Rationale
1	**Clarity before brevity**	Plain language & standard pro-words minimise misunderstandings.
2	**Single net-control per loop**	Avoids "dual control" confusion and ensures clear authority.
3	**Fail-safe design**	At least two independent communication paths for every critical function.
4	**Need-to-speak discipline**	Only authorised roles transmit on mission loops.
5	**Logged & reviewable**	Audio/chat logs retained $\geq$ 5 years for incident investigation & learning.
6	**Standards-led**	Framework mapped to FAA §417.111, NASA countdown-loop practice & ICS-205 radio-plan format [55, 9, 38].

4.7.3 Roles & Hierarchy

Level	Call-sign (example)	Mandate	Typical Equipment
Comms Director (CD)	`NET-1`	Owns comms plan, approves changes, chairs daily briefings	Fixed console, recording
Net Controller	`LC-CTRL`	Controls a specific loop (Launch-Control, Ground-Ops, Safety. . .)	Console + backup HT
Functional Lead	`PROP-LEAD`	Speaks for subsystem, authorises subordinate traffic	Headset
Operator / Specialist	`AV-2`	Provides data when asked; transmits only when instructed	Hand-held / chat
Observer / Visitor	—	Listen-only	Listen-only radio / livestream

Rule of thumb: only the Net Controller may approve cross-talk between loops.

4.7.4 Network Architecture & Equipment Allocation

Loop	**Purpose**	**Medium**	**Primary Channel**	**Backup Path**
Launch-Control	Countdown & flight events	UHF digital simplex	*TBD* MHz	Satellite push-to-talk
Ground-Ops	Loading, cranes, convoy	VHF analogue	*TBD* MHz	LTE group-call
Safety / Medical	Emergencies only	VHF analogue	*TBD* MHz	Mobile-phone voice
Engineering Chat	Non-critical coordination	Whatsapp/Telegram	`#eng-chat`	Slack
Public Affairs	Press & outreach	VoIP & phone	—	Mobile-phone voice

Equipment-allocation list maintained in the Comm-Matrix.

4.7.5 Standard Procedures

Situation	**Phraseology / Action**
Call-up	"<*Called station*>, this is <*Calling station*>, <message type>— <content>."
Acknowledgement	"**COPY**" (understood), "**SAY AGAIN**" (repeat), "**AFFIRMATIVE / NEGATIVE**".
Read-back	*Mandatory* for launch-commit, hold, abort & safety instructions.
Signal check	"Radio check." → "Read you **five by five**."
Priority override	"**BREAK-BREAK**" pre-empts traffic. Emergencies: "**STOP STOP STOP**".
Silence order	"**ALL STATIONS, THIS IS *Safety-CRITICAL*: RADIO SILENCE.**"
End of transmission	"**OUT**" (no response expected).

A	Alpha	N	November
B	Bravo	O	Oscar
C	Charlie	P	Papa
D	Delta	Q	Quebec
E	Echo	R	Romeo
F	Foxtrot	S	Sierra
G	Golf	T	Tango
H	Hotel	U	Uniform
I	India	V	Victor
J	Juliett	W	Whiskey
K	Kilo	X	X-ray
L	Lima	Y	Yankee
M	Mike	Z	Zulu

Figure 12: ICAO radiotelephony alphabet reference card.

*Example: "Mischung" would be called out as "**M**ike **I**ndia **S**ierra **C**harlie **H**otel **U**niform **N**ovember **G**olf".*

4.7.6 Planning Process (per campaign)

1. **Task & hazard analysis** of site operations.
2. Draft **ICS-205-L** [38] (launch variant): loops, frequencies, encryption.
3. **Assign roles** & issue call-sign sheet.
4. **Net-check & dry-run** $\geq$ T-48 h; document baseline RSSI & latency.
5. **Comms Readiness Review (CRR)**—Comms Director approval required.
6. Publish the "**Comm Card**" (wallet-sized PDF) to all staff.

4.7.7 Operational Timeline (excerpt)

Phase	Key Comms Milestones
Site Setup	Net-check, antenna deployment, UPS test
Integration	Daily radio check 08:00; maintain comms log
Launch Countdown	Full net discipline from T-120 min; "Green Net" calls at T-90/60/30
Flight & Recovery	Automatic hand-off to Recovery Net at L+*TBD* s
Post-Flight	Debrief on Safety Net; archive logs $\leq$ 24 h

4.7.8 Emergency & Degraded-Mode Communications

- **Primary loop failure** $\rightarrow$ switch to pre-agreed backup path.
- **Total radio failure** $\rightarrow$ satellite phone, then physical runner.
- **Mayday format:** "**MAYDAY MAYDAY MAYDAY**, this is <call-sign>…"
- **Hot-mic contingency:** Net Controller can remote-kill the transmitter at base-band.

4.7.9 Training & Certification

Module	Content	Frequency
L-COM-101	Radio basics, pro-word usage	Once per member
L-COM-201	Net controller duties, logging	Annual
Emergency Drill	Simulated loop loss & hand-off	Quarterly
Flight-loop Sim	Full countdown rehearsal	$\geq$ T-30 days

4.7.10 Training Frequency

Layer	Typical interval	Why it exists	Real-world examples
Shift / Daily	Every console shift or surgical list	Start-of-shift comm-checks keep language, call-signs and status formats consistent.	MCC "call to stations" before each wet-dress or real countdown lasts ~ 45 h and includes structured comms checks for every console team member [9].
Weekly–Bi-Weekly Integrated Sims	1–2 × per week during campaign	Full-team rehearsals exercise phraseology, loop etiquette and time tags under stress.	Shuttle/ISS era simulations held once or twice weekly.
Monthly / Quarterly Drills	1× per month (typ.) or $\geq 4\times$ per year	Maintains currency on uncommon but safety-critical scenarios (loss of comms, evacuation codes).	U.S. research-reactor licences mandate quarterly drills.
Annual / Semi-Annual Recurrent	1–2× per year	Formal refresher on procedures and human-factors lessons learned.	FAA ATC controllers complete two 8 h recurrent-training blocks per year.
Biennial / Licence Renewal	24 months	Deep re-qualification incl. simulated emergencies.	Nuclear-plant operators follow a two-year re-qualification cycle.
Mission-Specific Dress Rehearsal(s)	1–3 full-mission countdowns in final month	Enforces launch-day voice cadence with real hardware timelines.	Artemis I wet-dress rehearsal two months before first window [52].

4.7.11 Documentation & Records

- Voice recordings (`.wav`) per loop, UTC time-stamped.
- Chat exports (`.json`) captured each shift.
- Storage: encrypted NAS + off-site cloud; retention = 5 years.

4.7.12 Continuous Improvement

- Post-mission **Comms Hotwash** within 48 h.
- **Metrics**:
  - correct call-sign usage (%)
  - average response latency (s)
  - un-acknowledged transmissions (#)

4.7.13 Caveats & Limitations

- RF coverage assumes line-of-sight; verify on site.
- Licensing & encryption rules vary by country—obtain local authority approval.
- Human factors (fatigue, language) remain the dominant error source—training is mandatory.
- Telemetry & data links are out of scope (handled under Avionics ICD).

4.8 Logistics Cost Estimator

Purpose & Scope This page documents **how the Python command-line estimator works**, the assumptions it embeds, where the numbers come from, and what still needs refinement. The model is *only* intended for early-phase cost & carbon *screening*; once a launch window is known you should always request firm quotes—and obtain ATA carnets—from freight forwarders [95, 93, 88].

4.8.1 High-level Architecture

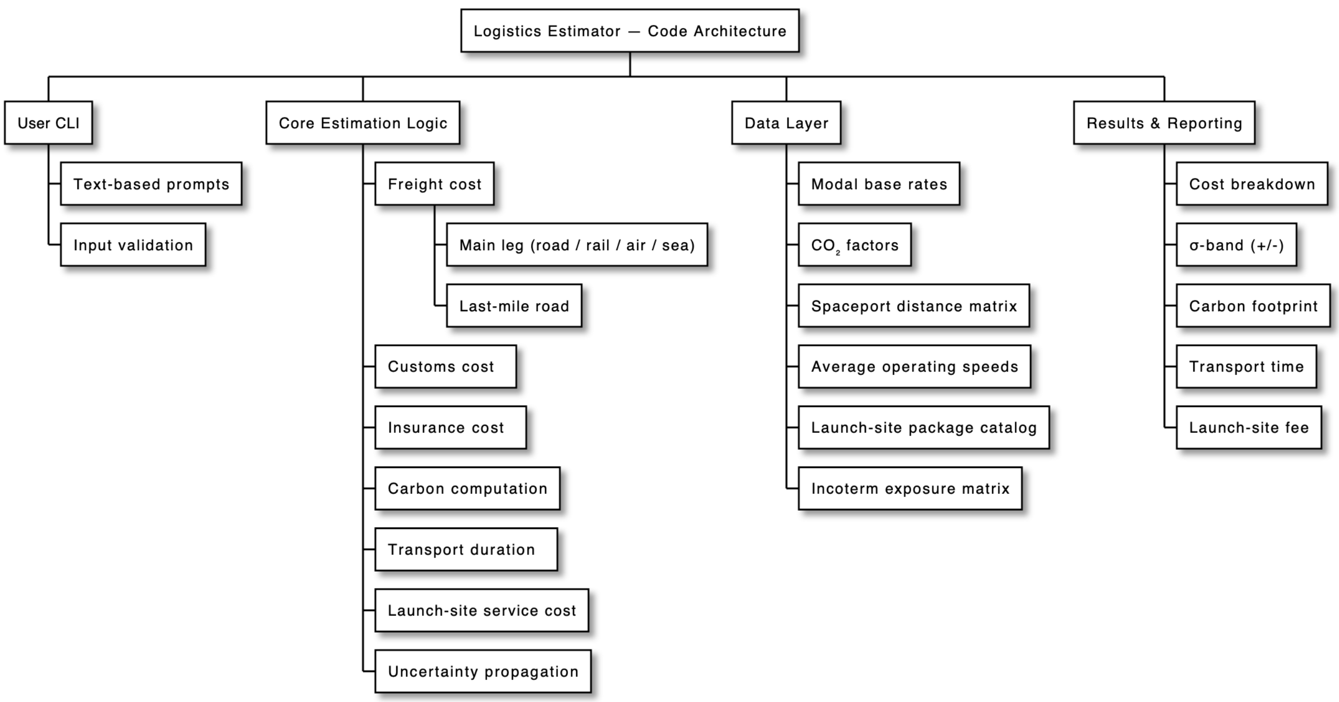

Figure 13: Work-breakdown structure of the logistics cost-estimator codebase.

4.8.2 Data Sources & Default Values

Item	Default value in code	Rationale / primary source
Road rate	0.55 CHF · t-km^{-1}	EU full-truck average cost divided by 20 t payload (inflation-indexed).
Rail rate	0.22 CHF · t-km^{-1}	Mid-point of European intermodal benchmarks (2024) [32].
Air rate	1.65 CHF · t-km^{-1}	Historic average long-haul air-cargo cost 2020–2024.
Sea rate	0.12 CHF · t-km^{-1}	FEU cost normalised after COVID-19 peak.

Item	Default value in code	Rationale / primary source
CO_2 factors	Road 62 g, Rail 22 g, Sea 16 g, Air 600 g · t-km^{-1}	BEIS/DEFRA 2023 tables [61].
Average speeds	Road 60, Rail 80, Air 800, Sea 30, Last-mile 40 km·h^{-1}	Operational planning factors (IMO/IRU studies).
ATA carnet processing	400 CHF flat	Swiss Chamber of Commerce fee schedule [95].
Security bond	0.4 % cargo value	Typical surety-bond premium.
Customs duty	0 CHF (temporary import)	Sweden & Portugal accept carnets [93, 88].
Insurance rate	1 % cargo value	Project-cargo market rule-of-thumb.

Launch-site service packages (Esrange)

Package	Inertial guidance	Telemetry provider	Cost [CHF]
basic	No	In-house	80 000
basic_tp	No	Spaceport	150 000
gnc	Yes	In-house	280 000
gnc_tp	Yes	Spaceport	350 000

Fixed great-circle distances (Lausanne ↔ spaceport)

Spaceport	Road [km]	Rail [km]	Air [km]	Sea [km]	Last-mile road [km]
Esrange (SE)	3000	3000	2200	—	50
Atlantic PT (Azores)	—	—	2700	3200	25

4.8.3 Calculation Methodology

Mathematical expressions follow directly from classical tonne-kilometre costing and simple error–propagation theory. All variables are defined in–line; distances are deterministic constants, cost rates are treated as random variables with mode-specific relative standard deviations (see Uncertainty section). Emission factors derive from EU/UK life-cycle inventories [57].

Freight cost : $C_{\text{freight}} = C_{\text{main},i} + C_{\text{last}}$

Transport duration : $T_{\text{total}} = T_{\text{main},i} + T_{\text{last}}$

Customs cost : $C_{\text{customs}} = (I_{\text{exp}} + I_{\text{imp}})\big(C_{\text{proc}} + \beta V\big)$

Insurance : $C_{\text{ins}} = I_{\text{ins}}\,\alpha V$

Launch-site services : $C_{\text{site}} = \gamma_{\text{pkg}}$

Total cost : $C_{\text{total}} = C_{\text{freight}} + C_{\text{customs}} + C_{\text{ins}} + C_{\text{site}}$

Emissions : $E_{\text{total}} = \sum_j f_j\, d_j\, m$

Uncertainty : $\sigma_{\text{total}} = \sqrt{\sum_k (\sigma_k\, C_k)^2}$

4.8.4 Caveats & Limitations

Area	Limitation	Consequence
Static distances	No route optimisation	$\pm$5–10 % error.
Terminal / handling fees	Not included	Intermodal costs slightly understated.
Average speeds	Single global mean	Corridor-specific congestion ignored.
Launch-site packages	Only Esrange priced	Other sites default to 0 (understate total).
Carbon factors	Single global mean	Rail emissions lower in Nordic energy mix.
Dangerous-goods surcharge	Not modelled	Actual rocket-motor shipments will cost more.

4.8.5 Upgrade Road-map

1. Integrate OpenRouteService API for true road/rail distances.
2. Pull monthly FIATA/TAC rate indices into SQLite.
3. Monte-Carlo uncertainty propagation.
4. FASTAPI micro-service wrapper.
5. JSON rule-engine for customs & carnet acceptability.
6. Launch-site catalog for additional spaceports.

4.8.6 Python Implementation

For the full Python code see section 8.2.

4.9 Environmental & Safety Report

In this next deliverable guidelines, placeholders and examples are written in red. They are meant to be removed by the template user when they fill it.

4.9.1 Sub-Orbital Launch Campaign

4.9.1.1 Header

Campaign Name ____________________

Launch Vehicle ____________________

Launch Window ____________________

Launch Site ____________________

Document Version ____________________

Prepared By ____________________

Reviewed By ____________________

Approved By ____________________

Date ____________________

Classification ____________________

Ensure version history is tracked in your document-management system; include signature blocks if your regulator requires wet or digital signatures.

4.9.2 Executive Summary

A concise (15 lines) statement of overall safety & environmental acceptability. Summarise top risks, mitigations, and a one-line "go / no-go" recommendation. Keep numbers (Pc, EC, key emissions) visible at a glance.

4.9.3 Background & Aim

Briefly explain the mission objective, why this site was chosen and the legal requirement to produce an ESR.

- *Explain why this campaign exists (science payload, technology demo, training flight, . . .).*
- *State the link to higher-level project documents: the CONOPS, the Launch Service Agreement, or the System Requirement Specification.*
- *Describe any lessons learned from prior campaigns that informed this ESR's scope.*

4.9.4 Regulatory Framework

List every applicable law, regulation or guidance.

- *List every piece of controlling legislation (national space act, environmental acts, air- and sea-space regulations, indigenous rights).*
- *Fill the table mapping each permit/licence/notification to the agency, legal reference and due date.*
- *Note relevant standards you voluntarily comply with – ECSS, ISO 14620, AIAA S-080, FAA AC 431.35-1, local Range Safety Manual, etc.*

Compliance Item	Agency	Contact Point	Due Date	Submitted
ISO 14620-1:2018	*ISO*	*contact@iso.org*	*Q3 2029*	*No*

4.9.5 Operator & Vehicle Description

Organisation ____________________

Vehicle Model ____________________

Propellant ____________________

Gross Lift-off Mass ____________________

Reliability History ____________________

- *Organisational description: hierarchy, safety culture statement, designated accountable manager.*
- ***Vehicle technical data:** stage count, propellant types, mass, thrust, I_{sp}, Δv budget. Reference Design Definition File (DDF) extracts or Product-Tree drawings.*
- ***Reliability history:** flight tally, success rate, ground-test statistics. Cite System Safety Program Plan (SSPP) or FMEA where probability numbers come from.*
- *Include any autonomous safety subsystems (AFSS); cross-reference the Flight Termination System Requirements Document.*

Add diagrams or exploded views in an Annex; keep the main text readable.

4.9.6 Launch Site & Infrastructure

Describe pad coordinates, support buildings, FTS ground stations, safe-distance zones.

- *Geographic coordinates, elevation, prevailing winds, seismic class, lightning protection level.*
- *Pad design loads, storage limits for hazardous materials.*
- ***Range assets:** telemetry, radar, tracking optics, command-destruct transmitter sites, power/-communication redundancies.*
- *Emergency-evacuation routes and muster areas, from the Range Safety CONOPS or Site Emergency Plan.*

4.9.7 Mission Profile

- *Narrative plus schematic timeline (T-0, max Q, apogee, engine cutoff, FTS arm, descent).*
- *Ground-track maps with latitude/longitude grids and impact ellipses. Show nominal and 3-sigma dispersions.*
- *Flight rules and abort triggers – reference Flight Rules Document or Launch Commit Criteria.*
- *Define the operational cadence (number of launches per season) to support cumulative-impact analysis later.*

4.9.8 Flight-Safety Methodology

Explain hazard-identification, fault-tree / event-tree logic, and risk metrics.

- *Identify the Hazard Identification technique used (functional FMEA, fault trees, event trees). Reference Hazard Analysis.*
- *Detail risk-metric definitions: Pc, EC, CEC – cite ECSS-Q-ST-30 Dependability and ISO 14620-2 Range Safety.*
- *State the software tools (e.g. RESSAM, SAVI, MAVERIC, DAFIT) and their validation status.*
- *Describe any conservatism factors, dispersion models, debris aerodynamics models (NASA Standard Breakup Model, AFSPC debris list, etc.).*

4.9.9 Modelling Inputs

Failure-Probability Data ______________________________

Debris Library ______________________________

Population Grid ______________________

Meteorology ______________________

- *Failure-probability database version and date; note whether you use industry generic data or your own hot-fire testing.*
- *Population data source: national census, tourist board statistics, seasonal weighting factors.*
- *Atmospheric profile source: radiosonde data, WMO station records; how many years of data used.*
- *Toxic cloud parameters: propellant composition, reaction products, meteorology-class mixing height – cite the Hazard Analysis if it exists.*

4.9.10 Flight-Safety Results

- *Provide tabulated risk metrics (Pc, EC, CEC) compared with regulatory thresholds.*
- *Narrative explains where the highest collective risk occurs and why.*
- *Include figures: individual-risk contours (10^{-5}, 10^{-6}), over-pressure iso-lines, toxic-cloud footprints with 1 ppm and 20 ppm contours.*
- *If mitigations (e.g. NOTAM boundaries, launch-time windows) bring risk down, state them explicitly.*

Metric	**Value**	**Acceptable Limit**
Pc (prob. of casualty)	______	______
EC (expected casualties)	______	______
CEC (catastrophic EC)	______	______

Include contour maps of individual-risk lines and collective-risk footprints.

4.9.11 Flight-Termination System (FTS)

Describe architecture, command chain, autonomous triggers, test & maintenance regime.

- *Block diagram of command path: vehicle receiver, safe/arm, ordnance, power supplies.*
- *Qualification summary: ordnance tests, receiver DESAT, vibration/EMI compliance.*
- *Autonomous limits if AFSS: algorithm reference (selectable abort limits, intent-based boundary).*
- *Link to FTS Test Procedures, FTS Acceptance Data Packages, MIL-STD-1576 compliance evidence.*

4.9.12 Environmental Baseline

Summarise existing conditions (air, water, noise, biodiversity, cultural heritage).

- ***Air:*** *existing NOx, particulate; meteorological class frequency.*
- ***Noise:*** *day/night background dB(A), special receptors (schools, wildlife).*
- ***Water:*** *pH, heavy metals, downstream fisheries.*
- ***Ecology:*** *protected species, migration paths, breeding seasons.*
- ***Socio-economic:*** *land use (agriculture, reindeer herding), tourism flows, heritage sites.*

4.9.13 Impact Mechanisms

- *List each pathway (air emissions, acoustic, vibration, debris, light pollution, waste water).*
- *For emissions: give chemical inventory by species, using NASA CEA or proprietary plume model.*
- *Noise: launch acoustic model (SOUND PROP, NMSIM).*
- *Debris: inert vs toxic fraction, terminal velocity, burial depth.*
- *Cumulative: reference ECSS-ST-HC-32 "Launch count environmental limits" if used by your authority.*

4.9.14 Impact Assessment

- *Apply a magnitude × sensitivity or likelihood × consequence matrix in line with national EIA guidance.*
- *List significance levels (Negligible/Minor/Moderate/Major) and justify each.*
- *For toxic clouds use TEEL or ERPG exposure guidelines; for noise use WHO guidelines or local regs.*
- *Cross-reference each assessment to the earlier baseline data.*

Receptor	Impact	Magnitude	Significance
Species A	*Noise*	*Moderate*	*Minor*
River X	*Contaminant runoff*	*Low*	*Negligible*

4.9.15 Mitigation & Monitoring Plan

Mitigations must be concrete, measurable and time-bound.

- *Launch-day marine exclusion zones (NOTMAR ...)*
- *Post-flight debris recovery within 24 h*
- *Quarterly water-quality sampling at Sites 1–3*

4.9.16 Stakeholder Consultation

- *Chronological log of meetings, public-hearing transcripts, indigenous engagement, written correspondence.*
- *Summaries of issues and operator responses; link any design changes back to the Requirements Baseline to show closed-loop action.*
- *If local law requires Free, Prior and Informed Consent (FPIC), document the evidence.*

Stakeholder	Date(s)	Issues Raised	Resolution
Local municipality	______		
Indigenous council	______	______	______

4.9.17 Emergency Preparedness

Describe scenario planning, resources, response roles, drill schedule.

- *Worst-credible incident list: pad fire, in-flight breakup, hazmat spill, off-nominal landing, SAR.*
- *For each scenario list response-time goals, command hierarchy, external agency roles.*
- *Show evacuation modelling (e.g. T-EVAC for toxic plume).*
- *Training schedule and last drill date; cross-reference the Site Emergency Response Plan.*

4.9.18 Legal Liability & Insurance

- *Identify the indemnification regime (operator, government, third parties).*
- *Give policy numbers, underwriter, effective dates, coverage per incident and aggregate.*
- *Mention any surety bonds or escrow for environmental remediation.*
- *Tie back to the Launch Licensing Application or Indemnification Agreement.*

4.9.19 Verification & Monitoring

- *Provide a Responsibility Assignment Matrix (RACI) linking each mitigation/commitment to a project role.*
- *List monitoring KPIs (e.g. "Noise < 75 dB(A) at receptor R2 during daytime").*
- *State deliverables post-flight: End-of-Mission Report, Compliance Certificate, Data-Package uploads.*
- *Reference the Project Verification & Validation Plan (ECSS-E-ST-10-02).*

4.9.20 Conclusions & Recommendations

State clearly whether the campaign is acceptable ***subject to*** *the commitments listed.*

- *Restate that all identified risks are within acceptable limits or list the conditions that must be met before final launch authority.*
- *Numbered commitments (C-01, C-02 . . .) so the regulator can track.*
- *Provide a sign-off line for the accountable manager and, if required, the independent range-safety authority.*

4.9.21 Annexes

List any and all add-on documents; keep the main body 150 pages.

- *Glossary / Acronyms*
- *Permits & licences copies*
- *Stakeholder correspondence and public-notice materials*
- *Pad & trajectory maps, large-format engineering drawings*
- *Independent peer reviews or third-party audits (if performed)*

4.10 Document Requirements and Description – Packaging Plan

Building on system-level processes, we zoom in on packaging, handling, and transport. The Packaging Plan formalizes procedures to ensure hardware integrity during shipment and storage.

Introduction This Document Requirements and Description (DRD) establishes the framework that the Packaging Plan (PKG) must satisfy. It provides a clear, traceable system for future revisions of the PKG as the Spaceshot project progresses into advanced phases [74, 23].

4.10.1 General Requirements

Purpose and Scope

- **REQ-PKG-001** *The Packaging Plan shall define packaging, handling, preservation, marking and stowage procedures for all Spaceshot mission components.* Ensures uniform procedures, avoiding operational risks [74, 23].

Applicable Standards

- **REQ-PKG-002** *The Packaging Plan shall comply with applicable requirements of NPR 6000.1H and MIL-STD-2073-1E.* Guarantees regulatory adherence, minimising non-compliance risk [74, 23].

4.10.2 Packaging and Preservation Requirements

Preservation Methods

- **REQ-PKG-003** *The Packaging Plan shall specify preservation methods based on component sensitivity and environmental exposure in accordance with MIL-STD-2073-1E methods.* Protects hardware from corrosion, moisture and degradation [23].

Preservation of Electronics

- **REQ-PKG-004** *Avionics and electronics shall be packaged using MIL-STD-2073-1E Method 50.* Shields sensitive electronics from moisture-induced failure [23].

Preservation of Mechanical Components

- **REQ-PKG-005** *The Packaging Plan shall specify if Method 20 or 30 is required for mechanical and structural components, depending on corrosion sensitivity and expected exposure.* Maintains structural integrity under varied environments [23].

