Project NOCTURNA

Recovery and Payload Technical Design Report

Redshift Aerospace

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"Mankind yearns for god's heaven!"

Contents

1. Executive Summary

Project NOCTURNA is a modular high-altitude aerospace research payload developed by **Redshift Aerospace** for the experimental validation of autonomous avionics systems, telemetry infrastructures, GNSS reliability, and redundant recovery architectures during atmospheric flight operations.

The payload is deployed at approximately **9,000 meters AGL**, where it transitions into an autonomous parachute-assisted descent phase while continuously recording and transmitting synchronized telemetry and navigation datasets including GNSS positioning, inertial measurements, barometric altitude, telemetry quality metrics, and avionics health parameters.

The mission focuses on evaluating:

- GNSS signal integrity and positional consistency;
- telemetry robustness during dynamic RF conditions;
- autonomous avionics reliability;
- redundant recovery-system performance;
- inertial and GNSS trajectory correlation accuracy.

The payload integrates:

- redundant avionics systems;
- autonomous recovery electronics;
- long-range telemetry communications;
- modular embedded architectures;
- independent power systems.

The structure was designed in **SolidWorks** and validated using **ANSYS finite-element simulations**. The payload follows a modular rail-and-bulkhead architecture manufactured from **Aluminum 6061-T6** and optimized to withstand compressive loading conditions approaching **6000 N**.

Internally, the platform uses