Desiccant and Moisture Control

- **REQ-PKG-006** *The Packaging Plan shall specify the quantity of desiccant required in each container.* Controls humidity for avionics reliability [23].

4.10.3 Container Selection and Design Requirements

Container Selection

- **REQ-PKG-007** *The Packaging Plan shall define container selection based on item fragility, value and anticipated environmental stress.* Balances protection with cost efficiency [23].

Container Reusability – High-Value Components

- **REQ-PKG-008a** *High-value or sensitive components must use long-life, multi-use containers capable of at least 100 transport cycles.* Reduces life-cycle cost and preserves hardware [23, 74].

Container Reusability – Moderate-Value Components

– **REQ-PKG-008b** *Moderate-value items may use short-life containers suitable for a minimum of 10 transport cycles.* Balances cost with adequate protection [23].

Packaging Validation

– **REQ-PKG-009** *The Packaging Plan shall provide a framework for validating packaging designs through environmental testing.* Confirms container performance under shock and vibration [23].

4.10.4 Marking and Identification Requirements

Critical Items Marking

– **REQ-PKG-010** *The Packaging Plan shall establish the labelling system for all Class I–III items.* Highlights critical hardware for safe handling [74].

General Identification and Tracking

– **REQ-PKG-011** *The Packaging Plan shall label containers with identification, handling instructions, orientation arrows and special requirements.* Facilitates tracking and reduces handling errors [23].

Hazardous Materials Marking

– **REQ-PKG-012** *Packages containing hazardous materials shall be labelled in compliance with all regulations.* Ensures legal and safety compliance [23, 74].

4.10.5 Handling and Transportation Requirements

Handling Procedures

– **REQ-PKG-013** *The Packaging Plan shall define safe handling procedures for fragile components, including lifting, loading and unloading.* Minimises human-factor damage [74, 23].

Monitoring During Transport

– **REQ-PKG-014** *The Packaging Plan shall specify when environmental monitoring devices are required for Class I and II items.* Verifies that transport conditions remain within limits [74, 23].

4.10.6 Documentation and Record-Keeping Requirements

Packaging and Handling Records

– **REQ-PKG-015** *A Packaging, Handling and Transportation record shall be maintained for each Class I item.* Provides traceability and accountability [74].

Compliance Documentation

– **REQ-PKG-016** *Documentation confirming compliance with hazardous-materials regulations shall be retained for each shipment.* Demonstrates regulatory conformity [74, 23].

Container and Packaging Documentation

- **REQ-PKG-017** *Detailed design and test documentation for reusable containers shall be available.* Supports reuse and audit readiness [23, 74].

4.10.7 Quality Assurance and Inspection Requirements

Packaging Inspection

- **REQ-PKG-018** *All packaging and container preparation processes shall undergo prescribed inspections.* Detects faults before shipment [23].

Receiving Inspection

- **REQ-PKG-019** *Receiving personnel shall inspect incoming shipments and report packaging failures.* Enables rapid corrective action [74].

4.10.8 Training and Compliance Requirements

Personnel Training

- **REQ-PKG-020** *Personnel responsible for packaging, handling and transport shall receive appropriate training.* Ensures safe, reliable operations [74, 96].

4.11 Packaging Plan: Template

4.11.1 Introduction

A Packaging Plan defines comprehensive packaging, handling, and transportation methods and procedures for all critical components for a given mission. It ensures reliability, compliance, and the integrity of mission-critical hardware from production to launch.

Describe:

- *Why this document is being written (Purpose)*
- *What aspect of the mission it concerns: which system/sub-system/assembly ? (Scope)*
- *What this document aims to achieve (Goal)*

4.11.2 Definitions

Packing: The action of putting items inside a box or container, generally preparing them for transportation or storage.

Packaging: Materials used to protect items during handling, transport, and storage, such as boxes, crates, bubble wrap, cushioning materials, and containers.

Storage: Keeping items safely in a specific place or facility until they're needed. Storage usually refers to a longer duration and emphasizes protection from damage or environmental conditions.

Stowage: The organized placement and securing of items inside a container or transport vehicle, ensuring they remain safe, stable, and accessible during transport.

Handling: Physically moving, lifting, carrying, or manipulating items or containers during packaging, transport, loading, unloading, and storage operations.

Container: A strong, reusable box or case designed to protect items during transport and handling. Containers vary in size, type, and durability based on what's being shipped.

Labeling: Marking a container or item with essential information such as contents, handling instructions, warnings, or tracking details.

Hazardous Materials: Items or substances that pose a risk to health, safety, property, or the environment during handling or transport. Special rules apply to their packaging, labeling, and shipping.

Preservation: Measures and techniques applied to protect items from environmental factors such as moisture, corrosion, dust, temperature changes, or damage during storage and transportation, ensuring they remain in good condition until use.

4.11.3 Reference Documents

Give the links to all of the documents which can give additional context to this document this includes: relevant standards, project requirements, system defintion, design definition files etc.

4.11.3.1 Reference Standards

- MIL-STD-2073-1E [23]
- NPR 6000-1H [74]

4.11.3.2 Used Templates

- Shipment Inspection Form Template. See section 8.4.
- Design Definition File Template
- Hazardous Items Compliance File. See section 4.13.
- Packaging Handling Record Templates. See section 8.6.
- Handling Procedures Template. See section 4.14.
- Package Label Template. See section 8.5.
- Item Label Template. See section 8.7.
- Hazardous Item Label Template. See section 8.3.
- Personnel Training Tracking Matrix Template. See section 23.
- Personnel Training Procedure Template. See section 4.12.

4.11.4 Packaging and Preservation

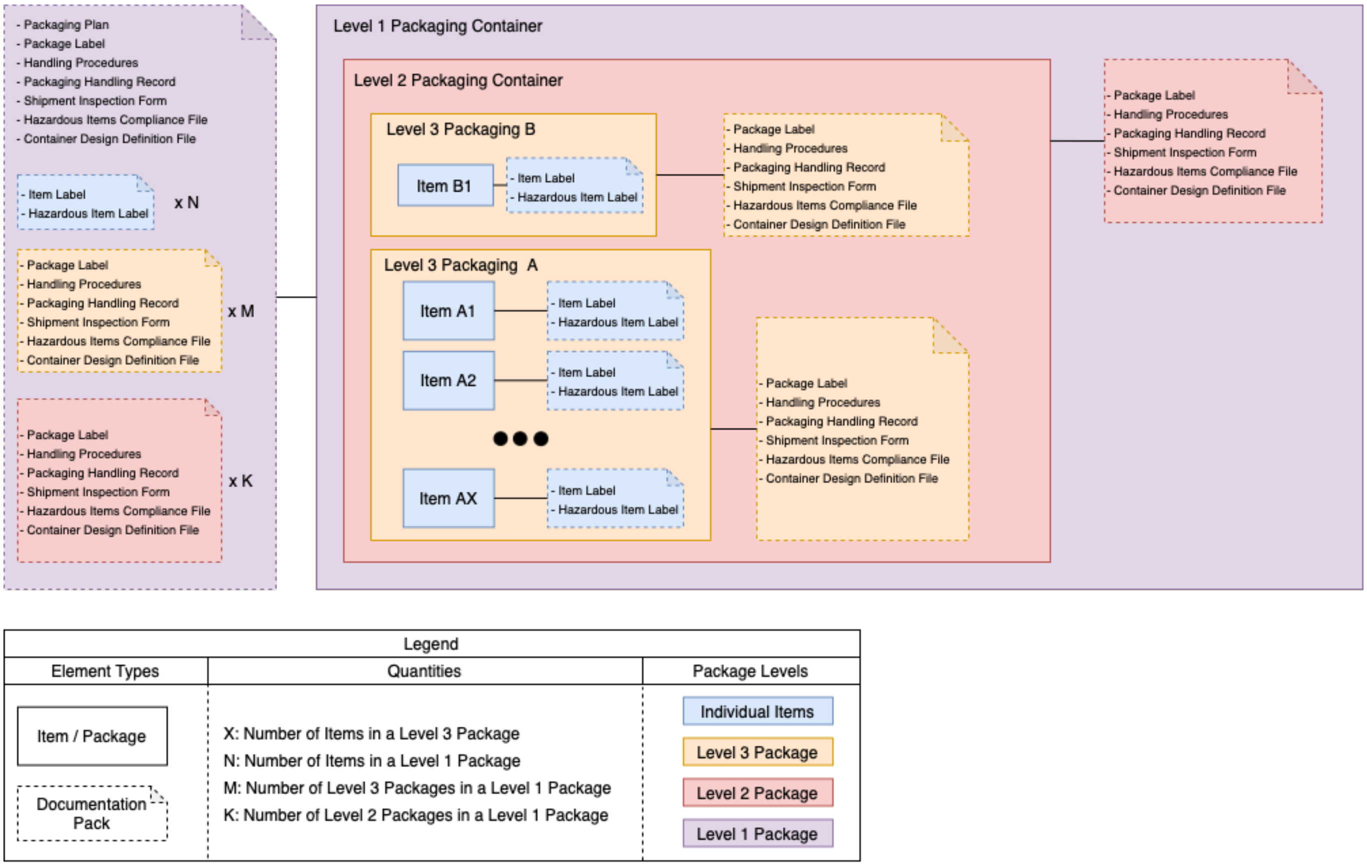

Figure 14: Packaging hierarchy Diagram

4.11.4.1 Packaging Hierarchy Levels

- **Level 1:** Most outwards container. Typically a maritime shipping container or large crate.
- **Level 2:** Intermediate level packaging. Designates the containers that are directly in contact with the level 1 containers.
- **Level 3:** Lowest Level of packaging container, are contained within two containers. Typically used as a form of item organisers.
- **Individual Items:** Designates all individual items packaged within a container. This includes assemblies/sub-assemblies of mechanical/electronics parts.

Use MIL-STD-2073-1E methods, tailored specifically to component sensitivity, including corrosion and moisture protection. Explain the reasoning behind chosing a specific method. Show calculations and tradeoffs if required.

The minimum quantity of desiccant to be used per unit pack shall be computed in accordance with either Formula I or II as applicable. The various values of "X" take into consideration the quality and types of dunnage. The inner container (when applicable) shall be considered in the dunnage calculations.

Preservation Methods

- Method 10 Physical protection
- Method 20 Preservative coating only
- Method 30 Waterproof protection
- Method 40 Watervaporproof protection
- Method 50 Watervaporproof protection with desiccant

Desiccant Formula (Adapted from MIL-STD-2073-1E)

$$U = CA + X_1D + X_2D + X_3D + X_4D$$

$$U = KV + X_1D + X_2D + X_3D + X_4D$$

Symbols used above are defined as follows:

U	The number of units of desiccant to be used.
C	17
A	Area of container (barrier) stated in square meters.
K	43
V	Volume within rigid metal container cubic meters.
X_1	17.6 for cellulosic material, including wood and any other material not noted below.
X_2	7.9 for bound fibers (synthetic or vegetable fibers bound with rubber).
X_3	4.4 for glass fibers (fiberglass).
X_4	1.1 for synthetic foams and rubber.
D	Kilograms of dunnage within the container.

4.11.4.2 Item List

Component ID	Component Description	Preservation Method	Justification	Desiccant Number (Method 50 only)
PP-SS-####	*Example Item*	*10*	*No particular packaging constraints*	*N/A*

4.11.5 Container Selection and Design

4.11.5.1 Container Selection

Select containers based on fragility, component value, and environmental stress according to the requirements in the next tab and explain the reasoning here.

Container Reusability

State which component qualify as high-value and which qualify as moderate-value. Based on this separation, define which components require the strongest containers.

Reusable container: A shipping and storage container that can be reused without impairment of its protective function and that can be repaired or retrofitted to prolong its life or modified to adapt it for shipment of items other than that for which it was originally intended.

- **Long life container (100 trips minimum)**: A shipping container that can be used repeatedly, and whose service life can be expected to equal the service life of the item it is designed to protect. These containers may be refurbished by appropriate maintenance practices to their original condition and subsequently reused.
- **Short life container (10 trips minimum):** A shipping container that can be reused for a limited number of times. The container is usually made of wood, plywood, fiberboard or similar material that has a limited life.
- **Multiapplication containers:** Multiapplication containers are designed to protect a variety of components within a given fragility and size range. They can be manufactured in a similar manner to that used for specialized containers. A multiapplication container can be either of the short-life or long-life variety. Long-life multiapplication reusable containers are made of rugged plastic construction containing internal cushioning pads or permanent shock mitigation systems (for example, shear mounts, steel coils, and springs) and are designed to protect repairable components packaged therein.
- **Specialized container:** Specialized containers are generally the long-life variety and are uniquely configured to support and protect a specific item, during handling and storage or to protect personnel and equipment from hazardous contents. Containers of this type frequently incorporate energy absorbing systems, temperature control systems or special features to make handling or shipment possible, easier or safer. Engineering drawings, or equivalent, are used to define form, fit, function, materials, tolerances and manufacturing techniques. Internal fixtures and other fitments within specialized shipping containers result from either original design efforts or the redesign or modification of an existing container to meet a specific application or need.

Packaging Validation

Establish which environmental tests (shock, vibration, humidity) are needed to validate packaging adequacy.

Container List

Component ID	Component Description	Component Value	Packaging Reusability	Container Type	Container Design Definition File *(Custom Only)*	Container Test Report

PP-SS-####	*Example Item*	*High*	*Yes: Long-Life Container*	*Custom*	Container Design Definition File Link	Container Test Report Link

4.11.5.2 Container Choice and Design Requirements

General Requirements

GEN-001 *All items shall be free of dirt and other contaminants that could cause deterioration.*
Ensures no additional cleaning by the customer and prevents premature degradation.
`D3951-18(2023), Section 5.1.1.1`

GEN-002 *Items susceptible to corrosion or deterioration shall be protected with preservatives or barrier methods.*
Minimizes damage risk from moisture or chemical exposure.
`D3951-18(2023), Section 5.1.1.2`

GEN-003 *Items requiring protection from physical damage or that are fragile shall be cushioned, wrapped, or otherwise protected to mitigate shock and vibration.*
Ensures safe delivery by reducing handling damage.
`D3951-18(2023), Section 5.1.1.3`

Unit and Intermediate Packaging

UIP-001 *Each unit package shall adequately contain and protect its contents for at least one year in enclosed storage.*
Facilitates secure handling and ensures item serviceability.
`D3951-18(2023), Section 4.1 & 5.1.2.1`

UIP-002 *Unless otherwise specified, the unit pack quantity shall be one each per package (except small, lightweight items).*
Standardizes presentation and handling; prevents damage from overpacking.
`D3951-18(2023), Section 5.1.2.2`

Shipping Containers

SC-001 *Shipping containers shall be capable of safe delivery and withstanding multiple handling events.*
Ensures containers protect goods through varying transport modes.
`D3951-18(2023), Section 5.1.4.2`

SC-002 *Containers shall allow for a minimum of one-year storage under enclosed conditions without degrading item quality.*
Guarantees adequate shelf-life and usability of contents.
`D3951-18(2023), Section 5.1.4.2`

COTS Container Selection

COTS-001 *Only containers tested under comparable shock, vibration, and climate extremes shall be deemed suitable for usage.*
Ensures containers proven to perform in harsh transport environments are used.
`Derived from MIL-STD-2073-1E (Preservation & Packing), ASTM D4169 (Test Methods)`

COTS-002 *All COTS containers, if fiberboard, shall be weather-resistant grades to allow up to one year's enclosed storage without degradation.*
Prevents deterioration of packaging material in long-term storage.
`Derived from ASTM D3951 (Section 5.1.4.2)`

COTS-003 *Suppliers shall provide traceable documentation of compliance with ISPM 15 for any wood-based COTS container solutions.*
Ensures adherence to phytosanitary regulations in domestic and international shipments.
`Derived from D3951 (Section 5.1.6.4)`

Custom Container Design

CCD-001 *Designers shall identify fragility factors, dimensional limits, and environmental constraints of the item before developing container form, fit, and function.*
Tailors protective features to the actual shock and climate sensitivities of the product.
`Derived from MIL-STD-2073-1E (Preservation Sections)`

CCD-002 *Design documents shall reference the relevant wood, fiberboard, or plastic container specifications to ensure correct materials and construction.*
Guarantees that containers are built to recognized performance standards.
`Derived from ASTM D3951, Table 1`

Custom Container Testing & Validation

CCTV-001 *All newly developed or modified container designs shall undergo dedicated testing to ensure that their design requirements are met.*
Establishes baseline performance against drops, vibration, and compression hazards.
`Derived from ASTM D3951, Section 7 & D4169`

CCTV-002 *Humidity and water-vapor transmission evaluations shall be performed for sealed or barrier-type containers to confirm conformance to MIL-STD-2073-1E moisture protection.*
Ensures watervaporproof or waterproof performance under known storage conditions.
`Derived from MIL-STD-2073-1E (Desiccant & Barrier Methods)`

CCTV-003 *The results of validation testing (including pass/fail criteria and any container rework) shall be documented for technical acceptance and future repeat usage.*
Creates a verifiable record of container compliance and aids in reusability.
`Recommended best practice based on MIL-STD-2073-1E & ASTM D3951`

4.11.6 Marking and Identification

4.11.6.1 Items Marking

Identify which items need labeling (according to item class in [74]. Provide the link to labels below.

- Class I: Mission-essential items that, in the event of loss, damage, or delay in shipment, would adversely affect the program or project.
- Class II: Delicate or sensitive items not covered by Class I or Class III. These items are those that may be damaged readily by improper handling.
- Class III: Items requiring special handling and monitoring.
- Class IV: Those items that may be transported or handled through the use of normal commercial transportation means.

4.11.6.2 Hazardous Materials Marking

Define labeling procedures compliant with regulatory requirements for transporting hazardous materials. Include a label for hazardous materials below.

Item Labels List

Component ID	Component Description	Item Class	Hazardous	Label Link	Hazardous Item Label Link
PP-SS-####	*Example Item*	*III*	*Yes*	*Label Link*	*Label Link*

4.11.7 Handling and Transportation

4.11.7.1 Handling Procedures

Define detailed guidelines for safe handling, manual lifting, and transportation, minimizing risks of damage. Link all the procedures in the table below.

4.11.7.2 Environmental Monitoring

Define which containers require environmental monitoring and why. Define which metrics need to be monitored out of the 4 possible:

- *shock*
- *vibration*
- *temperature*
- *humidity*

Indicate which metric is monitored in the table below.

Component ID	Component Description	Item Class	Hazardous	Handling Procedures Link	Monitored Item *(if Yes, include monitoring metrics)*

PP-SS-####	*Example Item*	*III*	*No*	Handling Procedures Link	*Shock, Temperature*

4.11.8 Documentation and Record-Keeping

4.11.8.1 Packaging and Handling Records

Define the objective of the packaging, handling, and transportation Records to ensure traceability and accountability. Provide the link of the record-keeping document. See section 8.6 for relevant template.

4.11.8.2 Hazardous Materials Compliance Documentation

Define the objective of the documentation for regulatory compliance regarding hazardous materials handling and packaging. Provide the link to the compliance document. See section 8.3 for relevant template.

4.11.9 Quality Assurance and Inspection

Packaging Inspection

List the inspections to be performed before shipping packages to document condition and detect damages. Once carried out, give the link to the completed inspection form(s) below. See section 8.4 for relevant template.

4.11.9.1 Receiving Inspection

List the inspections to be performed upon receiving packages to document condition and detect damages. Once carried out, give the link to the completed inspection form(s) below. See section 8.4 for relevant template.

4.11.10 Training

4.11.10.1 Personnel Training

List and specify the necessary training and certifications to be administered to the personnel responsible for packaging, handling, and transportation (especially related to hazardous materials). See section 4.12 for relevant template(s).

4.11.11 Annexes

Include supporting project files, checklists, examples, and relevant documentation.

4.12 Personnel Training Procedure Template

Safe and compliant packaging requires properly trained personnel. The next template outlines the certification and instructional protocols required for those handling critical or hazardous materials.

Training Title:
Date: **Duration:** **Location:**

4.12.1 Trainer(s) Information

Name	Title / Position	Organization	Contact (Email/Phone)
Name	*Team Leader*	*ERT*	*john.doe@epfl.ch*

4.12.2 Training Objectives

Describe in Details what the aim of the training is and what are the objectives. Try to exaplin how this training fits withng the borader team's missions.

- Objective 1:
- Objective 2:
- Objective 3:

4.12.3 Scope and Content

Detail the topics that were covered during the training. Explain how those topics relate to the training objectives.

Topics Covered:

- Item 1
- Item 2

List the most relevant skills that were practiced during the training, they can be very general, like public speaking and team work but also very subject-specific like first aid response.

Skills/Knowledge Gained:

- Skill 1
- Skill 2

Standards and Regulations Referenced:

Reference the standards used to create the training. If the training was conducted in partnership with an external entity, you can also reference that here.

- Standard 1
- Standard 2

4.12.4 Training Materials Used

Reference the material used in the training.

- Slides/Presentations:
- Manuals/Handbooks:
- Videos/Interactive Material:

4.12.5 Assessment Method

(check applicable method)

- [ ] Written Test
- [ ] Practical Demonstration
- [ ] Verbal Assessment
- [ ] Attendance Only

4.12.6 Certification Provided

- Certificate Issued *(Y/N)*:
- Certification Authority:
- Certificate Link:

4.12.7 Trainer's Approval

- **Trainer's Name:**
- **Training Date(s):**

4.12.8 Additional Notes/Remarks

4.13 Hazardous Material Compliance Documentation

- **Item ID:**
- **Date Issued:**
- **Version:**

4.13.1 General Information

Item	Details
Material Name	
Technical Name (if any)	
UN Number	
CAS Number (if any)	
Hazard Class / Division	
Packing class	
Physical State	

4.13.2 Classification and Regulatory Compliance

Check and verify compliance with applicable regulations:

Regulation / Standard	Applicable *(Y/N)*	Compliance Verified *(Date & Initial)*
ADR (Road Transport Europe)		
RID (Rail Transport Europe)		
ADN (Inland Waterways)		
IMDG Code (Maritime Transport)		
IATA Dangerous Goods Regulations (Air Transport)		
49 CFR Subtitle B (US DOT)		
ICAO Technical Instructions (Air Transport)		

4.13.3 Packaging and Marking Compliance

Item	Status / Details
Approved Packaging Used *(Y/N)*	
Packaging Approval Reference *(ID)*	

Item	Status / Details
Packaging Type *(Link)*	
Tested & Certified (UN Specification Marking) *(Y/N)*	
Proper Labeling & Marking Completed *(Y/N)*	
Hazard Labels Applied *(Y/N)*	
Proper Shipping Name Clearly Displayed *(Y/N)*	
Orientation Arrows (if applicable) *(Y/N)*	
Transport Documents Completed *(Y/N)*	

4.13.4 Safety & Handling Instructions

Hazard Type	Present *(Y/N)*	Recommended Precautions & PPE *(if applicable link detailed file)*
Explosive		
Flammable		
Corrosive		
Toxic		
Oxidizing		
Environmentally Hazardous		
Radioactive		
Reactive		

4.13.5 Emergency Procedures & Contacts

4.13.5.1 Emergency Response Information

- **Spill / Leak Response Procedures:**
- **Firefighting Procedures:**
- **First Aid Measures:**

4.13.5.2 24-hour Emergency Contact

Item	Details
Name	
Phone Number	
Email	

4.13.6 Transportation Route & Jurisdictions Crossed

Country / Jurisdiction	Compliance Checked *(Y/N)*	Approval Obtained *(Authority/Date)*	Notes / Restrictions
Switzerland			
Germany			
France			
Portugal			
Sweden			
Other (specify):			

4.13.7 Training & Competence Declaration

Personnel involved have received hazardous materials training:

Personnel Name	Role / Responsibility	Training Received (Date & Certification Ref.)

4.13.8 Certification & Signatures

I hereby certify that the above information is complete, accurate, and compliant with all applicable hazardous materials transportation regulations.

Role	Name	Signature	Date
Prepared by			
Team Lead / Systems Engineer			

4.14 Handling Procedures Template

Training alone is insufficient without clear operational guidance. The following handling procedures template ensure that all movement and manipulation of components is done with precision and safety.

Procedure ID:
Item/Container ID:
Revision:
Date Issued:
Prepared by:
Approved by:

4.14.1 Item/Container Description

- **Item(s) Description:**

Describe the items/packages covered by this document and why this document exists for those items.

- Container Design Definition File
- **Container Type** *(Long-life reusable, Short-life reusable, Single-use)*:
- **Fragility/Sensitivity:**

  List the relevant elements from the following possibilities:

- *Fragile*
- *Shock/Vibration Sensitive*
- *Temperature Sensitive*
- *Humidity Sensitive*
- *ESD Sensitive*
- **Hazardous Material** *(Y/N)*:
  – If yes, specify:

4.14.2 General Handling Precautions

Precaution Type	Applicable *(Y/N)*	Specific Instructions
Lifting		
Orientation		
Temperature Control		
Humidity Control		
ESD Protection		
Other (specify):		

4.14.3 Step-by-Step Handling Instructions

Step #	Description of Action	Responsible Personnel	Notes/Cautions
1			
2			
3			
4			
5			

(Add/remove rows as needed)

4.14.4 Emergency Procedures

- **In case of accidental drop or damage:**

  Describe in simple efficient terms, as bullet points, what are the steps to take in order to contain a potential item/package damage.

- **In case of hazardous material leak/spill:**

  Describe in simple efficient terms, as bullet points, what are the steps to take in order to contain a potential item/package damage.

- **Emergency Contact:**
  - Name:
  - Phone:
  - Email:

4.14.5 Documentation & Records

Relevant Documentation Required:
- Shipment Inspection Form
- Packaging Handling Record
- Hazardous Items Compliance File (if applicable)
- Container Design Definition File

4.14.6 Additional Notes & Remarks

4.14.6.1 Approval Signatures

Prepared by:	Date:
Approved by (Team Lead):	Date:

4.15 Compliance Framework Assessment and Rating

Beyond logistics and operations, regulatory adherence is central to mission readiness. This compliance framework allows for KPI tracking and checklist-based oversight before launch approval.

Header

- Version: ____________________
- Created: ____________________
- For mission: ____________________

4.15.0.1 Purpose

Give the team a one-page, low-friction way to prove we are compliant before pulling the launch pin. Ten KPIs + one checklist, nothing else to babysit.

4.15.1 Ownership

This Document is owned, tracked and maintained by the Chief Compliance Officer (CCO). See Section 8.9 for the role description.

4.15.2 How to Use This File

1. **Clone & rename** the file for your mission.
2. At **CDR** create the KPI table & checklist entries (leave values blank).
3. At **TRR** update values; flag amber/red early.
4. At **FRR** freeze the sheet → present the LRCI number; all checklist boxes must be ticked or a waiver recorded.
5. **After launch** add lessons-learned, bump version, archive.

4.15.3 Campaign Data

Field	Value
Launch site / window	
Target apogee	
Chief Compliance Officer	
Document owner	

4.15.4 KPI Dashboard/Compliance Matrix

The KPIs shall be assessed periodically on a predetermined basis to allow for consistent tracking. The individual in charge of tracking compliance is the Chief Compliance Officer (CCO). Due to the potential extensiveness of the task, individual KPI assessment should be spread across the full year. The time frame of each tracking task (evaluating the KPI and updating the database) shall be determined on a case-by-case basis at the moment where it is sensical.

#	Domain	KPI	Target	Value	Status
D1-1	Launch & Licensing	Licence lead-time (days)	14		
D1-2	Launch & Licensing	Licence accepted first pass? (Y/N)	Y		
D2-1	Export Control	Export-controlled items cleared (%)	100 %		
D2-2	Export Control	Export incidents	0		
D3-1	Standards & QA	Mandatory verifs closed by FRR (%)	100 %		
D3-2	Standards & QA	Major NCRs still open @ FRR	0		
D4-1	Environment	Environmental incidents	0		
D4-2	Environment	Waste-disposal log completed? (Y/N)	Y		
D5-1	Safety/Security	Recordable safety incidents	0		
D5-2	Safety/Security	Emergency drills completed? (Y/N)	Y		

Traffic-light Key

- = meets target (green)
- = within 20% or 1 minor deviation (orange)
- = outside amber band / “No” where “Yes” required (red)

4.15.5 Launch-Readiness Compliance Index (LRCI)

Manual calculation:

- Green = 1 pt
- Orange = 0.5 pt
- Red = 0 pt

$$\text{LRCI} = \left(\frac{\sum \text{Points}}{10}\right) \times 100$$

KPI colour count	Points	Example
Green	1	71
Amber	0.5	20.5
Red	0	10
Total points	$\sum Points/10$	0.75
LRCI (%)	Total × 100	75%

Interpretation

- 80% = Go
- 60–79% = Board discussion
- < 60% = No-go

4.15.6 Compliance-Item Checklist

- ***CI-001*** *FAA/CAA licence or waiver granted – pdf stored*
- ***CI-002*** *ITAR DSP-5 for GN&C board*
- ***CI-003*** *ECSS-E-ST-31-02 structural margins verified*
- ***CI-004*** *Spill-response kit staged at pad*
- ***CI-005*** *Emergency drill report signed and filed*

Add “(Waived – ref X)” if formally waived.

4.15.7 Roles & Contacts

Role	Name	Backup
Chief Compliance Officer		
Launch & Licensing		
Export Control		
QA lead		
Chief Safety Officer		

4.15.8 Lessons-Learned (post-launch)

Date	Observation	Follow-up

4.16 Incoterms Overview

To manage contractual and financial risk in procurement and freight, a concise overview of Incoterms® was developed. This ensures all stakeholders share a common understanding of liability and obligations.

4.16.1 Introduction

Incoterms® (International Commercial Terms) are a set of standardized rules published by the International Chamber of Commerce (ICC) to define the respective obligations, costs and risks borne by sellers and buyers in the delivery of goods under sales contracts [31]. First introduced in 1936 and most recently updated in 2020, these three-letter terms (e.g., EXW, FOB, CIF, DDP) are universally recognized and help avoid misunderstandings in domestic and international trade by clearly allocating who does what, and when the risk of loss or damage passes from seller to buyer [97].

4.16.2 Why Use Incoterms?

- **Clarity of obligations:** Specify exactly who arranges transport, handles export/import formalities, buys insurance, and pays freight.
- **Uniform interpretation:** Avoid divergent local customs or legal interpretations by referring to a globally accepted standard.
- **Risk management:** Pinpoint the exact moment and place where risk transfers from seller to buyer, which is crucial for insurance and liability.

4.16.3 Key Elements of Each Incoterm

1. **Delivery point** — Where the seller must make goods available.
2. **Transfer of risk** — The moment goods shift from seller's to buyer's responsibility (e.g., at seller's premises, on board a vessel, at the buyer's door).
3. **Cost allocation** — Which party pays for transport, insurance, load/unload, duties and taxes.
4. **Customs and formalities** — Who handles export clearance, import duties and documentation.

4.16.4 Incoterms List

Incoterm	Full Name	Category	Mode	Risk Transfers	Carriage	Customs	Insurance	Typical Use-cases
EXW	Ex Works	E-term	Any	Seller's premises	Buyer	Buyer	None	Prototype hand-offs, domestic pick-ups
FCA	Free Carrier	F-term	Any	To carrier / named place	Buyer	Either	None	Container exports by truck/rail
FAS	Free Alongside Ship	F-term	Sea	Quay at load port	Buyer	Either	None	Bulk commodities
FOB	Free On Board	F-term	Sea	On board at port	Buyer	Either	None	Break-bulk, traditional liner trades
CFR	Cost & Freight	C-term	Sea	On board at port	Seller	Either	None	Seller pays sea freight
CIF	Cost, Insurance & Freight	C-term	Sea	On board at port	Seller	Either	Seller (ICC C)	Buyer demands insurance
CPT	Carriage Paid To	C-term	Any	To first carrier	Seller	Either	None	Air-freight, multimodal parcels
CIP	Carriage & Insurance Paid	C-term	Any	To first carrier	Seller	Either	Seller (ICC A, 110%)	High-value electronics
DAP	Delivered At Place	D-term	Any	Destination (ready to unload)	Seller	Either	None	e-commerce, regional hubs
DPU	Delivered Place Unloaded	D-term	Any	Destination (unloaded)	Seller	Either	None	Project cargo
DDP	Delivered Duty Paid	D-term	Any	Destination (customs cleared)	Seller	Seller	Optional	Turn-key shipments

Categories:

- E-term = Seller's minimum obligation
- F-terms = Main carriage unpaid
- C-terms = Main carriage paid by seller, risk transfers earlier
- D-terms = Arrival terms, seller bears most obligations

† **DPU** (Delivered at Place Unloaded) replaced DAT (Delivered at Terminal) in the 2020 revision.

4.16.5 Key Observations & Selection Pointers

1. **Risk vs. Cost split** – Under C-terms the seller pays freight yet the buyer bears risk once goods are handed to the first carrier (CPT/CIP) or cross the ship's rail (CFR/CIF). Under D-terms seller keeps both risk and cost until arrival.
2. **Insurance** – Only CIF and CIP make insurance compulsory. CIF requires the minimum Institute Cargo Clauses (C), while CIP now mandates the broader ICC (A) cover ("all risks") for 110% of the contract value.
3. **Mode sensitivity** – FAS, FOB, CFR and CIF are for sea / inland-waterway freight only. Mixing them with containerised multimodal chains is discouraged; use FCA, CPT or CIP instead.
4. **Customs pinch-points** – EXW often complicates export procedures because the foreign buyer may lack a tax ID in the seller's country. Conversely, DDP burdens the seller with destination customs, VAT and local compliance.
5. **Deciding when** – The Incoterm should be locked before the purchase-order is signed (ideally in the RFQ stage), since it shapes price, liability, documentary wording and transport planning.
6. **Document drafting** – Always cite the term plus the named place and "Incoterms® 2020" in the contract (e.g., "FOB Hamburg Incoterms® 2020").
7. **Legacy terms** – Incoterms 2000/2010 terms such as DAT, DAF or DES are no longer recommended for new contracts, but remain valid if explicitly referenced in older agreements.

4.17 Logistics Management Plan

4.17.1 Introduction

This Logistics Management Plan is designed to give a clear blueprint for transporting hardware, organizing ground resources, and adhering to compliance regulations—all in a student-driven yet professional manner. It lays the groundwork for systemic, repeatable, and scalable logistics operations, ensuring each launch campaign proceeds with minimal risk, optimal cost, and maximum reliability.

4.17.1.1 Scope

Operational Coverage

*Detail below what your plan will cover. Bullet points below apply to **ANY** LMP but you need to be more specific depending on your spaceport choice, your particular constraints, the vehicle you are bringing and other specific aspects.*

- **From Lausanne to Launch Site and Back**
  Encompasses the entire logistics chain from the team's home base (EPFL) to potentially remote launch locations, and return transport post-launch.
- **Multimodal Transport:** Road, rail, sea, and air cargo.
- **On-Site Ground Operations:** Covers in-field camp setup, consumables resupply, equipment handling, and any local logistical support.
- **Full Lifecycle of Activities:** Planning, preparation, execution, on-site sustainment, and final tear-down/return.

Applicability

Detail below to what this document applies. Is it for a single launch? A multi-day launch campaign? Who is the target of the this document, who is the author and who is the reader? The bullet points below apply to ***ANY*** *logistics management plan but you ought to be more specific for the particular use case.*

- **All Launch Campaigns** (suborbital, orbital, test flights) and related engineering campaigns requiring remote logistics.
- **Entire EPFL Rocket Team** – from leadership to individual sub-teams handling hardware and test equipment.

Exclusions

Does **not** cover detailed flight operations (e.g., countdown procedures, payload integration) – focuses specifically on *material* and *personnel* movement and ground support.
Does **not** replace safety or technical design standards, although it references them to ensure alignment.

If some other aspects are not covered by your logistics management plan, make sure to include them in the section above.

4.17.2 Purpose

Detail below to what this document's purpose is. Similarly, the bullet points below apply to ***ANY*** *logistics management plan but you ought to be more specific for your particular use case.*

Establish a Unified Framework: Provide a single, authoritative reference for how the EPFL Rocket Team plans, executes, and monitors logistics—ensuring consistent, repeatable processes.
Streamline Coordination: Create clear lines of responsibility and communication among different sub-teams (engineering, operations, administration) and external stakeholders (carriers, spaceport authorities).
Mitigate Risks and Delays: Outline contingency measures (alternate routes, tracking tools, backup suppliers) to handle transport or customs disruptions, thereby protecting launch timelines.
Facilitate Training and Knowledge Transfer: Serve as an onboarding and reference document for new members—capturing best practices, checklists, and lessons learned for ongoing improvement.

4.17.3 Goals

Below are some general goals for this plan and good practices. If you have some other ambitions or you want to be more constraining, feel free to elaborate. The more precise you are the better for your reader.

1. **Reliable, On-Time Delivery**
   - Achieve $\pm$1–2 day certainty for critical shipments, enabling smooth integration into the rocket development and launch schedule.
   - Minimize last-minute air freight or emergency shipments through early planning.

2. **Cost Efficiency Without Compromising Quality**
    - Balance professional logistics services with in-house student operations to keep expenditures low while preserving reliability and learning opportunities.
    - Negotiate advantageous terms with freight forwarders or potential sponsors.
3. **Robust Ground Operations**
    - Guarantee that essential consumables (food, water, fuel) and base-camp equipment are consistently available on site—supporting the team during multi-day or multi-week campaigns.
4. **Clear Roles, Responsibilities, and Processes**
    - Define each logistics function (e.g., Logistics Lead, Chief Compliance Officer) and corresponding documentation procedures to prevent confusion and reduce error.
5. **Standardization and Scalability**
    - Adopt recognized standards to foster professional rigor and ensure processes remain effective as the team grows toward full orbital launches.
6. **Continuous Improvement**
    - Establish a cycle of post-mission reviews, corrective actions, and updated procedures to refine logistics across future campaigns.
    - Document lessons learned in a way that future cohorts can easily adopt and adapt.

Disclaimer
The Logistics Management Plan is a *living document*, updated regularly to reflect new insights, changing regulations, or the addition of new launch sites.

4.17.4 Complementary Documents

- **Packaging Plan Template** See section 4.11 — This document is meant to work in tandem with the packaging plan.
- **Incoterms Guide** See section 4.16 — Incoterms are standard system for establishing billing, risk transfer and delivery extent in supply chain. Understanding Incoterms helps understand the challenges of our own logistics.

4.17.5 Roles and Responsibilities

4.17.5.1 Role Sheets and Work Packages

Launch Logistics Lead (LLL) Manages the transportation and logistic processes for the full project. Interfaces with the Chief Compliance Officer. Supervises the work of the Transport Coordination Officer and the Transport Packaging Lead.
See Section: 8.10

Chief Compliance Officer (CCO) Ensures the Compliance Documentation is up-to-date. Tracks compliance-related KPIs and performs regular audits to guarantee standards are met.
See Section: 8.9

Transport Coordination Officer (TCO) Coordinates the transport operations. Interfaces with shipping companies and tracks logistic operations.
See Role Sheet: 8.11

Transport Packaging Lead (TPL) Interfaces with the different entities owning the packaging process. Is responsible of the whole project packaging processes.
See Section: 8.12

Training Manager (TMA) Handles Training planning, need analysis and programming during the mission. Interfaces with training-related external entities.
See Section: 8.12

4.17.5.2 Responsibility Assignment Matrix

As the deliverables evolve and the logistics management plan is put in action, the following Responsibility assignment matrix (RAM) should be kept updated. The screenshot below should also be kept up to date in order to provide all the information within this document.

- **Responsible:** Those who complete the task.
- **Accountable:** The one ultimately answerable for correct and thorough completion of the deliverable or task.
- **Consulted:** Those whose opinions are sought, typically subject-matter experts.
- **Informed:** Those who are kept up-to-date on progress, usually with one-way communication.

	Engineering Team			Logistics and Packing Team					Management Team							External Stakeholders		
	Systems Engineers	Team Leaders	Engineering Team Members	Head of Logistics	Launch Logistics Lead	Transport Coordination Officer	Transport Packaging Lead	Logistics Team Members	ERT President	ERT Vice-President	ERT Comitee	Head of Sponsoring	Chief Compliance Officer	Chief Financial Officer	Chief Safety Officer	Commercial Stakeholders	Academic Stakeholders	Regulatory Bodies
Packaging Plan																		
Subsytem-Level Document Ownership	A	R	R	I	C	C	C	I	I	I	I	I	C	I	I	C	I	C
Project-wide Document Ownership	R	R	C	I	C	C	A	I	I	I	I	I	C	I	I	C	I	C
Logistics Management Plan																		
Document Ownership	C	C	C	I	A	R	R	I	I	I	I	C	C	C	C	C	I	C
Compliance Framework Assessement and Rating																		
Document Ownership	C	C	I	C	R	R	R	C	C	I	I	I	A	I	I	C	I	C

Figure 15: Responsibility Assignment Matrix

An editable version exists on the EPFL Rocket Team Google Drive.

4.17.6 Transportation Strategy

The goal of this next section is to guide the decision-process for launch logistics. While the previous sections have attributed responsibilities and established a clear purpose for this document, the bulk of the work is yet to be done, notably: choosing transport modes, container choices and constraints, electing potential freight forwarders and establishing a clear work breakdown between professional contractors and in-house teams.

4.17.6.1 Decision Framework

The objective is to provide a comprehensive, data-driven and systemic decision framework. This system will be based on a very common weighted-sum trade-off matrix. The following template allows for decision record-keeping. A properly documented, consistent approach ensures that every strategic-level decision is not only understandable but also fits within the general team guidelines. See Section 4.18

4.17.6.2 Decision-Needing Items

Include in the table below all the trade-off analyses you performed in determining the logistics and transport strategy for the project. Include high-level as well as low-level trade-offs.

Item Name	Description	Options (non-exhaustive)	Link to Trade-Off Analysis
Segment-wide transport modes	Choosing the right transport mode on a given segment is dependent on a myriad of factors and should be assessed.	Internal waterways, Road, Maritime, Air	LINK
Shipping container bounds	Deciding whether limiting the largest allowable external package at 20 or 40 feet containers is relevant.	20 ft, 40 ft ISO Containers	LINK
Choice of Freight Forwarder	Choosing the right logistical partner is paramount.	DHL, UPS, FedEx	LINK
...			

4.17.7 Shipping Documentation

4.17.7.1 Labels, Marking and Responsibility

The relevant internal shipping labels and marking sheets are available in the packaging plan and will hence not be explored here. However, external documentation should nonetheless be researched and filled out in accordance with regulatory constraints. This shall be done by the Launch Logistics Team in consort with the Chief Compliance Officer.

4.17.7.2 Logistics Documentation

The Packaging Plan serves as the master document for the shipping documentation which should all be referenced within. A LMP is established per launch campaign or mission as relevant. While the packaging aspects are not directly referenced within this document, establishing one without building the other is a non-sense and both should be tackled relatively in parallel.

4.17.8 Schedule and Milestones Management

Now that the roles and responsibilities have been attributed and that a clear strategy has been defined, most of the planning can happen. The planning process itself can be decomposed in phases similarly to what is done for technical developments.

4.17.8.1 Logistics Timeline: Phases

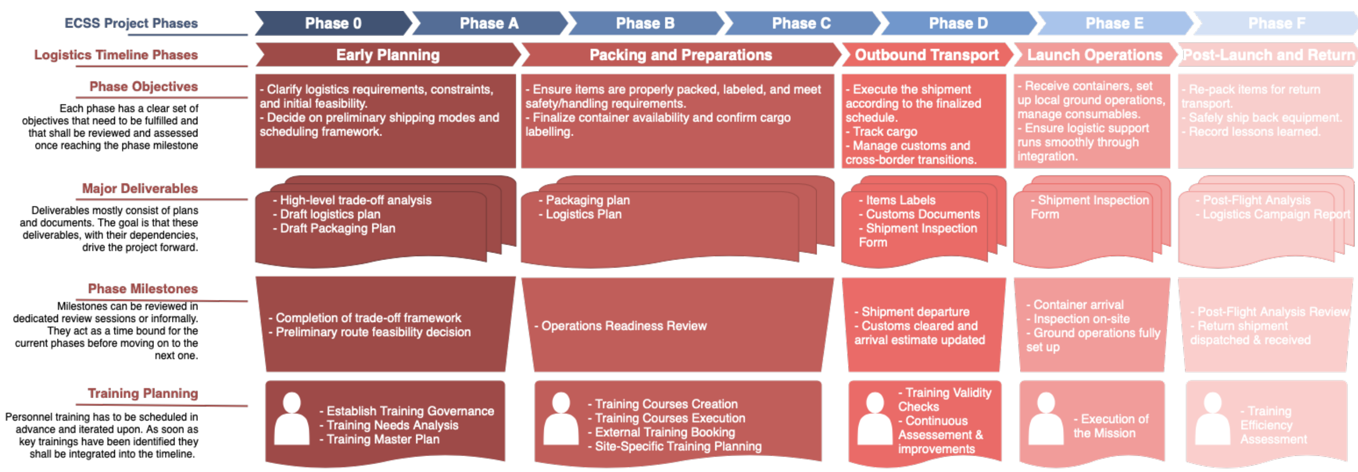

Figure 16: Launch Logistics Timeline

1. Early Planning

Goal: During this initial phase, the team defines high-level logistics requirements and constraints, explores preliminary shipping modes, and drafts essential methodologies (e.g., weighted-sum criteria, initial risk assessment). The objective is to build a clear foundation for all subsequent logistic decisions, ensuring everyone knows the core strategy and potential hurdles from the start.

Deliverables:

- *High Level* Logistics Strategy Trade-off Analysis
- *Draft* Packaging Plan
- *Draft* Logistics Management Plan
- *Draft* Training Needs Analysis
- *Draft* Training Master Plan

2. Packing and Preparations

Goal: In this phase, the team finalizes item-level packaging approaches, labels, and container requirements to meet safety, regulatory, and handling standards. By securing containers, verifying cargo manifests, and confirming each subsystem's readiness, the objective is to ensure every piece of hardware is properly packed, accounted for, and ready for transit without last-minute surprises.

Deliverables:

- *Low Level* Logistics Strategy Trade-off Analysis
- *Final* Packaging Plan
- *Final* Logistics Management Plan
- *Final* Training Needs Analysis
- *Final* Training Master Plan

Review:

- *Operations Readiness Review (ORR)*

3. Outbound Transport

Goal: Here, the team executes the actual shipment, adhering to the chosen route(s) and schedule. The focus is on maintaining real-time tracking, managing customs paperwork, and monitoring any in-transit risks or delays. The ultimate goal is to have the cargo reach the launch site on schedule and in good condition, preserving critical buffers for integration and testing.

Deliverables:

- Item Labels
- Customs Documentation
- Shipment Inspection Forms

4. Launch Operations

Goal: After the shipment arrives, this phase centers on local reception, unloading procedures, and ground operations. The team coordinates on-site resource provisioning (fuel, power, water), ensures the container contents are intact, and supports logistical needs during final preparations and the launch campaign. The objective is a smooth integration of all shipped hardware into the on-site workflow with minimal logistical friction.

Deliverables:

- Shipment Inspection Forms

5. Post-Launch and Return

Goal: Once the launch campaign concludes, the team repackages and ships equipment back to the home base or appropriate storage. Objectives include verifying a complete inventory, evaluating hardware for damage, and documenting lessons learned. This ensures that, by the end of this phase, all mission hardware is accounted for and the logistics process yields valuable insights for future campaigns.

Deliverables:

- Post Flight Analysis
- Logistics Campaign Report

4.17.9 Local Logistics and Consumables

The goal of local logistics is to ensure a smooth on-site operation once equipment, personnel, and consumables arrive at the launch site.

This includes:

- Securing Local Transportation: crane/forklift rentals, small-vehicle hire, final-mile container delivery from port/railhead to the actual launch pad.
- Managing Local Supply and Services: on-site consumables (food, water, fuel), local storage or warehousing, and any specialized ground support (e.g., pressure testing, cold-chain management).
- Coordinating with Local Vendors/Authorities: establishing service agreements for lodging, catering, or hardware spares to maintain readiness through the launch campaign.

4.17.9.1 Local Handling Vehicle List

Use the next table to specify what vehicle are needed for pre-launch and ground operations at the launch site. They can be sourced directly from the spaceport or from local renters. Every system that enhances human physical capacities is considered as a vehicle in the context of the following table.

Vehicle Type	Supplier/Contractor	Use Case	Estimated Price [CHF]
Forklift	Esrange Spaceport	Unloading the SLRS Segments from the truck	Sponsored

4.17.10 Last-Mile Delivery

In the case where the freight-forwarder does deliver to the launch site but to a nearby transport hub, coordinating and planning delivery is essential. This section provides a framework for planning this last transport segment with a dedicated provider.

Freight Forwarder Delivery Location A complete address and site description should be appended to this section. In practice, deliveries might not be made directly to the launch pad, but to a nearby transport node such as a train station or local warehouse. Planning final delivery from that point to the launch site is a responsibility of the Launch Logistics team.

Launch Site Location Same applies for the target delivery point. A reliable address and access instructions should be documented in the appendix. A link to a digital map itinerary shall be provided for team reference.

Distance by road to Launch Site: **1.3 km**
A map itinerary link shall be included separately.

Transport Provider Selection

If multiple options are available (either multiple providers or in-house vs. professional), refer to the strategy trade-off section and include a link to the trade-off analysis below.

- Last Mile Transport Provider Selection Trade-off

4.17.11 Consumables Sourcing

In the table below detail the local vendors you have found for any and all items (they can be grouped into categories) that need to be sourced locally. Think of fuels, pressurants, food, water, medical supplies, cleaning supplies and so on. If you cannot verify the reliability of a particular vendor, mark it as TBD (To Be Determined).

Vendor Name	Type of Shop	Items Categories Sold	Proximity to Base [km]	Reliability (1–5)
Migros	Supermarket	General goods	1	4
Linde	Liquid and gas supplier	Fuels, Pressurants	10	3

Purchasing Any and all locally made purchases should follow the usual order framework. All purchasing requests must be submitted through the appropriate channels and approved by an accredited supervisor.

Below is the list of all the order sheets filled during the launch campaign. Any purchasing request should go through the proper channels and be approved by an accredited supervisor.

Order List

Date (YYYY/MM/DD)	Price [CHF]	Sheet Link
2025/05/12	69.-	*See master purchasing sheet in section* **??**

4.17.12 Risk Management, Contingencies and Insurance

This section is dedicated to risk assessment and mitigation. The risk assessment is similar to the usual framework but a dedicated document is created for the purposes of the launch logistics. Provide the link to this document below as well as a short analysis if some aspects need to be detailed further.

Severity Matrix

Probability					
E	E1	E2	E3	E4	E5
D	D1	D2	D3	D4	D5
C	C1	C2	C3	C4	C5
B	B1	B2	B3	B4	B5
A	A1	A2	A3	A4	A5
	1	2	3	4	5
	Impact				

Matrix Legend

High Risk	E3 E4 E5 D4 D5 C5
Medium Risk	E2 D2 D3 C3 C4 B3 B4 B5 A5
Low Risk	A1 B1 C1 D1 E1 A2 A3 A4 C2 B2

Figure 17: Risk Assessment Template Grading System

ID	Risk Description	Probability	Impact	Severity	Mitigation	Post Mitigation Probability	Post Mitigation Impact	Post Mitigation Severity	Corresponding Requirement	Actions if risk still occurs
2025_MGT_XXX										

Figure 18: Risk Assessment Template

Risk Assessment Template

Logistics and Pre-Launch Operations Risk Assessment

The filled template shall be included here for future reference.

4.17.13 Training and Certifications

Logistics-related training falls under the same framework as the packaging-related training. The following templates allow for tracking the training procedures and determining which operator received which training.

- Training Procedure Template, see section 4.12.
- Personnel Training Tracking Matrix, see figure 23.

4.17.13.1 Training Procedures List

The following list should include all the training procedures relevant to logistical and operational aspects. Make sure to keep it up-to-date.

Training Name	Trainer Name	Training Procedure Link	Required Trainees	Effective Trainees (Last Updated)
Fire Extinguisher Operation	John Doe - CSO	LINK	4	2 (08/04/2025)

4.18 Logistics Strategy Trade-Offs Template

Selecting between shipping methods, providers, or routes involves trade-offs. The next deliverable is a template to perform structured decision analyses using weighted criteria.

This template is a modular guide to systematically evaluate and compare different logistics options (e.g., shipping modes, routes, vendor choices) using a weighted-sum approach. You should fill out one document for each discrete decision or trade-off the team needs to make. The sections below include instructions in these "REMOVE THIS TEXT" blocks; remove them (and their `.remove` tags) from your final version so that the final document appears concise for other readers.

4.18.1 Document Overview

4.18.1.1 Identification

- **Document Title:**
- **Date:**
- **Prepared By:**
- **Approved By:**

Provide basic metadata so future readers know who performed this trade-off, when it was done, and who approved it.

4.18.2 Purpose and Scope

4.18.2.1 Purpose

Explain the primary decision and objective of this trade-off analysis. For example, "to select an optimal shipping mode from Lausanne to Santa Maria that balances cost, transit time, and reliability."

In the "Purpose" section, specify why you are making this decision now and how it fits into the bigger project. State that you will apply a weighted-sum approach to evaluate or compare options.

4.18.2.2 Scope

Identify any constraints or boundaries. For instance, "this document only addresses final shipping from EPFL to the selected launch site. It does not address local ground transport at the launch site."

The scope clarifies what you are analyzing and what you are NOT analyzing (e.g., not covering short local deliveries if that's already decided). It helps future readers avoid confusion about the analysis boundaries.

4.18.2.3 Decision Overview

Decision Statement: *Summarize the problem in one sentence.*

Decision Options: *List all feasible options.*

- *Option A: Sea Container via Marseille → Ponta Delgada*
- *Option B: Direct Road Freight to Kiruna*
- *Option C: Air Freight (with budget considerations)*

4.18.3 Selection Criteria and Ratings

4.18.3.1 Criteria List

Criterion	Description	Unit/Scale
Cost	Total shipping cost	CHF
Time	Estimated transit time, door-to-door	Days
Reliability	Historical on-time performance	1–5
Risk	Risk score (probability × impact)	1–5
Cargo Handling Safety	Risk of breakage/loss during transfer	1–5
Flexibility	Ability to adapt to schedule shifts	1–5

4.18.3.2 Weights for Each Criterion

Criterion	Weight (%)	Reasoning
Cost	20%	We have a limited budget, so cost is crucial.
Time	20%	We must align with launch schedules.
Reliability	25%	Minimizing delays is essential for hardware readiness.
Risk	15%	Our internal risk framework suggests factoring risk scores.
Cargo Handling Safety	10%	Minimizes breakage or loss.
Flexibility	10%	Useful if schedules slip in rocket dev.

4.18.4 Data Gathering and Assumptions

Include cost quotes, transit time estimates, reliability stats, or environmental footprints if relevant. Indicate sources. Justify the rating for intangible/qualitative items.

4.18.5 Weighted Sum Calculation

4.18.5.1 Formula

Using indicia notation, let i represent the *option* (or route) being evaluated, and let j represent a particular *criterion*. We have m total criteria and n total options.

$$\text{Weighted Score for Option } i = \sum_{j=1}^{m} (\text{Score}_{i,j} \times \text{Weight}_j)$$

4.18.5.2 Score Table

Option	*Cost*	*Time*	*Reliability*	*Risk*	*Handling*	*Flexibility*	*Weighted Total*
Option A: Sea	*3×0.2*	*4×0.2*	*5×0.25*	*3×0.15*	*4×0.1*	*3×0.1*	***3.75***
Option B: Road	*4×0.2*	*3×0.2*	*4×0.25*	*4×0.15*	*3×0.1*	*4×0.1*	***3.65***
Option C: Air	*2×0.2*	*5×0.2*	*3×0.25*	*2×0.15*	*5×0.1*	*5×0.1*	***3.40***

4.18.6 Conclusion and Chosen Option

4.18.6.1 Final Ranking

Option A has the highest weighted score. Options B and C follow closely.

4.18.6.2 Rationale and Next Steps

Option A balances cost, time, and reliability most effectively. We will proceed with sea freight as the preferred logistics mode. Final confirmation with the freight provider and capacity check shall follow. A dedicated risk plan shall also be drafted.

4.18.7 Limitations and Warnings

This weighted-sum approach gives a simplistic view. Some intangible factors or real-world disruptions (like strikes, weather extremes) might not appear fully in the numeric scores. Also, the final ranking can vary if you change the weighting or scoring scale. If you require deeper analysis, refer to the internal risk assessment framework or more advanced modeling.

4.18.8 Sign-Off and Review

Name / Role	**Signature**	**Date**
Logistics Manager / Author Compliance Officer (optional) Project Lead		

4.19 Training Master Plan

Training becomes critical when system complexity and personnel turnover increase. This plan enables structured learning objectives and scheduling for team-wide capability building.

Header

- Project / Campaign:
- Version:
- Date:
- Author:

4.19.1 Purpose

Explain that the TMP translates the gaps identified in the Training-Needs Analysis (TNA) into an actionable, resourced, and time-bound plan. Tip: One sentence is enough; avoid repeating the whole TNA rationale.

4.19.2 Scope

Define which roles, subcontractors, and phases are covered. If some training will be handled by suppliers (e.g., launch-range safety briefing), call that out here to avoid double-booking in the schedule.

4.19.3 Ownership

- **Training Manager:** See section 8.13

Keep the cross-references lean—nobody likes to chase 20 links. Only list docs the reader must open to understand the TMP.

4.19.4 Training Objectives

ID	Objective Statement	KPI / Success Metric	Source Gap(s)
SH_TMP_OBJ_01	Ensure Incoterms® proficiency across shipping team	80% quiz score	SH_TCO_01

Tips:

- *Keep objectives **SMART**. Tie each objective to the gap IDs so you can prove closure.*
- *Mix compliance KPIs (pass/fail) with performance KPIs (cycle-time, error-rate).*

4.19.5 Training Catalogue & Delivery Plan

Course / Activity	Mode	Target Roles	Provider	Duration	Cost	Pre-req	Planned Window	Dependency
Incoterms® 2020	E-learning	TCO, TPL	ICC Academy	4 h	CHF 180 pp	Basic logistics	M02	TNA sign-off

Guidelines:

- ***Mode:** classroom, online, simulator, OJT (on-the-job), etc.*
- ***Dependency:** link to project activities (e.g., "must finish before first international shipment").*
- *Bundle micro-learning for soft-skills; don't schedule 3-hour blocks for a 30-minute topic.*

4.20 Training Needs Analysis

Complementing the training plan, analysis allows to identify existing knowledge gaps and prioritizes competencies. This ensures resources are targeted where most impactful.

Header

- Project / Work-Package:
- Version:
- Date of revision:
- Author:

Role ID	Role Title	Competency	Proficiency (1-3)	Req. Level (1-5)	Current Level	Gap	Weight	Gap Score	Evidence / Notes
LLL	Launch Logistics Lead	Incoterms® 2020	3	4	3	1	2	2	Needs refresher
TCO	Transport Coordination Officer	Customs Brokerage	2	3	1	2	2	4	New hire
CSO	Chief Safety Officer	FOPS	3	5	4	1	5	5	Continuous improvement

Figure 19: Training Needs Analysis Automated Excel Document

4.20.1 Purpose

State why this document exists (e.g., "to identify competency gaps for the Logistics & Launch Operations team so that an evidence-based Training Master Plan can be produced").

4.20.2 Scope

Clarify which project phases, roles, subcontractors, and geographic locations are covered. Exclusions (e.g., avionics technicians) should be explicit.

4.20.3 Methodology Summary

Describe the steps you used e.g., role inventory → competency catalogue → self/manager assessment → gap scoring → prioritisation.

4.20.3.1 Scoring Formula

Typical weighted gap score:

$$G_{r,c} = (L^{\text{req}}_{r,c} - L^{\text{cur}}_{r,c}) \times W_c$$

Where:

$$\begin{aligned} G_{r,c} &= \text{gap score for role } r \text{ on competency } c \\ L^{\text{req}} &= \text{required level (1–5)} \\ L^{\text{cur}} &= \text{current assessed level} \\ W_c &= \text{criticality weight for competency } c \text{ (0–3)} \end{aligned}$$

4.20.4 Role & Competency Matrix

Role ID	Role Title	Competency	Proficiency (1–3)	Req. Level (1–5)	Current Level	Gap	Weight	Gap Score	Evidence / Notes
LLL	Launch Logistics Lead	Incoterms® 2020	3	4	3	1	2	2	Needs refresher
TCO	Transport Coordination Officer	Customs Brokerage	2	3	1	2	2	4	New hire

Proficiency Level

- **[3] Mastery:** has passed an external, graded training.
- **[2] Intermediate:** has attended an external, non-graded training.
- **[1] Basics:** has attended an internal, non-graded training.

Required Level Status

- **5:** Mission Critical competence.
- **4:** Important competence.
- **3:** Useful competence.
- **2:** Nice to have competence.
- **1:** Already present competence.

Tips:

- *Keep role IDs in sync with the Work Breakdown Structure.*
- *Evidence column links to CVs, certificates, manager interviews, or simulation results.*
- *Automate Gap = Req – Current in Excel/Sheets so the table updates itself.*

4.20.5 Gap Prioritisation Heat-Map

Priority Tier	Gap Score Range	Description	Action Target	Backup(s)
A – Critical	≥ 6	Compliance / safety blocking items	Train before Phase B	Train 2 backup at the same time
B – High	3 – 5	Performance-critical but not show-stoppers	Train before Phase C	Train 1 backup
C – Moderate	1 – 2	Optimisation / nice-to-have	Train opportunistically	Train 1 backup if possible
D – None	0	Fully competent	No action	No backup training required

Adjust ranges to fit your weighting scheme.

4.20.6 Training Recommendations

Gap ID	Recommended Training	Mode	Provider	Duration	Cost Estimate	Target Date
SH_TCO_TNA_GAP_01	Incoterms® 2020 e-learning	Online	ICC Academy	4 h	CHF 180	Q1 2026

4.20.7 Risk & Mitigation Snapshot

Briefly mention residual project-risk if training is delayed. You may insert a screenshot of the logistics risk assessement matrix if relevant.

4.20.8 Approval

Name	Role	Signature	Date
	Project Manager Quality / HSSE Training Manager		

4.21 Conclusion

The deliverables presented in this chapter form the operational backbone of a student-led suborbital launch campaign. From packaging standards to risk frameworks, and from training plans to trade-off templates, each artifact translates abstract systems thinking into actionable tools. While some are designed as immediately deployable resources and others as templates for future campaigns, all share a common foundation: ensuring mission readiness, regulatory compliance, and logistical resilience.

The next chapter explores how these deliverables align with and enhance the EPFL Rocket Team's existing Systems Engineering framework. It demonstrates how they embed within the project lifecycle, trace to high-level requirements, and support iterative improvement across mission phases.

5 Integration

5.1 Introduction

Having defined, structured, and documented the key deliverables of this project, we now turn to their integration within the broader EPFL Rocket Team systems engineering architecture. This integration is not merely procedural — it is critical to ensuring that the tools, guidelines, and templates produced are not used in isolation, but actively contribute to mission success.

The deliverables introduced in the previous chapter form a modular yet interdependent system. Whether in packaging, compliance, training, or transport planning, each document adheres to shared standards, references common sources, and is designed to be continuously updated. However, for these tools to achieve their intended impact, they must be embedded into the team's existing operational model — one rooted in a combination of student initiative and structured engineering discipline.

This chapter thus addresses how the new logistics and operations documentation integrates with existing workflows, particularly the Systems Engineering Plan (SEP) and associated work breakdown structures. We begin by assessing the current framework and identifying where functional gaps previously existed — gaps that the current project now explicitly resolves. We then introduce a new proposed timeline and integration strategy that maps each deliverable onto the mission lifecycle, ensuring they are used at the correct stage and by the right stakeholders.

In doing so, we ensure that this project does not simply produce standalone documentation, but rather supports the evolution of the EPFL Rocket Team from a competition-based group into a launch-capable, self-sufficient engineering organization.

5.2 Assessment of the Existing Systems Engineering Framework

Before evaluating how the logistics deliverables developed in this project align with and reinforce the EPFL Rocket Team's engineering practices, it is essential to understand the foundational structure within which these deliverables are expected to operate. This section outlines the current Systems Engineering Process (SEP), its lifecycle phases, and highlights the pre-existing structural gaps that this project aims to address.

5.2.1 Overview of the SEP and Lifecycle Phases

The EPFL Rocket Team follows a phased Systems Engineering Plan (SEP) derived from industry best practices and tailored to fit the constraints of a student-run initiative. This framework is codified in the team's internal *Systems Engineering Handbook* [94]. The lifecycle is composed of a sequence of engineering phases, punctuated by formal reviews that mirror those used in professional spaceflight projects.

The typical mission lifecycle comprises the following phases:

- **Phase 0 – Mission Analysis**: Establishes mission objectives, constraints, and success criteria.
- **Phase A – Feasibility**: Defines top-level architecture and selects viable options through trade-off studies.
- **Phase B – Preliminary Design**: High-Level design of the system.
- **Phase C – Detailed Design**: Refines subsystems and interfaces, prepares verification matrices, and establishes test plans.

- **Phase D – Production and Qualification**: Hardware is built and integrated; verification campaigns are conducted.
- **Phase E – Operations**: Operational execution of the mission.
- **Phase F – End-of-Life**: Post-mission analysis and decommissioning.

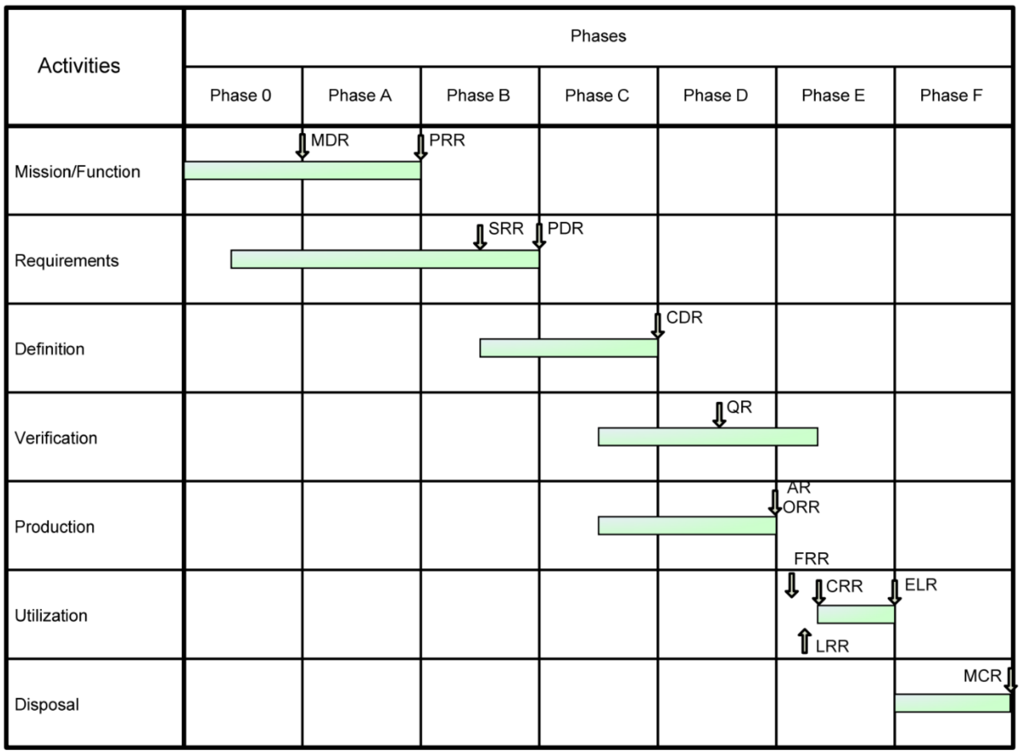

Figure 20: Typical Project Phases, per [25]

Each phase culminates in a milestone review (e.g., PDR, CDR, FRR), supported by dedicated documentation packages. This document hierarchy includes high-level design definitions, subsystem interface descriptions, verification plans, risk assessments, and operational planning files. However, as will be discussed in the next subsection, the logistics, compliance, and readiness domains were historically underdeveloped in this scheme.

5.2.2 Identified Gaps Prior to the Project

Before this project, the EPFL Rocket Team's Systems Engineering framework exhibited strong coverage in areas such as structural design, development, integration, and verification methodology. However, the logistics and compliance domains—despite being mission-critical for any real-world space project—remained notably under-represented.

The following core deficiencies were identified at the outset of this project:

- **Lack of Structured Documentation**: No formal templates or approved frameworks existed for packaging plans, logistics strategies, compliance frameworks, or training tracking.
- **Unclear Role Definitions and Ownership**: Prior to this work, there were no clearly defined positions such as *Launch Logistics Lead*, *Chief Compliance Officer*, or *Transport Packaging Lead*, leading to blurred responsibilities and poor continuity across campaigns.

- **No Integration with Phase Gates or Reviews**: Logistics and regulatory readiness were not embedded into any formal phase review. This meant that shipment planning, customs clearance, and training validation could be overlooked until late in the development cycle—introducing risk and uncertainty.

- **Missing Risk and Compliance Tracking**: While engineering risks were well-documented through design FMEAs and safety trees, there was no dedicated system to identify, rate, or track logistics-specific risks, nor was there a checklist or KPI system for regulatory compliance prior to launch readiness reviews.

- **Insufficient Training Infrastructure**: Critical logistics and safety knowledge (e.g., hazardous goods handling, Incoterms®, or customs documentation) lacked both structured delivery and competency validation across the team.

These deficiencies were corroborated by lessons-learned reviews from past missions such as *Nordend* and *Wildhorn*, where success often relied on ad hoc solutions and personal initiative rather than institutional processes. Furthermore, the increasing complexity and remoteness of future campaigns—such as potential launches at Esrange or the Atlantic Spaceport—highlighted that an operational overhaul was needed to ensure scalability and repeatability.

Section 4.6 introduced a suite of documents and tools developed to address these gaps. The next subsubsection now defines how this new material is scoped for integration within the broader systems architecture.

5.2.3 Scope of Integration

The integration of the deliverables produced in this project was guided by a functional mapping approach: each new document or tool was evaluated in terms of the specific gap it addressed and the systems engineering function it reinforced. While the existing SEP covered most technical domains in depth, operational support elements—especially those involving material flow, compliance, and readiness assurance—required dedicated extensions.

The integration scope is therefore intentionally selective and hierarchical, focusing on core logistics and operations domains while remaining extensible. The following categories define the functional scope of integration:

- **Operational Logistics Planning**: Deliverables such as the *Logistics Management Plan* (LMP) and *Packaging Plan* are integrated into Phases A, B and C activities, ensuring that logistics and transport considerations are embedded early in the lifecycle. These plans are explicitly scoped for physical goods movement and on-site readiness.

- **Regulatory Compliance and Risk Management**: The *Compliance Framework Assessment and Rating* introduces a measurable, phase-gated system for assessing regulatory readiness. It is integrated at key decision points such as the CDR, TRR, and FRR milestones, complementing existing safety reviews and system-level checklists.

- **Training and Human Reliability**: The *Training Needs Analysis* and *Training Master Plan* address the knowledge and competency layer of operational readiness. These are linked to project staffing and readiness reviews, and formally embedded into onboarding and campaign preparation workflows.

- **Cost and Trade-off Management**: The *Logistics Cost Estimator* and *Logistics Strategy Trade-Offs Template* provide tools for decision-making under resource and schedule constraints. These are made available to the Logistics Lead and Systems Engineers as analytical utilities to support project planning.

- **Templates and Modular Tools**: In some cases (e.g., trade-off templates, training matrices, packaging inspection forms), integration is intended not through schedule anchoring, but via availability and usability across multiple missions. These tools are designed as re-usable assets governed by role-based ownership rather than time-based triggers.

It is important to note that this integration effort was not about mandating exhaustive new processes, but rather about giving structure, clarity, and traceability to activities that were previously informal. In doing so, the scope of integration remained aligned with the maturity and scale of the team, while remaining scalable toward future orbital-class efforts.

In the next subsection, we explore the implementation strategy used to carry out this integration, including responsibility matrices and document governance principles.

5.3 Deliverables Integration Strategy

Having clarified the functional scope and lifecycle alignment of the new deliverables, this section presents the strategy used to embed them sustainably into the EPFL Rocket Team's systems engineering architecture. This involved defining clear integration points, assigning ownership and maintenance responsibilities, and aligning each deliverable to the team's documentation governance model. The approach taken ensures that the outputs of this project do not remain isolated but instead contribute to institutional memory and operational reliability.

5.3.1 Integration Map and Responsibility Matrix

The integration strategy was developed through a mapping process that associated each deliverable with one or more SE lifecycle phases, decision gates, and operational roles. This mapping is both horizontal (across lifecycle phases) and vertical (across role hierarchies), ensuring that each document or tool fits into a meaningful workflow and has a clear stakeholder.
Key integration anchors include:

- **CDR and TRR milestones:** Integration of the *Compliance Framework*, *Logistics Management Plan*, and *Training Plans* into review package checklists.
- **Phase B–C preparation:** Packaging- and transport-related deliverables such as the *Packaging Plan*, *Cost Estimator*, and trade-off templates are referenced in preparation tasks for material readiness.
- **Post-launch phases:** The *Logistics Campaign Report* and associated inspection checklists are triggered post-mission, ensuring continuous improvement cycles.

	Engineering Team			Logistics and Packing Team					Management Team							External Stakeholders		
	Systems Engineers	Team Leaders	Engineering Team Members	Head of Logistics	Launch Logistics Lead	Transport Coordination Officer	Transport Packaging Lead	Logistics Team Members	ERT President	ERT Vice-President	ERT Comitee	Head of Sponsoring	Chief Compliance Officer	Chief Financial Officer	Chief Safety Officer	Commercial Stakeholders	Academic Stakeholders	Regulatory Bodies
Packaging Plan																		
Subsytem-Level Document Ownership	A	R	R	I	C	C	C	I	I	I	I	I	C	I	I	C	I	C
Project-wide Document Ownership	R	R	C	I	C	C	A	I	I	I	I	I	C	I	I	C	I	C
Logistics Management Plan																		
Document Ownership	C	C	C	I	A	R	R	I	I	I	I	C	C	C	C	C	I	C
Compliance Framework Assessement and Rating																		
Document Ownership	C	C	I	C	R	R	R	C	C	I	I	I	A	I	I	C	I	C

Figure 21: Responsibility Assignment Matrix, as shown in figure 15

A responsibility matrix (maintained in the Logistics Management Plan) was defined using a modified RACI model. Each deliverable is linked to a primary owner—usually a role with operational accountability (e.g., Launch Logistics Lead, Transport Packaging Lead, Chief Compliance Officer). Secondary responsibilities are defined for consultative and informative roles, such as Systems Engineers and Administrative Officers. This framework ensures that no deliverable is orphaned and that maintenance responsibilities are persistent across project cycles.

5.3.2 Document Governance & Ownership

Ensuring the longevity and usability of each deliverable required a coherent approach to document governance. Several principles were applied:

- **Centralization of Access:** All deliverables were created and structured to be directly integrated into the team's `wiki.js`-based knowledge management system, which serves as the central repository for the SE framework. Markdown and LaTeX compatibility were used to streamline formatting and publishing.
- **Template Standardization:** Documents such as the *Packaging Plan*, *Risk Assessment*, and *Trade-Off Templates* were developed with modularity and reusability in mind. The use of consistent formatting conventions (e.g., `\begin{remove}` blocks) supports clarity for future users, differentiating between editable fields and stable content.
- **Version Control and Maintenance Responsibility:** Versioning fields and approval tables were embedded into some deliverables, and linked to designated roles in the Responsibility Assignment Matrix (RAM). This ensures traceability across iterations, and aligns with practices outlined in the Systems Engineering Handbook.
- **Lightweight Onboarding:** For newly created templates or tools, short usage instructions and embedded references to related documents were included. This supports intuitive use by new users and reduces the overhead associated with future onboarding.
- **Non-Redundancy with Existing SE Artifacts:** Where relevant, new deliverables explicitly defer to or reference existing documents (e.g., Systems Engineering Plan, Risk Analysis, Technical Requirements Specifications). This avoids duplication and maintains a single-source-of-truth paradigm.

Collectively, these strategies transform the project's outputs from stand-alone documents into living, maintainable components of the EPFL Rocket Team's broader operational framework. In the next section, we explore how these elements are scheduled, reviewed, and synchronized with key lifecycle milestones.

5.4 Timeline and Review Embedding

An essential aspect of making logistics and operations documentation useful is ensuring that it does not remain static. To be actionable, deliverables must be synchronized with project milestones, updated through formal reviews, and leveraged during decision points. This section outlines how the integration strategy presented above is operationalized over time, within the mission lifecycle and through internal validation mechanisms.

5.4.1 Phase-by-Phase Integration

Each deliverable is designed to support a particular phase of the lifecycle, providing just-in-time information and structure. Figure 22 shows how the new deliverables build upon the existing list presented in figure 2.

				0	A	B		C	D		E		F
	Deliverable Name	ABV.	Type	MDR	PRR	SRR	PDR	CDR	QR	AR	FRR	LRR	MCR
System	Mission Statement and Description	MSD	Definition										
	Stakeholder Value Network	SVN	Definition										
	Compliance Framework Assessement and Rating (KPIs)	CFAR	Tracking										
	Compliance Framework Assessement and Rating (Items)	CFAR	Requirements										
	State Of The Art	SOTA	Definition										
	External Forces Identification	EFI	Definition										
	Outcomes of Interest	OOI	Definition										
	Functional Analysis	FUA	Definition										
	Systems Engineering Plan	SEP	Planning										
	Technical Requirements Specifications	TS	Requirements										
	Costs Budgets	CBU	Tracking										
	Risk Assessment	RAS	Tracking										
	Concept of Operations	COP	Planning										
	Timeline	TIM	Planning										
	System Trade-Offs	SYT	Design										
	System Decomposition	SYD	Design										
	Block Diagram	BDI	Interface										
	Design Structure Matrix	DSM	Interface										
	System Overview	SYO	Tracking										
	Documentation Plan	DOP	Planning										
	Training Needs Analysis	TNA	Definition										
	Training Master Plan	TMP	Planning										
	Interface Control Document	ICD	Interface										
	System Sizing	SYS	Tracking										
	Technology Readiness Assessment	TRA	Tracking										
	Safety Plan	SAP	Planning										
	Verification Plan	VEP	Verification										
	Manufacturing Assembly Integration and Verification Diagram	MAIV	Planning										
	Operation Plan	OPP	Planning										
	Packaging Plan	PKG	Planning										
	Logistics Management Plan	LMP	Planning										
	Environmental and Safety Report	ESR	Planning										
	Packaging Labels and Forms	PKG	Tracking										
	Logistics Campaign Report	LCR	Closure										
	Mission Report	MRE	Closure										
	Review Item Discrepancy	RID	Feedback										

Figure 22: Expanded Phase-Mapped Deliverables List

Figures 22 and 16 provide a visual representation of this alignment, showing how each logistics document or activity slots into the broader mission planning framework.

Rather than forcing all outputs to map directly to ECSS lifecycle phases (e.g., Phase A, B, C...), a hybrid strategy is adopted in which internal **Logistics Timeline Phases**—defined as *Early Planning, Packing and Preparations, Outbound Transport, Launch Operations, Post-Launch and Return*—are overlaid on the ECSS framework to improve operational granularity. These mappings are illustrated in Figure 16, while Figure 22 shows how logistics deliverables align with major systems engineering milestones.

5.4.1.1 Early Planning (Logistics Timeline Phase) / ECSS Phase 0

This foundational phase focuses on capturing feasibility, transport requirements, and early stakeholder needs. The logistics-related deliverables initiated here include:

- **Draft Logistics Management Plan (LMP)** – establishes baseline assumptions, outlines the intended transport approach, and maps interface responsibilities.
- **Draft Packaging Plan (PKG)** – begins identifying packaging requirements, container categories, and preliminary environmental constraints.
- **Training Needs Analysis (TNA)** and **Draft Training Master Plan (TMP)** – scope out operator training gaps and prepare scheduling of required sessions.
- **Logistics Strategy Trade-Offs** – enable early decisions about shipping mode, container sizing, and freight forwarder engagement.

These documents are designed to converge toward the Preliminary Design Review (PDR), allowing transport feasibility to be validated alongside technical readiness.

5.4.1.2 Packing and Preparations (Logistics Timeline Phase) / ECSS Phase A–B

This second phase finalises item-level logistics and aligns them with system-level hardware readiness. During this period:

- The **LMP** and **PKG** reach maturity and are reviewed at the Operations Readiness Review (ORR).
- Training identified in the TMP is deployed (e.g., Incoterms, customs brokerage, equipment handling).
- The **Compliance Framework Assessment and Rating (CFAR)** begins active usage, especially for verifying alignment with transport-related regulatory requirements.

By the end of this phase, all materials and team members should be logistically and procedurally ready for execution of the transport operation.

5.4.1.3 Outbound Transport (Logistics Timeline Phase) / ECSS Phase C

This execution-oriented phase covers the physical movement of components. Key deliverables include:

- **Container Labels and Handling Forms**
- **Customs Documentation**

- **Shipment Inspection Forms**

These documents are generated in accordance with templates defined in the PKG. The TMP ensures that designated personnel are trained and authorized for cargo handoff, hazard declaration, and customs brokerage processes.

5.4.1.4 Launch Operations (Logistics Timeline Phase) / ECSS Phase D

Upon arrival at the spaceport, the LMP governs ground logistics including crane rental, consumables resupply, and last-mile delivery coordination. In this phase:

- **Shipment Inspection Forms** are reused to verify incoming items' condition and traceability.
- The **Environmental and Safety Report (ESR)** is submitted to external authorities as part of the launch authorization package.

The logistics team shifts to a support role, ensuring all hardware and support equipment are safely staged and integrated into campaign operations.

5.4.1.5 Post-Launch and Return (Logistics Timeline Phase) / ECSS Phase E–F

The final phase encompasses logistics closure activities. Primary deliverables include:

- **Logistics Campaign Report (LCR)** – consolidates observations, incidents, and lessons learned across all logistics stages.
- Closure updates to the **CFAR**, particularly regarding KPI review and compliance incident tracking.

The TMP is also updated to reflect any newly uncovered training deficiencies or success stories, enabling cyclical improvement of the training ecosystem.

5.4.1.6 Cross-Cutting Integration Logic

Rather than confining logistics to a single point in the project lifecycle, this framework deliberately distributes responsibilities and documentation across all six ECSS phases. This ensures that operations planning, regulatory compliance, and team readiness are embedded—not appended—to the engineering process.

As such, logistics becomes a first-class citizen in the overall system lifecycle, with each deliverable anchored to a milestone and validated through both internal and external review mechanisms.

5.4.2 Internal Review Process

A key aspect of embedding logistics and operations within the Systems Engineering Framework is ensuring their visibility and validation through the project's formal review structure. Each logistics deliverable is integrated into at least one major review event, ensuring alignment with the technical baseline, compliance expectations, and readiness for execution.

As illustrated in Figure 22, most logistics-related outputs follow a staged development pattern, where drafts are initiated in early phases (Phase 0/A) and progressively refined until validated in the context of higher-maturity milestones (CDR, FRR, etc.).

Document Maturity and Review Anchors The following review mapping governs when and how logistics deliverables are validated:

- **Training Needs Analysis (TNA)** and **Training Master Plan (TMP)** are introduced and reviewed during **Phase A**, ahead of skill-specific onboarding and course design. These are confirmed by the **Operations Readiness Review (ORR)** in Phase B.
- The **Packaging Plan (PKG)** and **Logistics Management Plan (LMP)** are both iterated from Phase 0 onward, and reach maturity by the ORR. Post-ORR updates are typically limited to operational refinements.
- The **Compliance Framework Assessment and Rating (CFAR)** operates on a continuous basis but is explicitly reviewed at **CDR** (to validate assumptions and structure) and at **FRR** (to validate KPI values and checklist completion).
- The **Environmental and Safety Report (ESR)** is reviewed no later than CDR, as it forms part of the external licensing file submitted to spaceport authorities and regulatory entities.
- The **Logistics Campaign Report (LCR)** is the only deliverable exclusive to the post-launch closure phase. It is reviewed during the **Post-Flight Analysis Review (PFAR)** to document findings, gaps, and proposed improvements for future missions.

Review Modalities and Team Interfaces Each internal review includes the relevant logistics leads—typically the Launch Logistics Lead (LLL), Transport Packaging Lead (TPL), and Chief Compliance Officer (CCO). Depending on the phase and subject matter, subsystem leads (e.g., avionics or propulsion) and admin/finance officers may also be involved. The training component (TNA/TMP) is reviewed in tandem with operations safety officers to ensure cross-consistency between regulatory obligations and internal practices.

Tailored Maturity Levels Following the progressive elaboration principle, deliverables are not expected to be fully complete at their first review checkpoint. Instead:

- *Drafts* are reviewed for coherence, scope, and assumptions at early milestones (e.g., PDR).
- *Final versions* are reviewed for readiness, completeness, and operability at execution milestones (e.g., ORR, FRR).

This staged validation process prevents last-minute bottlenecks and encourages early engagement with logistics content across the broader engineering and operations teams.

Review Integration Benefits This integrated approach ensures that logistics concerns are not isolated from system-level decisions but are systematically verified against schedule, hardware readiness, and regulatory compliance. It reinforces the idea that launch campaigns succeed not only through engineering design, but also through seamless, reviewed, and traceable logistics execution.

5.5 Impact of Integration on Operational Performance and Compliance Maturity

The successful development and integration of the logistics and operations framework have brought about measurable and transformative improvements to the EPFL Rocket Team's project execution capabilities. This section critically evaluates those impacts by identifying pre-existing deficiencies—both internal and observed across comparable teams—and demonstrating how the introduced deliverables and processes directly mitigate them. The framework's true value is realized in its ability to move the team from reactive, improvised operations toward a proactive, compliance-driven, and resilient mission structure.

5.5.1 Addressing Known Operational Pain Points

The framework directly targets recurring operational bottlenecks and risks that were previously observed either internally or across other student rocketry organizations. These include issues in packaging, last-mile logistics, regulatory compliance, cost control, communications, and lessons-learned capture. In many cases, previous project iterations or campaigns relied on ad-hoc practices, undocumented processes, or individual memory. These gaps, while manageable during low-complexity campaigns, present mission-critical vulnerabilities as project scale increases.

5.5.1.1 Packaging and Handling

In past EPFL Rocket Team campaigns, equipment was transported using generic crates or informal packaging methods—some hardware was loosely bubble-wrapped, often not secured, and fragile components were occasionally placed underneath heavier items. These choices led to unnecessary wear, loss of time on site, and non-negligible risk of mission failure. This reflects a broader issue also reported by DARE, who ultimately engaged a professional supplier for Stratos II+ crate design after similar damage issues emerged [18].

The newly institutionalized Packaging Plan template now follows MIL-STD-2073 logic and introduces crate-specific shock and tilt indicators, load/unload maps, and tool prioritization zones. These measures ensure packaging is planned from the outset—not post-facto—enabling hardware safety, efficient ground ops, and regulatory readiness.

5.5.1.2 Travel and Transport Logistics

Prior logistics operations often lacked cohesion: transport vehicles were booked late, the team manifest was informally compiled, and customs documentation was either incomplete or improvised (e.g., ATA carnets hastily filled or absent). This situation mirrors the breakdown experienced by USC RPL during Traveler III's desert transit when an aging trailer failure caused a critical 6-hour delay [22].

The Logistics Management Plan (LMP), supported by the Transport Coordination Officer role and a robust RACI model, prevents such issues by enforcing structured manifests, route planning, redundancy allocation, and customs documentation timelines. The embedded framework now imposes gate checks on legal and operational transport readiness, thus professionalizing the entire logistics chain.

5.5.1.3 Regulatory Compliance and Safety

Historically, hazmat transport (e.g., igniters, ethanol, Li-ion packs) was conducted without formal declarations or transport classification, relying purely on luck to clear customs and range procedures. This scenario parallels the Singapore SEDS 2023 case, where a student-built rocket was impounded days before launch due to undeclared components entering the U.S. [86].

To address this, the Compliance Framework Assessment and Rating (CFAR) template was introduced to catalogue every regulatory requirement—UN codes, IATA and ADR declarations, ATA carnet IDs, and mandatory inspections—with deadlines and assigned owners. A live Compliance Matrix now integrates seamlessly with campaign planning and the Launch Readiness Review process.

5.5.1.4 Cost Modeling and Decision-Making

Cost and carbon modeling previously relied on legacy estimates from past campaigns or heuristic adjustments (e.g., scaling EUROC 2021 invoices). This approach was fragile when targeting new sites like Esrange, where prior data did not exist. This matches HyEnD's reliance on third-party DLR-STERN funding to overcome cost uncertainty for their 2023 Esrange campaign [71].

The newly introduced Python estimator allows early-phase modeling of transport scenarios based on itemized crate data, delivery modes (truck, sea, air), and containerization logic. Outputs include cost projections, CO_2 impact, and range of uncertainty, feeding directly into funding, insurance, and planning cycles.

5.5.1.5 Radio Communications and Launch Safety

Radio communications were traditionally managed through verbal briefings held just before the countdown, with no shared terminology, escalation hierarchy, or read-back requirement. In one documented incident, the term "hold" was misheard as "go," resulting in a launch with disabled avionics—Traveler III again being a cautionary example [22].

The Comms Protocol Guidelines (CPG) template now formalize radio scripts, assign roles, define escalation ladders, and enforce mandatory read-back. Integration Test sign-offs verify that each operator understands and can execute their responsibilities, while on-site rehearsals reduce ambiguity.

5.5.1.6 Knowledge Retention and Continuous Learning

Prior to the current effort, lessons-learned were inconsistently recorded and rarely consulted—resulting in repeated mistakes and wasted cycles. For example, PFARs (Post-Flight Analysis Reviews) were occasionally held but rarely documented with rigor. DARE's publication following Stratos III disintegration exemplifies the importance of transparency in student teams [24].

The Logistics Campaign Report (LCR) template, introduced here, forces structured post-mortem documentation of all campaign facets—logistics, compliance, training, safety. Linked to each year's planning checklist, this ensures that critical learning outcomes are accessible to the next cohort, institutionalizing institutional memory.

5.5.2 EPFL Rocket Team-Specific Improvements

In addition to examples from other student teams, numerous pain points documented across the team's own campaign history—from Bella Lui I to Nordend—are directly addressed by this framework:

- Packaging and crate tie-downs are now planned in advance and verified via checklist, eliminating informal packing practices.
- Customs and hazmat compliance are now embedded in the CFAR matrix, reducing dependence on chance border crossings.
- Role continuity and responsibility drift are addressed by the integration of a Responsibility Assignment Matrix (RAM) and a permanent "Operations" work package in the WBS.
- Integration Test tracking, training sign-offs, and role backups are systematized via a Training Matrix.

These changes raise the team's operational maturity and compliance culture without overburdening members or diluting student agency. Every procedural template is designed for clarity, modularity, and maintainability, ensuring that new contributors can enter and contribute with minimal friction.

5.5.3 Integration as Enabler of Mission Success

The cumulative impact of this framework is not just technical—it is cultural. It builds accountability where there was ambiguity, resilience where there was fragility, and repeatability where there was guesswork. By structuring the intangible aspects of logistics and compliance, the framework acts as a multiplier for launch readiness, safety, and team continuity. In doing so, it offers the EPFL Rocket Team a scalable foundation not only for near-term suborbital campaigns but also for future transitions toward orbital-class missions.

5.6 Interfaces with Other Teams and Systems

Beyond improving logistics and compliance operations internally, the new framework actively reshapes how these domains interface with other EPFL Rocket Team entities. This chapter explores how the structured approach enhances cross-functional collaboration, institutional alignment, and external communication. Effective systems engineering is inherently integrative—its value is contingent on seamless interfaces between disciplines. The operational framework succeeds not only by formalizing documents but by embedding itself into team dynamics and enabling shared understanding between units with diverging objectives, timescales, and vocabularies.

5.6.1 Coordination with Subsystems

The introduction of a comprehensive logistics framework requires close synchronisation with all technical subsystems, particularly for planning dependencies and physical handling constraints. Historically, logistics coordination was reactive. This approach often led to bottlenecks as we have now shown.

With the current framework, these risks are mitigated in three key ways:

1. **Bidirectional Planning Integration:** Deliverables such as the Packaging Plan and Logistics Management Plan now interface upstream with subsystem readiness reviews and downstream with the overall project schedule. Subsystem leads are expected to provide preliminary packing dimensions, fragility classifications, and environmental tolerances during the mid-phase of system definition (Phase B/C), rather than retroactively during system qualification.

2. **Joint Ownership of Interfaces:** The introduction of Responsibility Assignment Matrices (RAMs) for logistics and packaging ensures that subsystem leads co-sign packing, inspection, and handling responsibilities. This replaces the former siloed model, where ownership was often ambiguous.

3. **Embedded Logistics Reviews:** Dedicated logistics checkpoints are now integrated into key technical reviews, particularly the Integration Test and Launch Readiness Review. These checkpoints verify the alignment between packaging logic, integration workflows, and transport constraints.

Moreover, the Training Matrix ensures that subsystem personnel involved in physical operations (e.g., bolting, lift points, gas line connections) are qualified under common protocols, thus minimizing safety risks or process deviations during on-site operations. This cultivates a shared operational language across disciplines—an essential prerequisite for safe, repeatable system delivery.

5.6.2 Collaboration with Admin and Finance

The framework also forges a stronger link between the operational and administrative arms of the EPFL Rocket Team. Previously, budget forecasts for logistics, customs, and transport were compiled using extrapolated values or historical invoices, disconnected from real-time campaign planning. This created budgeting gaps, limited funding negotiations, and obscured the true cost of specific missions.

The integration of the Python-based logistics cost estimator into the planning workflow corrects this misalignment. Admin and finance teams now gain:

- **Quantitative Cost Breakdown:** The estimator outputs detailed cost components (freight, last-mile delivery, customs, insurance), which are used to prepopulate budget requests and funding applications. This enables finer control over sponsor negotiations or internal trade-offs.
- **Carbon Footprint Accountability:** The same tool provides CO_2 estimates per mode and per crate, supporting the team's broader sustainability initiatives and reinforcing EPFL's environmental commitments.
- **Data-Driven Decision Support:** Admin can now validate procurement or transport requests against the LMP and cost model, ensuring that proposed expenditures are consistent with the chosen campaign strategy. This facilitates smarter procurement, milestone-based payments, and better tracking of contingency usage.

In parallel, the Training Master Plan (TMP) and Compliance Framework Assessment and Rating (CFAR) act as reporting tools to quantify team preparedness, maturity level, and alignment with external standards. These are valuable artefacts when interfacing with sponsors, safety boards, or third-party service providers, strengthening the team's institutional profile and funding credibility.

5.6.3 Communication with External Stakeholders

Finally, one of the most crucial but historically underdeveloped interfaces was that with external stakeholders—launch authorities, customs agents, freight providers, and regulatory bodies. The ambiguity of past documentation, lack of consistent labeling, and informal communications posed risks not only to hardware safety but also to institutional trust.

The revised framework establishes robust communication channels through:

- **Standardized External Documentation:** Templates such as the Packaging Plan, Logistics Management Plan, and Inspection Sheets are written in industry-compatible formats and include external appendices (e.g., ATA carnet templates, hazardous goods declarations) ready for submission to customs, range operators, or insurers.
- **Compliance-Facing Readiness Artifacts:** The CFAR provides a one-page compliance readiness dashboard that allows quick assessments by regulatory authorities during campaign review. This not only speeds up licensing procedures but also signals a level of professionalism and operational maturity that few student teams possess.
- **Clear Lines of Responsibility:** With named points of contact per document (LLL, CCO, TCO), external parties are not left guessing who to reach out to for logistics, compliance, or documentation queries. This reduces friction during transit delays, customs inspections, or emergency interventions.

The collective result is a drastic reduction in unforced errors at critical interfaces: no more delays at border crossings due to missing papers, no more launch hold-points due to miscommunication with range control, and no more ambiguous ownership during high-stress campaign phases.

In sum, this framework does not just optimize internal workflows—it structurally enhances the reliability, reputation, and operational scalability of the EPFL Rocket Team by actively supporting every major interface across the system-of-systems that underpins a successful launch campaign.

5.7 Cultural and Organizational Impact

Beyond formal deliverables and system interfaces, the long-term success of the logistics and compliance framework depends on the culture it fosters. Process documents and templates are only effective when they shape behavior, instill discipline, and remain flexible enough to adapt to a volunteer-driven, high-turnover student team environment. This section explores how the project contributes to building a sustainable operational culture—one that transcends any individual cohort or campaign and can underpin the team's aspirations toward reaching orbit.

5.7.0.1 Compliance as a Shared Value, Not a Checklist.

The framework positions compliance not merely as a regulatory burden but as an enabler of safe and professional operations. By embedding CFAR checkpoints within major reviews (FRR, ORR) and defining success through multi-KPI dashboards rather than binary approvals, the team learns to treat regulatory tasks as integral to mission planning. Over time, this builds psychological safety around transparency: teams are encouraged to surface gaps early rather than mask them.

5.7.0.2 Readiness Through Frictionless Repetition.

Repeatability—across launches, sites, and generations—is the cornerstone of operational excellence. Instead of reinventing processes for each campaign, the new framework provides base plans that reduce decision fatigue, allow reuse of past materials, and encourage deliberate iteration. Templates like the Logistics Management Plan or Packaging Plan start simple but are structured to accommodate increasing complexity, enabling a progression from tactical compliance to strategic foresight.

5.7.0.3 Visual and Document Literacy.

By emphasizing visual tools (RAMs, Gantt-based milestones, compliance matrices), the framework shifts team literacy from ad-hoc verbal coordination to shared visual abstractions. This makes it easier for new members to understand project status, roles, and constraints at a glance—especially important in multicultural and multidisciplinary teams where ambiguity can otherwise breed inaction.

5.7.1 Training and Knowledge Transfer

Sustaining operational know-how across academic cycles is a persistent challenge in student-led engineering projects. Turnover is high, roles are fluid, and experiential learning is often undocumented. This project introduces structured solutions to these organizational weaknesses, converting individual competence into institutional memory.

5.7.1.1 Institutionalizing Critical Skills.

The Training Needs Analysis (TNA) and Training Master Plan (TMP) define not only what knowledge is needed, but who is accountable for it, and by when. This enables forward scheduling of training modules long before a campaign begins, ensures minimum competency thresholds per role, and enforces the use of standardised learning pathways (e.g., ICC-accredited Incoterms® courses).

5.7.1.2 Backup Capacity as Risk Mitigation.

Historically, some mission-critical tasks (e.g., customs paperwork, hazardous goods declarations) were known only by one person. The framework's requirement that each critical task has an identified backup—not just as an informal suggestion but as a tracked project attribute—drastically reduces the team's exposure to single-point failures. This backup model also enhances inclusivity: junior members gain structured pathways to responsibility, reducing barriers to contribution.

5.7.1.3 Retention Through Meaningful Onboarding.

The use of pre-filled, example-rich templates (e.g., ESR, LMP, CFAR) lowers the activation barrier for new contributors. Instead of facing a blank page or unstructured folder, they inherit working documents shaped by past campaigns. This tangible handover creates a sense of continuity and professional pride, anchoring the team's identity not just in success but in method.

In short, this framework transforms logistics and compliance from reactive overheads into proactive cultural assets. It redefines operational maturity as a property of how knowledge is shared, how decisions are structured, and how preparedness is encoded—not in intuition, but in process.

5.8 Long-Term Vision and Scalability

5.8.1 Making Logistics a Mission Enabler

As the EPFL Rocket Team scales toward more ambitious launch profiles, including orbital-class objectives, the ability of its internal frameworks to evolve from campaign-by-campaign support tools into long-term strategic assets becomes critical. This subsection assesses the alignment of the developed logistics and compliance framework with aerospace industry best practices and evaluates whether it meets the fundamental operational requirements of real-world launch campaigns.

5.8.1.1 Alignment with Industry Standards and Practices.

A central goal of this project was to benchmark internal processes against existing norms from space agencies, defense logistics, and industrial launch operators. As established in Chapter **??**, source documents such as MIL-STD-2073-1E[23], NPR 6000.1H[74], and ECSS standards (e.g., ECSS-E-ST-20-07C[25]) form the backbone of packaging, handling, inspection, and lifecycle traceability across the industry. The project does not attempt to replicate their full scope—doing so would be impractical for a student-led organization—but instead distills their operational essence into fit-for-purpose templates and decision workflows.
For instance:

- The Packaging Plan template directly references MIL-STD-2073-1E preservation methods, container life cycles, and barrier specifications, adapting them to the team's component scale and reuse constraints.
- The Compliance Framework and CFAR structure emulate the functional decomposition of a Launch Readiness Review (LRR) checklist found in agency playbooks, with milestone-driven verification gates and hazard identification embedded within the schedule.
- The Logistics Strategy Template formalizes the use of weighted trade-off analyses, a common method in aerospace supply chain planning, making it usable by engineering students without formal logistics training.

These examples confirm that while the framework is not exhaustive, it is industry-informed, pragmatically scoped, and designed for upwards compatibility.

5.8.1.2 Representative of True Launch Campaign Constraints.

Modern launch logistics are multidimensional: they involve not only technical and transport constraints, but regulatory compliance, contractor interfacing, insurance, customs brokerage, and real-time communications. The developed deliverables collectively simulate and prepare the team for this reality.

The Logistics Management Plan, for example, is not just a transport checklist—it encodes RACI matrices, role handovers, contingency buffers, and dependency mapping. Similarly, the Communications Guidelines do not merely list radio protocols; they incorporate behavioral expectations under stress, modeled after range safety procedures in government and commercial launchpads.

This fidelity to the lived complexity of space campaigns helps bridge the pedagogical gap between educational objectives and industrial expectations. It also gives team members early exposure to the integrated nature of launch operations—preparing them not only to execute tasks, but to understand their position in the system of systems that is a space mission.

5.8.1.3 Scalability to Larger Campaigns and New Sites.

A recurring theme in aerospace operations is scalability: can a process work not just once, but under a broader envelope of conditions? The framework was deliberately constructed with this in mind:

- Templates like the Packaging Plan or LMP are content-agnostic—they can be reused across suborbital, orbital, or static test campaigns with minimal rework.
- The cost estimator tool incorporates parametric inputs (mass, volume, distance, mode) rather than campaign-specific hardcoding, enabling rapid feasibility analysis for future missions.
- The Compliance Framework Assessment and Rating (CFAR) isolates each regulatory requirement as a modular item with traceability and documentation status, allowing it to expand in scope without restructuring the entire system.

From ESRANGE in northern Sweden to new potential launch pads in the Azores, the framework has been designed to support multi-modal logistics, multiple currencies, varying customs regimes, and on-site operational heterogeneity. It thereby positions logistics not as an afterthought or risk, but as a competitive advantage and mission enabler.

In summary, the project does not merely approximate launch logistics—it embeds their real-world logic into a student-accessible structure. By aligning with professional standards and supporting expansion in both geographic and operational scope, the framework serves as a scalable scaffold for future campaigns, ensuring the EPFL Rocket Team can grow its ambitions without compromising readiness or rigour.

5.9 Summary and Conclusion

Chapter 5 has demonstrated that the developed logistics and compliance framework does far more than fill procedural gaps: it integrates deeply and bidirectionally into the EPFL Rocket Team's systems engineering lifecycle. Beginning with a critical assessment of the existing Systems Engineering Plan (SEP), the chapter outlined how key operational deficiencies—ranging from documentation gaps to review misalignment—are directly addressed by new, structured deliverables.

A deliberate integration strategy was presented, using both lifecycle-phase alignment and responsibility mapping to ensure that the framework is not static, but actively reviewed, updated, and deployed. The timeline and internal review sections reinforced this by embedding each deliverable into the real decision-making cadence of the team's engineering process. Subsequently, a comprehensive analysis was conducted to assess how this integration improves mission performance: by reducing operational risk, increasing repeatability, enhancing knowledge transfer, and establishing compliance as a cultural pillar.

The framework's interfaces with subsystems, admin/finance, and external stakeholders further validated its systemic value. By structuring those relationships and standardizing interactions, it reinforces operational resilience across technical and administrative boundaries.

Finally, the long-term vision section confirmed that the project's scope, methodology, and outputs are directly aligned with industry best practices and scalable across mission types and sites. The project thus elevates logistics and compliance from auxiliary considerations to core enablers of mission success.

In conclusion, the work presented in this chapter positions logistics not merely as a supporting function, but as a structured, scalable, and strategically integrated discipline within the EPFL Rocket Team—ready to meet the demands of increasingly complex, multi-phase, and geographically distributed launch campaigns.

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6 Future Work

6.1 Future Work Breakdown

This section outlines the outstanding tasks required to fully mature and operationalize the logistics and compliance framework introduced in this report. These tasks are grouped by functional category and target both technical, procedural, and cultural shortcomings identified during the project post-analysis. Each bullet point below represents a discrete future initiative that will support the long-term integration, usability, and robustness of the system.

6.1.1 Operationalization and Testing

- Develop a dry-run logistics simulation: crate packing, customs inspection, and radio drills.
- Implement a full Failure Mode and Effects Analysis (FMEA) for logistics operations.
- Introduce a Logistics Maturity Model to calibrate implementation depth to mission scale.
- Design and run checklists for operational rehearsals before each major campaign.

6.1.2 Subsystem and Documentation Integration

- Add packaging and handling appendices for GNC, Recovery, and Payload systems.
- Build formal change control mechanism (change request template, changelog register).
- Implement a Logistics–Systems Engineering sync (risk matrix, trade logs, SE reviews).

6.1.3 Training and Knowledge Management

- Expand the Training Master Plan to include lifting, crate handling, emergency response, export control.
- Define mandatory re-certification cycles and thresholds for role-critical training.
- Introduce structured onboarding with short video briefings and documentation primers.
- Formalize backup role coverage for every critical operator.

6.1.4 Compliance and Content Deepening

- Populate CFAR with cross-references to specific ECSS, IATA, and customs documentation.
- Add live examples for 2–3 hazardous chains (e.g., igniters, pressure vessels).
- Define a Data Confidentiality and Access Protocol for sensitive documents.

6.1.5 Digitalization and Tools

- Move key deliverables to collaborative version-controlled platforms (Notion, Git).
- Integrate sign-off status tracking into shared dashboards or databases.
- Implement error propagation and uncertainty analysis in the Python cost estimator.

6.1.6 Governance, Reviews and Metrics

- Add sunset and obsolescence criteria to all long-lived deliverables.
- Define periodic review triggers and ownership for updates.
- Develop a Campaign Maturity Index to benchmark across years.

6.2 Future Work Packages

This subsection attributes each cluster of tasks to a responsible role or work package lead. Tasks are grouped to maximize continuity and skill alignment. Coordination remains the responsibility of the Launch Logistics Lead (LLL) and the broader Systems Engineering management structure.

Work Package 1: Head of IT

Responsible for digital infrastructure, version control, and platform integration.

- Move CFAR, LMP, TMP, and RAM tables to collaborative platforms (GitHub, Notion).
- Implement access control for sensitive folders and shared drives.
- Enable version-tracking and edit history for live documents.

6.2.1 Work Package 2: Chief Compliance Officer (CCO)

Ensures depth and reliability of regulatory deliverables.

- Populate CFAR cross-links to ECSS, IATA, and ADR standards.
- Add examples for each hazardous transport classification (e.g., UN3480).
- Build a regulatory reference library accessible from within the wiki.

6.2.2 Work Package 3: Head of Logistics (HL)

Owns all packaging, transport and operational dry-runs.

- Lead logistics simulation (rehearsal, crate packing, vehicle inspection).
- Develop and execute Failure Mode Analysis workshops.
- Establish site-specific adaptation plans for ESRANGE, Santa Maria, etc.

6.2.3 Work Package 4: Chief Safety Officer (CSO)

- Implement hazardous goods handling SOPs.
- Contribute to ESR, CFAR, and inspection workflows.
- Co-design rehearsals for launch-day emergency drills.

6.2.4 Work Package 5: Training Manager (TMA)

- Expand TMP and TNA to include recovery, comms, legal compliance.
- Design and run onboarding modules and quiz-based certifications.
- Audit Training Matrix completion and recertification status.

6.2.5 Work Package 6: Transport Packaging Lead (TPL)

- Develop subsystem-specific crate appendices (GNC, payload).
- Define tie-down, lift-point, and shock indicator procedures.
- Document load/unload SOPs for each mission site.

6.2.6 Work Package 7: Chief Financial Officer (CFO) and Vice-Presidency (VP)

- Use cost estimator outputs for pre-campaign funding applications.
- Track cost deltas vs. estimates; refine estimator coefficients.
- Link CO_2 estimates to team-wide sustainability metrics.

6.2.7 Work Package 8: Systems Engineers (SEs)

- Integrate logistics risks into system risk matrix.
- Feed trade-off decisions into subsystem-level logs.
- Ensure reviews include cross-domain checkpoints (e.g., CFAR sign-off at CDR).

6.2.8 Future Work Package Summary Table

Work Package Owner	Assigned Tasks Summary
Head of IT	Platform migration, version control, access protocol
Chief Compliance Officer	Deepen CFAR content, hazardous examples, regulatory references
Head of Logistics	Simulation, FMEA, multi-site adaptation plans
Chief Safety Officer	Hazmat SOPs, ESR contribution, emergency drills
Training Manager	TMP/TNA expansion, onboarding, matrix auditing
Transport Packaging Lead	Subsystem crate integration, load/unload procedures
Chief Financial Officer & Vice Presidency	Cost estimator refinement, CO_2 tracking, budgeting interface
Systems Engineers	Cross-link SE risks/trades, logistics phase reviews

6.3 Paving the Way for a Firehorn 9 Implementation

To ensure the framework transitions from documentation to operational practice, a targeted deployment during the next launch campaign—*Firehorn 9*—is both logical and necessary. As a smaller-scale mission with a concrete launch objective, Firehorn 9 provides an ideal proving ground for testing the integration and usability of the deliverables developed in this project.

Implementation should begin with lightweight adoption: select 3–4 core tools such as the *Packaging Plan*, *Training Matrix* and *Compliance Tracking Matrix*. These can be adapted with minimal overhead and provide immediate value in standardizing operations. Ownership should be assigned explicitly within the campaign team's Work Breakdown Structure, and document maturity levels tracked via the project's review calendar.

Early onboarding meetings and workshops should be organized to familiarize subsystem leads with the scope and usage of these tools, and feedback loops should be established to capture user friction points. The outcome of this pilot integration will inform further refinements and support the creation of a more compact, mission-ready version of the full framework—ultimately validating its scalability and cementing its relevance ahead of larger launches like *Spaceshot*.

7 Conclusion

7.1 Project Takeaways

This project demonstrates that logistics, compliance, and operational planning are not secondary concerns but integral components of mission success. By creating a coherent framework grounded in both aerospace standards and student-team constraints, the project validates the hypothesis that engineering maturity is as much about process discipline as it is about technical proficiency.

From a technical systems engineering standpoint, the most salient takeaway is the feasibility of scaling professional-grade operational tools and workflows down to the student-team level without compromising usability or ownership. Templates such as the Packaging Plan and Compliance Framework illustrate that regulatory foresight, risk identification, and role-based accountability can be embedded in a way that is lightweight yet impactful.

Another key lesson is that success in logistics depends on convergence—not only between systems and disciplines, but also across phases, roles, and institutional memory. Documents were explicitly designed to interlink: the cost estimator feeds the Logistics Management Plan; the Training Matrix ties into the Integration Test checklists; the CFAR maps back to the Launch Readiness Review. This relational architecture ensures that each deliverable does not exist in isolation, but contributes to a tightly coupled operational system.

Perhaps most importantly, the project reveals how high-ambition student teams such as the EPFL Rocket Team can cultivate a culture of compliance, preparedness, and learning without sacrificing agility. The result is not a rigid bureaucracy, but a modular framework that grows with the team's capabilities. In practical terms, this positions logistics as a true mission enabler—on par with propulsion, avionics, or payloads—as the team scales toward orbital goals.

7.2 Critical Outlook

Despite its comprehensive scope and ambition, this project is not without limitations—some structural, others conceptual. While its deliverables form a robust starting point, several foundational assumptions, execution trade-offs, and unresolved questions must be addressed if this framework is to deliver sustained value beyond its initial implementation.

7.2.1 Integration Is Documented—But Is It Lived?

The project makes a strong case for integration by mapping deliverables onto lifecycle phases, assigning ownership, and establishing review anchors. However, whether these integrations are truly internalized within the team's practices remains unproven. There is no guarantee that future project leads will enforce the CFAR, review the Logistics Management Plan at TRR, or maintain the compliance checklist rigorously. While this risk is acknowledged, mitigation remains weak: adoption is assumed rather than demonstrated. Without real-time enforcement mechanisms or usage analytics, the framework risks becoming shelfware.

7.2.2 Role Proliferation vs. Role Saturation

Several new roles were introduced to give operational structure: Launch Logistics Lead, Transport Packaging Lead, Chief Compliance Officer, and others. While theoretically sound, the assumption that these positions will be consistently staffed and maintained is optimistic. The Rocket Team remains a volunteer-based, high-turnover environment. It is unclear whether sufficient human capital exists to fill and sustain these roles long-term, especially in non-glamorous domains like customs, insurance, or incident reporting. The framework presumes organizational stability where fluctuation is the norm.

7.2.3 Training: Structured, but Not Yet Systemic

The Training Needs Analysis and Master Plan are important steps toward institutionalizing knowledge. But they still lack the mechanisms to ensure enforcement or evaluation. There is no system yet in place to validate that training was delivered, absorbed, or retained. There is no audit trail, no feedback loop. Training remains decoupled from performance metrics, and without this connection, its effectiveness will be difficult to justify or iterate. Moreover, reliance on external certification (e.g., ICC Academy) is sensible, but funding and access logistics are not addressed.

7.2.4 Templates Are Not Systems

A significant portion of the work consists of templates—structured, standardized, and carefully crafted. But templates alone do not constitute a system. They are entry points, not guarantees of usage. There is no templating engine, metadata repository, or linked document management system to ensure versioning, traceability, or document life-cycle management. While Markdown and LaTeX compatibility improve accessibility, this technical scaffolding falls short of what might be expected in a software-driven document control system. Templates without automation or enforceability remain vulnerable to neglect.

7.2.5 Impact Remains Hypothetical

Although the report references past campaign pain points (e.g., Nordend, Bella Lui), the framework itself has not yet been subjected to the pressures of a full-scale campaign. There has been no empirical trial of the cost estimator during actual freight negotiations, no field application of the ESR in range clearance, and no post-flight validation of Campaign Reports. Without such deployment data, impact claims remain theoretical. Real-world constraints—budget overruns, site delays, interpersonal friction—could expose brittle points in the system. Until tested under operational conditions, the framework's robustness is aspirational.

7.2.6 Regulatory Scope Is Incomplete

While the Compliance Framework introduces a structured KPI model and a regulatory checklist, it remains relatively shallow in legal depth. Areas such as insurance law, dangerous goods classification under evolving IATA DGR editions, GDPR for personnel data during training, or customs regimes for dual-use technologies are outside the scope. Yet they remain mission-relevant. The framework currently provides a surface-level abstraction, but not a compliance database or legal liaison system. This limits its applicability for more complex missions or for coordination with governmental authorities.

7.2.7 No Mechanism for Continuous Feedback or Evolution

Once delivered, who evolves the framework? Who version-controls the templates across years? What if a major campaign alters the baseline assumptions (e.g., shipping lithium batteries overseas)? These questions are not answered. The framework lacks a governance structure beyond first-use ownership. It does not offer a process for feedback collection, retrospective revision, or cross-campaign lessons beyond the post-launch LCR. For something so essential to institutional learning, this is a major gap.

7.2.8 Strategic Alignment with Mission Planning Remains Underdeveloped

While integration with lifecycle phases is well articulated, the alignment with broader project strategy (e.g., when to launch, what to prioritize, or what trades to make) is underrepresented. For example, the cost estimator operates in isolation—it does not feed into an optimization loop or inform campaign scoping exercises. Similarly, the training matrix exists apart from performance dashboards. There is no integration between logistics metrics and top-level KPIs for mission readiness. The framework supports execution, but not yet planning or prioritization.

7.2.9 The Framework Is Overfitted to the EPFL Context

Though based on real-world references, the framework is tailored to EPFL Rocket Team dynamics. This makes replication by other teams harder unless they share similar structures, toolchains, and cultural values. Portability—while not a core objective—could limit broader academic value. More abstracted models, role-agnostic templates, or parameterized versions of key documents could increase adaptability and allow the framework to evolve into a cross-team standard.

7.2.10 Conclusion

In summary, while the project delivers a rich, well-researched, and operationally valuable framework, it cannot yet claim strategic, organizational, or institutional permanence. Its current strength lies in its documentation, clarity, and intent—but these do not self-execute. Sustained benefit will require not only adoption, but adaptation. The framework must survive the test of turnover, stress, scale, and time. Only then can it be considered a truly integrated element of the EPFL Rocket Team's systems engineering foundation.

7.3 Lessons Learned

This project, while formally defined as a technical and methodological contribution to the EPFL Rocket Team's systems engineering framework, was also, in many respects, a deeply formative journey — technically, organizationally, and personally. The lessons it yielded go far beyond checklists and templates.

7.3.1 On Systems Thinking and Launch Operations

A key realization from this project was the sheer scope and depth of systems engineering as applied to real-world aerospace operations. While the EPFL Rocket Team has long championed in-house design and manufacturing of propulsion, avionics, and structures, launch logistics and campaign operations had remained in the shadows — assumed to be solvable through improvisation or urgency.

This work revealed how misguided that assumption can be. From customs brokerage to hazardous goods declarations, from packaging standards to operational readiness reviews, it became clear that success in spaceflight is not just about designing rockets, but about architecting the infrastructure and organizational readiness that enables those rockets to fly. The expanded framework demonstrated how even a student team can integrate elements of ECSS, MIL-STD-2073, and NASA readiness culture without losing flexibility or purpose. It also taught the author that systems engineering is not about paperwork — it's about taming complexity, managing uncertainty, and designing with intentionality.

7.3.2 On Technical Mastery and Academic Purpose

Among the technical domains tackled, packaging and cost estimation stood out for their difficulty. Packaging was one of the first deliverable and required multiple iterations to bridge the gap between military-grade specifications and practical implementation within the team. Cost estimation, on the other hand, demanded unfamiliar skills in

Python modeling and parameterization, underlining the importance of tool-building over hardcoding.

Yet what emerged from this process was a deeper understanding of how standards can serve not as constraints, but as educational scaffolding. By filtering, reducing, and adapting professional requirements to the realities of a student team, the author discovered a new layer of academic value: systems engineering not as compliance, but as pedagogy.

7.3.3 On Planning, Restraint, and the Role of the Systems Engineer

Initially, the project ambition was maximalist — the goal was to build everything, and do it "right." But such ambition can be a double-edged sword. Midway through, the author had to confront a common systems engineering dilemma: how much is too much?

This tension between thoroughness and usability revealed itself in multiple ways. Some documents risked becoming over-engineered, inaccessible to newcomers. Usability became a retrospective concern, prompting future work on lightweight operational handbooks and Firehorn 9 test integrations. Through this, the author learned one of the hardest lessons in systems engineering: building something sustainable sometimes means building less, but better.

It also redefined the author's understanding of their role within the EPFL Rocket Team. As a propulsion systems engineer, their domain was initially technical. But this project revealed the broader remit of a systems engineer: to look beyond subsystem boundaries, improve frameworks, and enable long-term coherence across cycles and cohorts.

7.3.4 On Human Growth and Legitimacy

While technically ambitious, this was also a solo project — which made it both liberating and demanding. There was no formal obligation to succeed. If the project failed, the team would revert to past methods. If it succeeded, it would raise the bar. This absence of pressure paradoxically created space for risk-taking and intellectual exploration, ultimately leading to a stronger outcome.

But it also demanded emotional maturity. Finding legitimacy — as a student, a systems engineer, a contributor to something larger — required introspection. Not just about competence, but about humility, about knowing when to ask for help, and about exposing oneself to criticism in order to grow. As the project unfolded, the author came to appreciate that legitimacy is not conferred — it is earned through quality, resilience, and the courage to revise your own assumptions.

7.3.5 On Team Culture and Institutional Memory

One of the most striking insights was how fragile student team memory can be. Unless structure is imposed, knowledge dissipates. Lessons are lost. Mistakes are repeated. This project showed how process can preserve memory, how documentation can empower newcomers, and how visual and modular tools can foster clarity in high-turnover environments.

It also reinforced that cultural change is slow — and must be designed for. Compliance must become a shared value, not a policing mechanism. Readiness must become habitual, not exceptional. The true measure of the framework's success will not be its LaTeX formatting or its technical elegance, but whether it is used, adapted, and challenged by future generations.

7.3.6 On Pride, Perspective, and Purpose

The proudest moments — from final presentations to the delivery of this report — were not defined by external validation, but by internal coherence: the feeling that something useful, rigorous, and lasting had been built. This project synthesized a vast field, one that combines strategic planning, regulatory fluency, operations management, and engineering foresight. In doing so, it showed that launch logistics is not ancillary to rocketry — it is rocketry.

Perhaps the deepest lesson is that systems engineering, when done right, is invisible. It leaves behind no single hero, but a stronger system. And in that, this project finds its final value: not in the size of the report, but in the resilience of the team it seeks to serve.

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8 Appendix

8.1 Project Description

	Year 2025 **EPFL Rocket Team** **SEMESTER PROJECT DESCRIPTION**	Year: 2025 Date: 11/11/2024 Page: 1 / 2

Preliminary assessment of pre-launch operations and logistics for a suborbital vehicle

Project: Spaceshot project, EPFL Rocket Team
Prepared by: Matthieu Tonneau
Approved by: Antoine Marchand

Responsible TL:
Responsible SE: Matthieu Tonneau
Academic supervisor:

Project Description

Context: The EPFL Rocket Team's goal is to fly a rocket that will reach the Karman line by 2030. Due to the inherent constraints of this spaceshot (SH) mission, the launch is expected to happen at a dedicated launch site in Europe. Because of this, many constraints will affect the operations of the team before reaching the launch day.

Project overview: This project shall delve into what the specific constraints are and how they will affect the team. A particular care shall be put into examining how those constraints vary from one launch site to another. The end goal of the project is to craft a detailed pre-launch operations (packing for transport, unpacking at launch site, integration and on-site testing) and logistics (transport and supply chain) plan on a per-launchsite basis. This plan shall encompass multiple aspects: personnel, equipment, timeline and consumables with their respective dependencies, required preparation, lead time and schedules.
The exact scope shall be defined at the start of the project with the agreement of the supervisor. The role of the project is also to derive good practices and deliverable templates that can be integrated seamlessly with the current team approach of systems engineering and project management. This shall be based on relevant european and NASA standards while ensuring that the approach is suitable for the team both from an efficiency and thoroughness standpoint.

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Student gain: Systems engineering, requirement engineering, interface management, system modeling, space mission operations, space mission logistics.

A general idea of the tasks unfolding:

- **[2 weeks]:** State of the art
- **[1 week]:** Consolidated scope definition and review
- **[10 weeks]:** Operations study:
  - **[1 week]:** Identification of key relevant deliverables
  - **[2 weeks]:** Expanding the Systems Engineering Plan (SEP) for phases D through E, putting the emphasis on launch preparation and planning.
  - **[1 week]:** Integration of the expanded SEP into current existing framework
  - **[1 week]:** Systems Engineering Review of updated framework
  - **[5 weeks]:** Case study on the SH launch: applying the developed framework while patching any deficiencies.
- **[1 week]:** Preliminary Operations Review (POR) for the SH launch

Reference links:

- ECSS-M-ST-10C: Space project management, Project planning and implementation (http://everyspec.com/ESA/download.php?spec=ECSS-M-ST-10C.048180.pdf)
- ECSS-E-ST-10C: Space engineering, System engineering general requirements (http://everyspec.com/ESA/download.php?spec=ECSS-E-ST-10C.047801.pdf)
- ECSS-E-ST-10-06C: Space engineering, Technical requirements specification (http://everyspec.com/ESA/download.php?spec=ECSS-E-ST-10-06C.048163.pdf)
- ECSS-E-ST-70C – Ground systems and operations (https://ecss.nl/standard/ecss-e-st-70c-ground-systems-and-operations/)
- Nasa Systems Engineering Handbook – Appendix T (https://www.nasa.gov/wp-content/uploads/2018/09/nasa_systems_engineering_handbook_0.pdf)

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8.2 Cost Estimator Code Implementation

```python
#!/usr/bin/env python3
"""
EPFL Rocket Team - Logistics & Launch Cost Estimator
Version: 0.5  (adds transport time & launch-site cost options)
"""

from dataclasses import dataclass
from typing import Tuple

#  1. DATA - tweak here only

ORIGIN = "lausanne_CH"

SPACEPORTS = {
    # km from Lausanne to main gateway for each mode
    # None → physically or commercially impossible
    "esrange_SE":  {"road_km": 3000, "rail_km": 3000, "air_km": 2200, "sea_km": None},
    "atlantic_PT": {"road_km": None, "rail_km": None, "air_km": 2700, "sea_km": 3200},
}

MODAL_BASE_RATES = {            # CHF per t-km
    "road": 0.55,
    "rail": 0.22,
    "air":  1.65,
    "sea":  0.12,
}

# road leg from hub/port/airport to pad (km, rate)
LAST_MILE = {
    "road": (0,   0.55),        # already on road
    "rail": (50,  0.60),
    "air" : (50,  0.70),
    "sea" : (20,  0.55),
}

EMISSIONS = {                   # g CO -eq / t-km
    "road": 62,
    "rail": 22,
    "air":  600,
    "sea":  16,
}

# average speed on the main leg (km/h) - conservative operational figures
AVG_SPEED_KMH = {
    "road": 60,
    "rail": 80,
    "air": 800,
```

```python
    "sea": 30,
}

# assumed speed for all last-mile road transfers (km/h)
LAST_MILE_SPEED_KMH = 40

CUSTOMS_PARAMS = {
    "carnet_fee_chf":      400,
    "bond_premium_pct": 0.004,    # 0.4 %
}

INCOTERM_EXPOSURE = {          # (export_duty, import_duty, insurance)
    "EXW": (False, False, False),
    "FCA": (True,  False, False),
    "CPT": (True,  False, False),
    "CIP": (True,  False, True ),
    "DAP": (True,  False, True ),
    "DPU": (True,  False, True ),
    "DDP": (True,  True,  True ),
}

LAUNCH_SITE_PACKAGES = {
    # key → (no GNC/in-house, no GNC/port, GNC/in-house, GNC/port)
    "esrange_SE": {
        "basic"    :  80_000,    # no GNC, in-house telemetry
        "basic_tp" : 150_000,    # no GNC, spaceport telemetry
        "gnc"      : 280_000,    # GNC, in-house telemetry
        "gnc_tp"   : 350_000,    # GNC, spaceport telemetry
    }
}

#  2. DATA-CLASSES

@dataclass
class Cargo:
    mass_t: float
    value_chf: float

@dataclass
class Quote:
    freight: float
    customs: float
    insurance: float
    site: float
    carbon_kg: float
    time_h: float
    total: float

#  3. HELPERS
```

```python

def _km(dest: str, mode: str) -> float:
    d = SPACEPORTS[dest][f"{mode}_km"]
    if d is None:
        raise ValueError(f"{mode.capitalize()} transport to {dest} unavailable.")
    return d


def freight_stats(cargo: Cargo, dest: str, mode: str) -> Tuple[float, float, float]:
    """Return (freight_cost_chf, carbon_kg, duration_h)."""
    km_main = _km(dest, mode)

    cost_main   = km_main * MODAL_BASE_RATES[mode] * cargo.mass_t
    carbon_main = km_main * EMISSIONS[mode]       * cargo.mass_t / 1_000
    time_main_h = km_main / AVG_SPEED_KMH[mode]

    km_last, rate_last = LAST_MILE[mode]
    cost_last   = km_last * rate_last * cargo.mass_t
    carbon_last = km_last * EMISSIONS["road"] * cargo.mass_t / 1_000
    time_last_h = km_last / LAST_MILE_SPEED_KMH

    return (
        cost_main + cost_last,
        carbon_main + carbon_last,
        time_main_h + time_last_h,
    )


def customs_cost(cargo: Cargo, pay_export: bool, pay_import: bool) -> float:
    if not (pay_export or pay_import):
        return 0.0
    fee  = CUSTOMS_PARAMS["carnet_fee_chf"]
    bond = cargo.value_chf * CUSTOMS_PARAMS["bond_premium_pct"]
    return fee + bond


def insurance_cost(cargo: Cargo) -> float:
    return 0.01 * cargo.value_chf

#  4. ESTIMATOR

def estimate(
    cargo: Cargo,
    dest: str,
    incoterm: str,
    mode: str,
    site_cost: float = 0.0,
) -> Quote:
    freight, carbon, time_h = freight_stats(cargo, dest, mode)
```

```python
    pay_exp, pay_imp, pay_ins = INCOTERM_EXPOSURE[incoterm]

    customs   = customs_cost(cargo, pay_exp, pay_imp)
    insurance = insurance_cost(cargo) if pay_ins else 0.0

    total = freight + customs + insurance + site_cost
    return Quote(freight, customs, insurance, site_cost, carbon, time_h, total)

#  5. CLI

def _menu(prompt: str, options: Tuple[Tuple[str,str], ...]) -> str:
    for i, (k, label) in enumerate(options, 1):
        print(f"  {i}) {label}")
    try:
        choice = int(input(prompt).strip())
    except ValueError:
        raise ValueError("Numeric selection expected.") from None
    if not 1 <= choice <= len(options):
        raise ValueError("Invalid selection.")
    return options[choice-1][0]


if __name__ == "__main__":
    print("\n- EPFL Rocket Team Logistics & Launch Cost Estimator -\n")

    try:
        mass = float(input("Cargo mass [t] : ").strip())
        value = float(input("Cargo value [CHF] : ").strip())
    except ValueError:
        raise SystemExit(" Numeric input expected - aborting.")

    dest = _menu("\nDestination ? ", (
        ("esrange_SE",  "Esrange - Kiruna (SE)"),
        ("atlantic_PT", "Atlantic Space Consortium - Azores (PT)"),
    ))

    mode = _menu("\nMain transport mode ? ", (
        ("road", "Road"),
        ("rail", "Rail"),
        ("air",  "Air"),
        ("sea",  "Sea"),
    ))

    incoterm = _menu("\nIncoterm ? ", (
        ("EXW","EXW"), ("FCA","FCA"), ("CPT","CPT"), ("CIP","CIP"),
        ("DAP","DAP"), ("DPU","DPU"), ("DDP","DDP"),
    ))

    # optional launch-site package - only defined for Esrange for now
```

```
    site_cost = 0.0
    if dest in LAUNCH_SITE_PACKAGES:
        pkg = _menu("\nEsrange launch service package ? ", (
            ("basic",    "No GNC  + in-house telemetry    (CHF  80 000)"),
            ("basic_tp", "No GNC  + spaceport telemetry  (CHF 150 000)"),
            ("gnc",      "GNC     + in-house telemetry    (CHF 280 000)"),
            ("gnc_tp",   "GNC     + spaceport telemetry  (CHF 350 000)"),
        ))
        site_cost = LAUNCH_SITE_PACKAGES[dest][pkg]
        print(f"  → Package selected : {pkg} (CHF {site_cost:,.0f})\n")

    cargo = Cargo(mass, value)

    try:
        quote = estimate(cargo, dest, incoterm, mode, site_cost)
    except (KeyError, ValueError) as e:
        raise SystemExit(f" {e}") from None

    print("\n- Summary -")
    print(f"Destination : {dest}")
    print(f"Mode        : {mode.title()}")
    print(f"Incoterm    : {incoterm}\n")

    print("*** Cost breakdown ***")
    print(f"Freight        : CHF {quote.freight:,.0f}")
    print(f"Customs (ATA)  : CHF {quote.customs:,.0f}")
    print(f"Insurance      : CHF {quote.insurance:,.0f}")
    print(f"Launch site    : CHF {quote.site:,.0f}")
    print(f"CO-eq         : {quote.carbon_kg:,.0f} kg")
    print(f"Transport time: {quote.time_h:,.1f} h  (~{quote.time_h/24:,.1f} days)")
    print("--------------")
    print(f"Total          : CHF {quote.total:,.0f}\n")

```

8.3 Hazardous Item Label Template

Hazardous Item Label

Container ID:

Shipment ID/Reference:

Hazard Information

- **Material Name:**
- **UN Number:**
- **Hazard Class / Division:**
- **Packing Class:**
  - ☐ I
  - ☐ II
  - ☐ III
- **Net Quantity:**
- **Physical State:**
  - ☐ Solid
  - ☐ Liquid
  - ☐ Gas

Emergency Response Information

- **In Case of Emergency (Leak, Spill, Fire):**
- **Emergency Contact:**
  Name:
  Phone:
  Email:

1

Danger & Precautions

Risks Associated	Precautions and Handling Instructions
☐ Explosive	☐ Avoid impacts, shocks, friction
☐ Flammable	☐ Keep away from ignition sources
☐ Corrosive	☐ Wear protective gear
☐ Toxic	☐ Do not inhale or ingest; avoid skin contact
☐ Oxidizing	☐ Keep away from combustible materials
☐ Reactive	☐ Avoid contact with incompatible substances

Documentation & Certification

- **Compliance Documents Completed:**
  - ☐ Yes
  - ☐ No
- **Certification Reference:**
- **Approval Authority & Date:**

Packaged by:
Date:

2

8.4 Shipment Inspection Form

Shipment Inspection Form

Date:
Inspector Name:
Shipment ID/Reference:

Shipment Type:

- ☐ **Outgoing Shipment (Expedition)**
- ☐ **Incoming Shipment (Reception)**

1. Shipment Information

(Complete for both Outgoing and Incoming shipments)

Item	Detail / Information
Origin (Sender)	
Destination (Receiver)	
Date of Inspection	
Expected Departure/Arrival Date	
Actual Departure/Arrival Date	
Carrier Name	
Tracking Number	
Bill of Lading Number	
Container Identification Number(s)	
Associated Critical Item Label ID	

2. Packaging Inspection Checklist

(Complete for both Outgoing and Incoming shipments)

Checkpoint	Pass	Fail	Comments
Correct Container(s) Selected	☐	☐	
Container Condition (Physical damage)	☐	☐	
Container Integrity (seals, locks)	☐	☐	
Container Markings/Identification	☐	☐	
Correct Preservation Method Applied	☐	☐	
Preservation Condition (humidity, seal)	☐	☐	
Proper Desiccant Used	☐	☐	
Humidity Indicators	☐	☐	
Proper Cushioning Applied	☐	☐	
Packaging Documentation Included	☐	☐	
Hazardous Material Labeling	☐	☐	

3. Component Condition Checklist

(Primarily for Incoming shipments)

Component ID	Pass	Fail	Comments
	☐	☐	
	☐	☐	
	☐	☐	
	☐	☐	
	☐	☐	
	☐	☐	
	☐	☐	
	☐	☐	
	☐	☐	
	☐	☐	
	☐	☐	
	☐	☐	
	☐	☐	

Note: Document specific component conditions (corrosion, scratches, breakage, ESD damage, etc.)

4. Environmental Indicator Verification

(Complete for both Outgoing and Incoming shipments)

Indicator	Pass	Fail	Measurement	Corrective Action Taken
Shock	☐	☐		
Vibration	☐	☐		
Humidity	☐	☐		
Temperature	☐	☐		

5. Outgoing Shipment Specific Checks

(Complete ONLY for outgoing shipments)

Checkpoint	Pass	Fail	Comments
Proper Documentation Attached	☐	☐	
Appropriate Handling Instructions Included	☐	☐	
Transportation Mode Confirmed	☐	☐	
Regulatory Compliance	☐	☐	
Container Properly Labeled	☐	☐	
Monitoring Devices Installed and Activated	☐	☐	

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6. Incoming Shipment Specific Checks

(Complete ONLY for incoming shipments)

Checkpoint	Pass	Fail	Comments
Shipment Documentation	☐	☐	
Container Condition Upon Arrival	☐	☐	
Receiving Inspection Documentation	☐	☐	
Damage or Discrepancies Reported	☐	☐	
Corrective Actions Initiated	☐	☐	
Monitoring Devices Data Collected	☐	☐	

7. Final Inspection Approval

(Complete for both Outgoing and Incoming shipments)

Inspection Outcome	Selection
Approved (All checks Pass)	☐
Conditionally Approved	☐
Rejected (Critical failures)	☐

Inspector Name and Signature:
Date:

Approval (Team Lead/Project Manager):
Date:

8. General Notes and Observations

(Complete for both Outgoing and Incoming shipments)

EPFL ROCKET TEAM

8.5 Package Label Template

Package Label

Container ID:
Shipment Reference / ID:

Origin:
Destination:

Contact Information:

- **Packaged by:**
- **Packaging Date:**
- **Contact Name:**
- **Contact Phone/Email:**

Container Information

- **Container Type:**
  - ☐ Long-life (Reusable)
  - ☐ Short-life
  - ☐ Single-use
- **Container Preservation Method:**
  - ☐ Method 10 (Physical Protection)
  - ☐ Method 20 (Physical Protection with Preservative)
  - ☐ Method 30 (Waterproof Protection)
  - ☐ Method 40 (Watervaporproof Protection)
  - ☐ Method 50 (Watervaporproof with Desiccant)
- **Desiccant Units Installed (if applicable):**
- **Monitoring Devices Installed:**
  - ☐ Shock Indicator
  - ☐ Vibration Indicator
  - ☐ Temperature Indicator
  - ☐ Humidity Indicator

Special Handling Requirements

Orientation	Fragility	Moisture / Humidity	Temperature Control
☐ Upright Only	☐ Fragile	☐ Keep Dry	☐ Temp Controlled
☐ Horizontal	☐ Handle with Care	☐ Humidity Control	☐ Not Required

Hazardous Material Information

(See detailed file for more information)

- ☐ **Contains Hazardous Materials**
- **Material Description:**
- **UN Number:**
- **Classification:**
- ☐ **Documentation Completed**

Container Contents

Item ID	Description	Classification	Quantity

General Notes/Remarks:

8.6 Packaging Handling Record Template

Packaging Handling Record

Shipment ID / Reference Number:
Item Description:
Class (I, II, III, IV):
Container ID Number:
Critical Item Label Reference:

Shipment History Log

Date (YYYY-MM-DD)	**Time** (UTC)	**Operation Performed**	**Location**	**Responsible Person**	**Condition Check** (Pass/Fail)	**Monitoring Devices Activated** (Y/N)	**Comments**

Date (YYYY-MM-DD)	**Time** (UTC)	**Operation Performed**	**Location**	**Responsible Person**	**Condition Check** (Pass/Fail)	**Monitoring Devices Activated** (Y/N)	**Comments**

Date (YYYY-MM-DD)	**Time** (UTC)	**Operation Performed**	**Location**	**Responsible Person**	**Condition Check** (Pass/Fail)	**Monitoring Devices Activated** (Y/N)	**Comments**

Date (YYYY-MM-DD)	**Time** (UTC)	**Operation Performed**	**Location**	**Responsible Person**	**Condition Check** (Pass/Fail)	**Monitoring Devices Activated** (Y/N)	**Comments**

8.7 Item Label Template

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ITEM LABEL

Item ID:
Description:

Classification (check):

- ☐ Class I (Critical)
- ☐ Class II (Delicate)
- ☐ Class III (Special Handling)
- ☐ Class IV (General)

Preservation Method: [10 / 20 / 30 / 40 / 50]

Special Care:

- ☐ Fragile
- ☐ ESD Sensitive
- ☐ Moisture Sensitive
- ☐ Hazardous

Packaged by:

Date:

ERT EPFL ROCKET TEAM

8.8 Personnel Training Tracking Matrix

Personnel Training Tracking Matrix							
Personnel Name	**Role / Position**	**Attended**	**Competence Assessment Passed**	**Certificate Issued**	**Certificate Link**	**Signature of Personnel**	**Notes**
John Doe	Team Leader	Yes	Yes	Yes			

Figure 23: Personnel Training Tracking Matrix

8.9 Chief Compliance Officer Role Description

Year 2025
EPFL Rocket Team

ROLE DESCRIPTION

Year:	2025
Date:	31/04/2025
Page:	1 / 3

Chief Compliance Officer (CCO)

Project:	Project Spaceshot, EPFL Rocket Team	**Approved by:**	Matthieu Tonneau
Prepared by:	Matthieu Tonneau	**ERT Supervisor:**	ERT President

Role Description

The Chief Compliance Officer (CCO) typically serves as the point person who ensures that all team activities meet relevant legal, regulatory, and safety requirements, as well as any governing rules from competitions or organizations overseeing high-powered rocketry.

Those activities are divided across 6 categories:

1. Regulatory and Permitting Oversight
2. Compliance Documentation and Record-Keeping
3. Liaison with Compliance-Related Stakeholders
4. Training and Education
5. Collaboration with Engineering and Project Leads

Detailed Work Package

1. Regulatory and Permitting Oversight:

- **High-Powered Rocketry Regulations:** In many regions, launches of rockets above certain impulse thresholds (e.g., Class 2 or 3 high-powered rockets in the U.S.) require specific waivers or permits from authorities such as the FAA. The CCO ensures the team understands and meets these requirements.
- **Local/State Requirements:** Some states, municipalities, or campuses may have additional rules regarding storage and handling of rocket motors or launch operations. The CCO coordinates with local authorities and school administration to secure any necessary permits.
- **Range Safety & Flight Waivers:** The CCO works with the appropriate regulatory agency (e.g., FAA in the U.S.) or rocketry associations (NAR, Tripoli) to secure flight windows, altitude waivers, and site approvals.

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2. Compliance Documentation and Record-Keeping

- **Compliance Framework:** The CCO is tasked with establishing, maintaining and updating the general ERT Compliance Framework and its Key Performance Indicators.
- **Compliance Matrix:** The CCO has ownership over the compliance matrix and is in charge of tracking all of its items over his or her mandate. When necessary, the CCO highlights trends and evolutions based on the data and gives recommendations to the management and engineering teams accordingly.
- **Internal Audits:** The assessment of the KPIs is conducted during internal audits which are spread out over a year. The specific timeframe for each internal audit is determined in consultation with the engineering and management teams in order to happen at the most sensical time.

3. Liaison with compliance-related stakeholders

- **Regulatory Agencies**: Serves as the primary point of contact for the FAA (or equivalent), local fire marshal, campus risk management office, etc.
- **Rocketry Associations**: Coordinates membership and certifications with organizations such as the National Association of Rocketry (NAR) or Tripoli Rocketry Association, which often have their own safety codes and high-power certification processes.

4. Training and Education

- **Student Instruction**: Conducts training sessions on relevant regulations (e.g., FAA regulations for amateur rockets in the U.S.) and competition-specific rules.
- **Certification Pathways**: Helps team members pursue individual rocketry certifications if required by competition rules (e.g., NAR Level 1, 2, 3).
- **Culture of Compliance**: Encourages a mindset that meeting regulations and following best practices is essential—not just a "box-checking" exercise.

5. Collaboration with Engineering and Project Leads

- **Integration of Compliance in Design:** Works alongside propulsion, structures, avionics, and recovery teams to ensure design choices meet regulatory and safety criteria from the start (e.g., total impulse category, altimeter redundancy).
- **Change Control:** Ensures that if the team changes motors, materials, or flight profiles, they update permits and safety analyses accordingly.

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- **Competition Rules:** Keeps track of any new or revised rules from student rocket competitions (e.g., EUROC) and helps integrate them into the design and launch planning.

Reference links:

- Compliance Framework, Assessment and Rating

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8.10 Launch Logistics Lead Role Description

Year 2025
EPFL Rocket Team

ROLE DESCRIPTION

Year:	2025
Date:	31/04/2025
Page:	1 / 3

Launch Logistics Lead (LLL)

Project:	Project Spaceshot, EPFL Rocket Team	**Approved by:**	Matthieu Tonneau
Prepared by:	Matthieu Tonneau	**ERT Supervisor:**	ERT President

The Launch Logistics Lead (LLL) oversees the **end-to-end logistics** strategy for the EPFL Rocket Team's mission campaigns—covering **transport mode selection, scheduling, customs/regulatory compliance** (in close coordination with the CCO), **ground operations**, and overall supply chain reliability. The LLL ensures that every necessary piece of hardware, equipment, and consumable arrives at the launch site on time, within budget, and in conformance with all relevant regulations.

These responsibilities fall under **five** main categories:

1. **Logistics Planning and Scheduling**
2. **Interfacing with Transport and On-Site Stakeholders**
3. **Risk Management and Contingency Planning**
4. **Budget and Cost Control for Logistics**
5. **Team Leadership and Cross-Functional Coordination**

DETAILED WORK PACKAGE

1. Logistics Planning and Scheduling

- **Master Timeline:** Develop and maintain the logistics section of the master project schedule, aligning departure/arrival windows with rocket build and integration timelines.
- **Mode Selection:** Choose optimal shipping methods (road, rail, sea, or air) per location (Azores, Esrange, etc.) balancing cost, reliability, and speed.
- **Buffer Management:** Factor in contingency times (±1–2 day arrival certainty) and track shipping milestones to prevent delays to critical path tasks.

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2. Interfacing with Transport and On-Site Stakeholders

- **Freight Forwarder Liaison:** Establish relationships with selected logistics partners or sponsors; finalize shipping contracts and ensure compliance with packing requirements (in coordination with the TCO and TPL).
- **Launch Site Coordination:** Communicate container arrival details, local equipment rentals (forklift, crane) needs, and on-site consumable arrangements with the ground facility managers (e.g., Santa Maria or Esrange staff).
- **Customs Collaboration:** Work with the Chief Compliance Officer (CCO) to prepare and submit relevant documents (ATA Carnet, export/import forms).

3. Risk Management and Contingency Planning

- **Risk Register Oversight:** Maintain a logistic-specific risk log (port strikes, ferry delays, road closures) and define response actions.
- **Real-Time Adjustments:** Monitor progress and decide on fallback options (e.g., expedite by air if delayed).
- **Insurance:** Verify cargo insurance policies and claims procedures.

4. Budget and Cost Control for Logistics

- **Cost Estimation:** Compile shipping quotes, handle negotiations, and propose cost-effective solutions to meet mission needs.
- **Expenditure Tracking:** Track actual transport invoices, keep within the allocated logistics budget, and report variances.
- **Sponsorship Opportunities:** Seek and manage in-kind or discounted partnerships with transport companies.

5. Team Leadership and Cross-Functional Coordination

- **Team Assignments:** Ensure the TCO, TPL, and other supporting members clearly understand tasks and timelines.
- **Cross-Department Collaboration:** Work with engineering leads (structures, propulsion) to confirm readiness of hardware for packing and shipping.

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- **Post-Mission Debriefs:** Conduct lessons-learned sessions with the entire logistics team to improve future campaigns.

Reference links:

- Logistics Management Plan

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8.11 Transport Coordination Officer Role Description

Year 2025		Year:	2025
EPFL Rocket Team		Date:	31/04/2025
ROLE DESCRIPTION		Page:	1 / 2

Transport Coordination Officer (TCO)

Project:	Project Spaceshot, EPFL Rocket Team	**Approved by:**	Matthieu Tonneau
Prepared by:	Matthieu Tonneau	**ERT Supervisor:**	ERT President

The Transport Coordination Officer (TCO) is responsible for the **day-to-day operational interface** with freight carriers, customs brokers, and other transport-service providers. The TCO executes the detailed **booking, tracking, and in-transit support** for all cargo shipments, ensuring real-time visibility and on-time delivery. This role reports to the Launch Logistics Lead (LLL) and works closely with the Chief Compliance Officer (CCO) on export/import requirements.

These activities are organized under **four** key areas:

1. **Carrier Booking and Documentation**
2. **Shipment Tracking and Status Reporting**
3. **Customs Liaison (in Coordination with the CCO)**
4. **Issue Resolution and Operational Adjustments**

DETAILED WORK PACKAGE

1. Carrier Booking and Documentation

- **Freight Quotations & Bookings:** Solicit freight quotes from multiple carriers (sea, road, rail, or air), compare costs and transit times, and finalize bookings with chosen providers.
- **Shipment Documentation:** Prepare or obtain required shipping papers (Bills of Lading, CMR notes, Air Waybills) in coordination with the LLL and the compliance officer to ensure accuracy.
- **Load Plans & Handoffs:** Share container load/stowage info (from the Packaging Plan and TPL) with carriers so they understand cargo composition.

2. Shipment Tracking and Status Reporting

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- **Real-Time Monitoring:** Utilize carrier portals or IoT trackers to monitor container locations and environmental conditions (when relevant).
- **Progress Updates:** Send daily or weekly shipping status to the LLL; highlight any deviations that might require action.
- **ETA Management:** Continuously update expected arrival times and share with on-site contacts who will handle unloading.

3. Customs Liaison (in Coordination with the CCO)

- **Export/Import Filings:** Assist the CCO with creating or submitting customs declarations, carnets, and hazard declarations. Provide carriers with correct commodity codes, valuations, etc.
- **Cross-Border Coordination:** Communicate with customs brokers at each border crossing to avoid clearance delays.
- **Compliance Checks:** Ensure no missing or incorrect paperwork that could result in cargo holds.

4. Issue Resolution and Operational Adjustments

- **On-the-Ground Coordination:** If a container is delayed or rerouted, manage alternative solutions (switch carriers, expedite partial shipments).
- **Carrier Escalations:** Open claims or escalation tickets for damaged or lost goods.
- **Documentation of Incidents:** Log disruptions and resolved solutions for future process improvement.

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8.12 Transport Packaging Lead Role Description

Transport Packaging Lead (TPL)

Project:	Project Spaceshot, EPFL Rocket Team	**Approved by:**	Matthieu Tonneau
Prepared by:	Matthieu Tonneau	**ERT Supervisor:**	ERT President

The Transport Packaging Lead (TPL) focuses on the **physical preparation** of hardware and support equipment for shipping, ensuring proper **container loading, bracing, and compliance** with all packaging requirements. The TPL collaborates closely with the **Packaging Plan** owner (if separate) and ensures every item is **safely stowed and labeled** inside shipping containers prior to handover to carriers.

Core responsibilities align with **five** major areas:

1. **Packaging Plan Alignment and Execution**
2. **Container Loading / Unloading Supervision**
3. **Stowage and Bracing Methods**
4. **Labeling and Marking Compliance**
5. **Post-Shipment Inspection and Re-Pack for Return**

DETAILED WORK PACKAGE

1. Packaging Plan Alignment and Execution

- **Plan Familiarity:** Thoroughly understand the existing Packaging Plan (item-level instructions, hazardous item packaging, labeling specifics).
- **In-House Prep Work:** Coordinate with sub-teams to ensure all mechanical/electronic assemblies are suitably pre-packaged (bags, crates, foam inserts) before container loading day.
- **Preservation Methods:** Where relevant, confirm desiccants, water/vapor-proof barriers, or shock-absorbing materials are applied per the Packaging Plan.

2. Container Loading / Unloading Supervision

- **Loading Day Coordination:** Lead the team physically loading the shipping

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container(s). Oversee correct item placement, weight distribution, tie-down, and safe forklift use.

- **Unloading at Destination:** Provide or coordinate guidelines for on-site crew to safely remove items without damaging them or the container.
- **Damage Prevention:** Check for potential shifting hazards or insufficient bracing.

3. Stowage and Bracing Methods

- **Adherence to Standards:** Use MIL-STD-2073 or equivalent bracing instructions. Confirm that crates/boxes are blocked and cushioned properly.
- **Fragile / Oversized Items:** Devise special rigging or supports for large rocket sections, pressurized cylinders, or sensitive electronics.
- **Shock & Vibration Minimization:** Integrate foam padding or custom frames as needed.

4. Labeling and Marking Compliance

- **Label Standards:** Ensure each package is labeled for content identification (Class III, hazardous material, "Fragile," "This Side Up," etc.) as required by the Packaging Plan and regulatory codes.
- **Container Markings:** Clearly mark container ID, net/gross weights, orientation instructions, and shipping documents pocket if needed.
- **Hazmat Placards:** If shipping hazardous items, confirm the correct hazmat placards or hazard labels are attached (coordinate with the CCO).

5. Post-Shipment Inspection and Re-Pack for Return

- **Arrival Condition Checks:** Inspect the container and cargo upon arrival for damage or tampering. Document findings with the TCO.
- **Return Shipment Prep:** Post-launch, plan and supervise re-packing (if needed). Re-apply any necessary packaging or bracing for the homeward trip.
- **Lessons Learned:** Update the Packaging Plan or bracing methods based on any real-world shipping issues encountered.

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Reference links:

- Logistics Management Plan
- Packaging Plan

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8.13 Training Manager Role Description

Year 2025
EPFL Rocket Team

ROLE DESCRIPTION

Year:	2025
Date:	13/05/2025
Page:	1 / 3

Training Manager (TMA)

Project:	Project SH, EPFL Rocket Team	**Approved by:**	Matthieu Tonneau
Prepared by:	Matthieu Tonneau	**ERT Supervisor:**	Matthieu Tonneau

1 Role Mission

The Training Manager owns the end-to-end training lifecycle for every subsystem and phase of the rocket programme. He/She ensures that:

- Competency gaps are identified through a Training Needs Analysis (TNA),
- An actionable Training Master Plan (TMP) is issued and kept current,
- Training is delivered, tracked, and reported so that the team remains safe, compliant, and launch-ready.

2 Key Accountabilities

	Work-Package Area	Core Responsibilities
1	Training Governance & Strategy	• Define the training policy and annual roadmap. • Align the training budget, scope, and priorities with the Systems Engineering V-cycle and programme milestones. • Chair the monthly Training Review Board.
2	Training Needs Analysis (TNA) Ownership	• Maintain the TNA header data (project, version, date, author). • Define purpose, scope, and reference documents. • Curate the Role & Competency Matrix; keep role IDs in sync with the WBS. • Run the self/manager assessment campaign and calculate weighted gap scores. • Classify gaps into Priority Tiers A-D and update the heat-map.

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3	Training Master Plan (TMP) Development & Execution	• Translate gap IDs into SMART training objectives with KPIs and target dates. • Build and publish the Training Catalogue & Delivery Plan (course, mode, provider, pre-reqs, window, dependencies). • Secure resources (instructors, budget, simulators) and coordinate with subsystem leads and suppliers. • Issue TMP revisions at every gate (Phase 0 → A, A → B, …).
4	Delivery & Logistics	• Schedule classes, e-learning licences, simulator slots, and on-the-job rotations. • Ensure prerequisite checks and manage attendee rosters. • Capture attendance, quiz scores, and certification evidence; archive in the Document Management System.
5	Performance Tracking & Reporting	• Monitor KPI dashboard (gap-closure rate, training completion %, cost vs. budget). • Run after-action reviews and feed lessons learnt into the next TNA cycle. • Present status at Engineering & Operations Reviews and to external auditors if required.
6	Risk Management & Continuous Improvement	• Record residual project risk if training slips; escalate blocking items. • Propose mitigation actions (back-up trainees, vendor alternatives, schedule re-sequencing). • Benchmark against industry best practice; update methodology, scoring weights, and catalogue annually.

3 Interfaces

- Subsystem Leads & Discipline Chiefs – validate competency requirements and approve training success.
- Project Controls & Finance – align on budget allocations and cost tracking.
- Quality / HSSE – ensure training complies with safety standards and audit criteria.
- External Providers – negotiate course content, seat numbers, and delivery windows.

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4 Authority

- Approve internal training materials and course syllabi.
- Authorise training expenditure up to the limit set by the Treasurer.
- Stop-work on activities where mandatory certification has lapsed.

5 Required Profile

- Education: Bachelor's in Engineering, Education, or Project Management.
- Experience: ≥ 2 years coordinating multi-disciplinary training or project controls; exposure to rocketry or aerospace a plus.
- Skills: Scheduling (MS Project / Sheets), data analytics, facilitation, stakeholder management.
- Certifications: Train-the-Trainer or project-management certificate preferred.

6 Reference Documents

- Systems Engineering Handbook
- Risk Assessment
- Training Needs Analysis
- Training Master Plan

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8.14 Project Midterm Presentation

Spaceshot

ERT EPFL ROCKET TEAM

Preliminary assessment of pre-launch operations and logistics for a suborbital vehicle

Wednesday, 08.04.2025

Project Goals

Matthieu Tonneau

Initial Timeline:

- **[2 weeks]:** State of the art
- **[1 week]:** Consolidated scope definition and review
- **[10 weeks]:** Operations study:
  - **[1 week]:** Identification of key relevant deliverables
  - **[2 weeks]:** Expanding the Systems Engineering Plan (SEP) for phases D through E, putting the emphasis on launch preparation and planning.
  - **[1 week]:** Integration of the expanded SEP into current existing framework
  - → **[1 week]:** Systems Engineering Review of updated framework
  - **[5 weeks]:** Case study on the SH launch: applying the developed framework while patching any deficiencies.
- **[1 week]:** Preliminary Operations Review (POR) for the SH launch

State-of-the-Art

Matthieu Tonneau

Separated into to assess the two aspects:

- **Methodology:** methods applied to the planning and scheduling for suborbital class vehicles launch operations
- **Practices:** current and past practices for suborbital class vehicles launch operations

Lessons Learned:

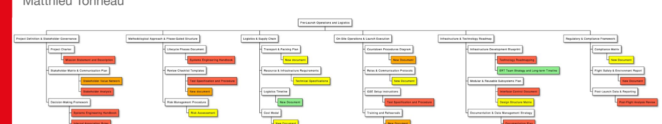
- Most if not all derived from MIL and NASA Standards.
- Adapt to ERT Scale and Scope

Extensive Comparison of the two Launch Site options:

- Esrange, Kiruna, Sweden
- Atlantic Spaceport Consortium, Santa Maria, Azores, Spain

Consolidated Scope

Matthieu Tonneau



- Project Definition & Stakeholder Governance
- Methodological Approach & Phase-Gated Structure
- Logistics & Supply Chain
- On-Site Operations & Launch Execution
- Infrastructure & Technology Roadmap
- Regulatory & Compliance Framework

→

Name	Type	Existing
Mission Statement and Description	Text-based	Yes
Stakeholder Value Network	Diagram	Yes
Stakeholder Analysis	Text-based	Yes
Systems Engineering Handbook	Text-based	Yes
Internal Association Rules	Text-based	Yes
Test Specification and Procedure	Text-based	Yes
New document (Review Checklist)	Diagram	No
Risk Assessement	Table	Yes
New document (Transport & Packing Plan)	Table	No
Technical Specifications	Table	Yes
New Document (Logistics Timeline)	Figure	No
New Document (Cost Model)	Table	No
New Document (Countdown Procedures)	Diagram	No
New Document (Roles & Comms)	Table	No
Test Specification and Procedure	Text-based	Yes
Technology Roadmapping	Text-based	Yes
ERT Strategy and Long-term Timeline	Figure	Yes
Interface Control Document	Text-based	Yes
Design Structure Matrix	Table	Yes
Documentation Plan	Text-based	Yes
New Document (Compliance Matrix)	Table	No
New Document (Training and Rehearsals)	Diagram	No
New Document (Flight Safety & Env.)	Text-based	No
Post-Flight Analysis Review	Text-based	Yes

Structured into 24 Deliverables:

- 9 New
- 15 Already exist

New Deliverables

Matthieu Tonneau

• Review Checklist	Not Started, mostly for late phases (D & E)	→ Diagram
• Logistics Management Plan	Almost Done	→ Text-Based
• Packaging Plan	Done	→ Text-Based
• Logistics Timeline	Done, Integrated within LMP	→ Diagram
• Cost Model	Not Started, benched for now	→ Table
• Countdown Procedures	Not started	→ Diagram + Text
• Roles and Communications	Partly done, lacking communication procedures	→ Table
• Compliance Matrix	Done	→ Text + Table
• Training and Rehearsals Framework	Done, within packaging plan	→ Table
• Flight Safety & Environment Report	Not started	→ Text-Based

Result:
- 1 in progress
- 5 done
- 4 not started

Compliance Framework Assessment and Rating

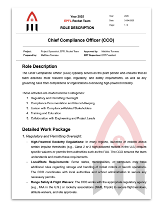
Matthieu Tonneau

Launch and Orbital Licen...

KPI Name	KPI Unit	# KPI Mean	Trend	Last Value	Last Update	% Value 1	% Value 2
Sucessful Launch Probability	[%]	0.8	Improved	85%		75%	85%
Documentation Completeness	[%]	#DIV/0!	N/A	#N/A			
Launch Schedule Adherence	[%]	#DIV/0!	N/A	#N/A			
Cost of Regulatory Compliance	[%]	#DIV/0!	N/A	#N/A			
Risk of Regulatory Delay	[%]	#DIV/0!	N/A	#N/A			

Need:
- Bridge knowledge and culture over multiple years
- Track evolution of the team over time

Objective:
- Continuous audits of the team
- Track Key Performance Indicators over multiple projects
- Build a track-record and a culture of compliance



Packaging Plan

Matthieu Tonneau

Need:
- Have a Systemic and Clear approach to packaging
- Provide a scalable system up to Spaceshot Launch
- Have a framework for tracking, handling, packing and shipping high-value components

Objective:
- Cover all aspects of "Packaging"
- Along Logistics Management Plan guide Engineering teams with a readily usable system

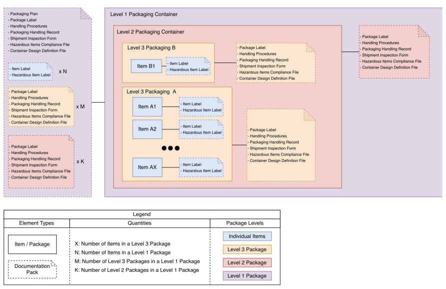
Packaging Plan

Matthieu Tonneau

Based on *NASA NPR6000-1H* & *MIL-ST-2073-1E*

Implementation
- Container **Hierarchy**
- Component **Value**
- Container **Reusability**
- Item **Class**
  - CLass I: Mission-essential items
  - Class II: Delicate or sensitive items not covered by Class I or Class III. Class III: Items requiring special handling and monitoring.
  - Class IV: Those items that may be transported or handled through the use of normal commercial transportation means.
- **Preservation** Method
- Container Design **Requirements**
- **Hazardous Materials** Handling and Documentation

Packaging Plan
Matthieu Tonneau



- Shipment Inspection Form Template
- Design Definition File Template
- Hazardous Items Compliance File
- Packaging Handling Record Templates
- Handling Procedures Template
- Package Label Template
- Item Label Template
- Hazardous Item Label Template
- Personel Training Tracking Matrix Template
- Personnel Training Procedure Template

Total: 11 New Documents Templates

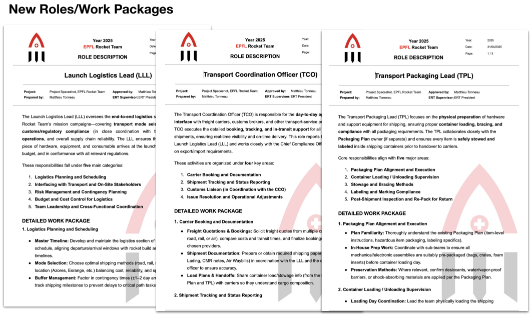
Logistics Management Plan
Matthieu Tonneau

Need:
- Similar to packaging
- Provide a framework for strategic logistical decisions

Objective:
- Since packaging is taken care of: handle transportation to launch site entirely
- Cover: Roles and Responsibilities, Strategy, Shipping Documentation, Schedule and Milestones, "Local" Logistics, Consumables, Risk Management, Personnel Training

Logistics Management Plan
Matthieu Tonneau

New Roles/Work Packages



Logistics Management Plan
Matthieu Tonneau

Responsibilities Management: RACI Matrix

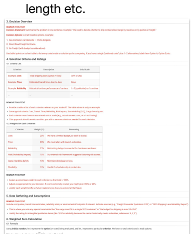
	Engineering Team			Logistics and Packing Team					Management Team							External Stakeholders		
	Systems Engineers	Team Leaders	Engineering Team Members	Head of Logistics	Launch Logistics Lead	Transport Coordination Officer	Transport Packaging Lead	Logistics Team Members	ERT President	ERT Vice-President	ERT Comitee	Head of Sponsoring	Chief Compliance Officer	Chief Financial Officer	Chief Safety Officer	Commercial Stakeholders	Academic Stakeholders	Regulatory Bodies
Packaging Plan																		
Subsytem-Level Document Ownership	A	R	R	I	C	C	C	I	I	I	I	I	C	I	I	C	I	C
Project-wide Document Ownership	R	R	C	I	C	C	A	I	I	I	I	I	C	I	I	C	I	C
Logistics Management Plan																		
Document Ownership	C	C	C	I	A	R	R	I	I	I	I	C	C	C	C	C	I	C
Compliance Framework Assessement and Rating																		
Document Ownership	C	C	I	C	R	R	R	C	C	I	I	I	A	I	I	C	I	C

Logistics Management Plan

Matthieu Tonneau

Logistics Strategy

- Perform tradeoffs to make high-level decisions: launchsite, freight-forwarder, shipping method etc.
- As well as low-level: Choice of last-mile delivery courier, maximum allowable container length etc.



Goal:

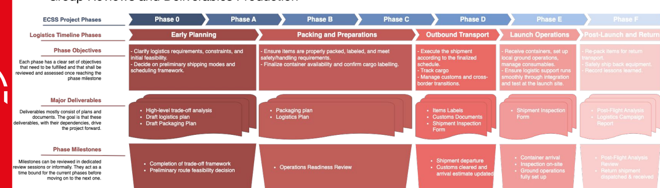
- Track Decisions and Ensure consistency

Logistics Management Plan

Matthieu Tonneau

Logistics Timeline

- Map the actions onto project phases
- Group Reviews and Deliverables Production



Logistics Management Plan

Matthieu Tonneau

Local Logistics

- Operational vehicles: forklifts, trucks, cars etc.
- Consumables: Food, Fuels, Water, medical supplies etc.
- Last-Mile Delivery

Local Handling Vehicle List

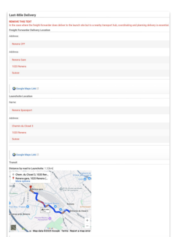
REMOVE THIS TEXT
Use the Next Table to specify what vehicle are needed for pre-launch and ground operations at the launch site. They can be sourced directly from the spaceport or from local renters. Every system that enhances human physical capacities is considered as a vehicle in the context of the following table.

Vehicle Type	Supplier/Contractor	Usecase	Estimated Price *CHF*
Forklift	Esrange Spaceport	Unloading the SLRS Segments from the truck	0.- (Sponsored)

Consumables Sourcing

REMOVE THIS TEXT
In the table below detail the local vendors you have found for any and all items (they can be grouped into categories) that need to be sourced locally. Think of fuels, pressurants, food, water, medical supplies, cleaning supplies and so on. If you cannot the reliability of a particular vendor, mark it as TBD (To Be Determined).

Vendor Name	Type of Shop	Items Categories Sold	Proximity to base of operations *(km)*	Reliability *(1 to 5, qualitative)*
Migros	Supermarket	General goods	1	4
Linde	Liquid and gases supplier	Fuels, Pressurants	10	3



Logistics Management Plan

Matthieu Tonneau

Risk Management

- Same Framework as usual ERT
- Impact/Probability assessment based on ECSS Framework
- Dedicated document for logistics and pre-launch operations

ID	Risk Description	Probability	Impact	Severity	Mitigation	Post Mitigation Probability	Post Mitigation Impact	Post Mitigation Severity	Corresponding Action Items
General - Systems Engineering									
SE-PM-01	Not enough project overview amongst SEs and TLs	4	4	16	Use periodic internal reviews to obtain overview Use 3D printed mockups of the entire LV to obtain overview	2	3	6	Organize internal reviews Organize 3D printed mockup assembly
SE-PM-05	Loss of information during in-between-two-years personnel rotation	4	3	12	Document designs thouroughly, give some time to new members to understand their attributed designs, organize events dedicated to personnel rotation (CDR 2, 1-on-1 discussions between members, kickoff meetings)	3	2	6	Organize an SE discussion during to discuss in-between-two-years personnel rotation
Avionics									
AV-PM-01	Cost overrun	1	3	3	Keep track of budgets	1	1	1	Keep track of budgets
AV-PM-04	Too much work	3	4	12	Divide and conquer, be vocal about what we can and can't do.	2	2	4	Be communicative
Flight Dynamics									
FD-PM-01	TMs get lost in development and start wasting time	2	3	6	Clearly display goals in the FD timeline	1	3	3	update FD timeline regularly, mention it at meetings
FD-PM-05	Missing members next semester	3	4	12	Recruit capable ERT members from SP or next recruitement session	2	4	8	prepare sexy FD presentation with CFD and plots. Already look for members now
Ground Segment									
GS-PM-01	Budget overrun for the Camera Module	3	2	6	Optmize hardware with a minimum number of iteration and solve as much problem as possible with software solutions	2	2	4	Use modular developement hardware to be able to only buy components missing
GS-PM-03	TM have to much work	3	3	9	Focus on only critical missions and ensure good time management	2	2	4	We have 2 years, enjoy this long time to do things in advance. If necessary, put aside nice to have project like camera modules
Payload									
PL-PM-01	Budget overrun for the Acoustic Levitation Prjoect	1	4	4	Try to optimize the components bought, buy cheaper components, reuse ERT s	1	2	2	
PL-PM-04	Mass overrun for one of the PL's projects	4	5	20	Brainstorm new ideas for configuration, ask ST for advices on what pieces don't	2	5	10	
Propulsion									
PR-PM-01	Budget overrun	4	3	12	Ask for tecnical sponsoring for large expensens	3	2	6	Ask for sponsoring when ordering specific Hardware
PR-PM-06	Intellectual Property propagation to thirds	2	1	2	Write papers about important developements to avoid possible problems of confidentail knowledge.	1	1	1	Write documetation of what we are doing
Recovery									
RE-PM-01	Budget overrun for the main parachute	2	3	6	Ensure that the methods of fabrication, material and stitching procedure corresponds to what's been done/reported in the previous ERT Projects	1	3	3	Ask veterans in case of questions / Study rigourously previous manufacturing procedures / Alocate specific buget to materials / Prioritize in house manufacturing
RE-DN-10	Goals for CR1 are not met	4	4	16	Make a more precise timeline and implement an "updates" slide in the WM slides where the TM quickly marks the stage of completion of their previous week perspective.	2	4	8	Add more details and subgoals to the RE Notion timeline / Add and explain to the members the "updates" slides, how to use it and its purpose / If sub-assembly catches some delay, discuss privately with the member what's causing said delay and how the TL can work with the TM to catch it up

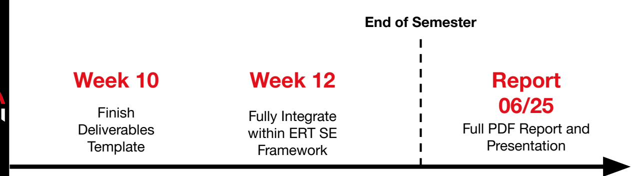
What's Left

Matthieu Tonneau

- Flight Safety and Environment Report
- Review Checklist
- Countdown Procedures
- Cost Model

Next Steps

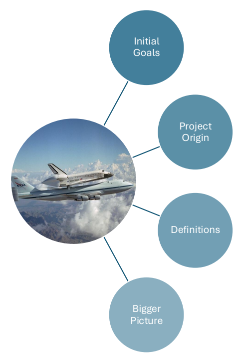
Matthieu Tonneau



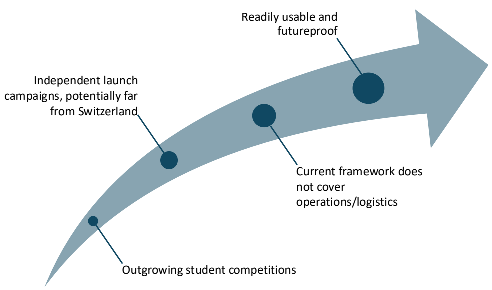
8.15 Project Final Presentation

Introduction

Introduction



Introduction Project Origin



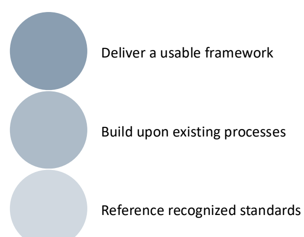
Introduction Definitions

"The process of **planning** and **organizing** to make sure that **resources** are in the **places** where they are **needed**, so that an **activity** or process happens **effectively**."

"Business operations refer to the **activities**, **processes** and **systems** that a company uses to **deliver** its products or **services** to customers and achieve its business **objectives**."

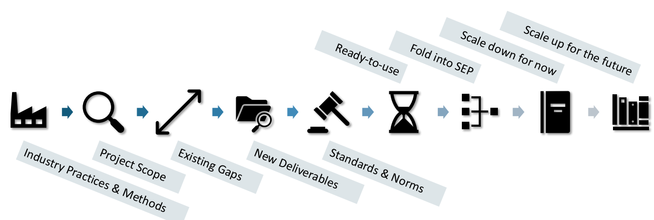
Introduction Initial Goals

Introduction Bigger Picture

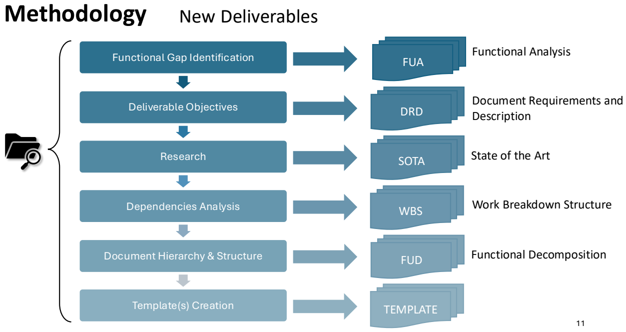


Methodology

Methodology

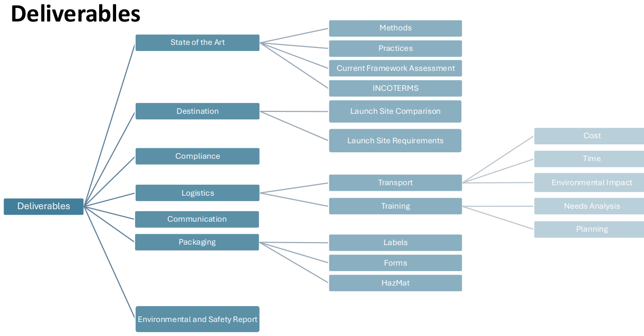


Methodology New Deliverables



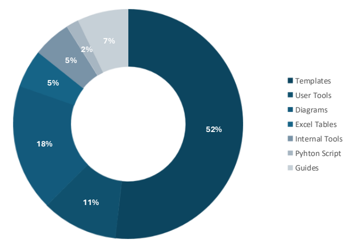
Deliverables

Deliverables



Deliverables Metrics

- 4 **State-of-the-art** Documents/**Guides**
- 3 **Project-specific** Tools
- 6 **User-oriented** Tools
- 5 New **Work Packages**
- 29 Individual **Templates**
- 35 **Requirements**
- 10 **Diagrams**
- 180+ **References**
- 3 **Excel** Documents
- 1 **Python** Script



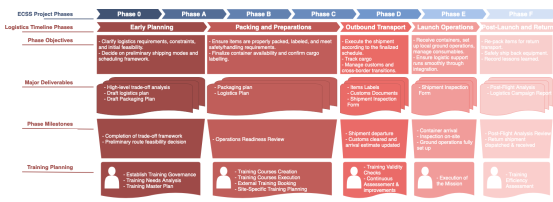
DOCUMENTS CREATED

Integration

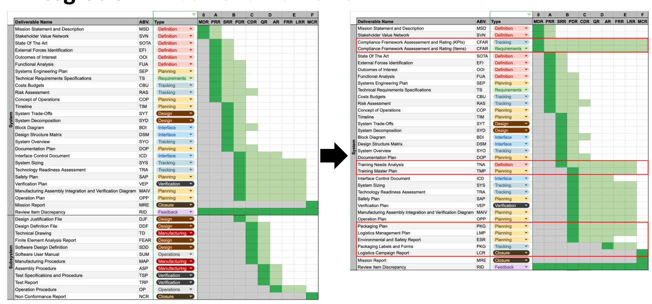
Integration Current Framework

				0	A	B		C	D		E		F
	Deliverable Name	ABV.	Type	MDR	PRR	SRR	PDR	CDR	QR	AR	FRR	LRR	MCR
System	Mission Statement and Description	MSD	Definition										
	Stakeholder Value Network	SVN	Definition										
	State Of The Art	SOTA	Definition										
	External Forces Identification	EFI	Definition										
	Outcomes of Interest	OOI	Definition										
	Functional Analysis	FUA	Definition										
	Systems Engineering Plan	SEP	Planning										
	Technical Requirements Specifications	TS	Requirements										
	Costs Budgets	CBU	Tracking										
	Risk Assessment	RAS	Tracking										
	Concept of Operations	COP	Planning										
	Timeline	TIM	Planning										
	System Trade-Offs	SYT	Design										
	System Decomposition	SYD	Design										
	Block Diagram	BDI	Interface										
	Design Structure Matrix	DSM	Interface										
	System Overview	SYO	Tracking										
	Documentation Plan	DOP	Planning										
	Interface Control Document	ICD	Interface										
	System Sizing	SYS	Tracking										
	Technology Readiness Assessment	TRA	Tracking										
	Safety Plan	SAP	Planning										
	Verification Plan	VEP	Verification										
	Manufacturing Assembly Integration and Verification Diagram	MAIV	Planning										
	Operation Plan	OPP	Planning										
	Mission Report	MRE	Closure										
	Review Item Discrepancy	RID	Feedback										
Subsystem	Design Justification File	DJF	Design										
	Design Definition File	DDF	Design										
	Technical Drawing	TD	Manufacturing										
	Finite Element Analysis Report	FEAR	Design										
	Software Design Definition	SDD	Design										
	Software User Manual	SUM	Operations										
	Manufacturing Procedure	MAP	Manufacturing										
	Assembly Procedure	ASP	Manufacturing										
	Test Specifications and Procedure	TSP	Verification										
	Test Report	TRP	Verification										
	Operation Procedure	OP	Operations										
	Non Conformance Report	NCR	Closure										

Integration   New Timeline



Integration   Current Framework



Conclusion

Conclusion   Why do we need this ?

Issues that arose (**ERT** & **Others**)

- Limited planning in packaging → **Packaging Plan**
- Customs Documents hastily filed → **Compliance Framework**
- Work Packages left to TL & SE → **New Roles**
- Transport delays → **Transport Model**
- Communication mishaps → **Communication Procedures**
- Cost planning failure → **Cost Model**
- Cumbersome lessons transmission → **Exhaustive Guidelines**
- No consistency in recurring documentation → **Standardized Templates**

Conclusion

- Balance between **thoroughness** and **usability**
- Emphasis on providing a "**keys-in-hand**" solution
- Heavily **documented**, **sourced** and **referenced**
- Integrates within **existing processes**
- Expands on **mission-critical** avenues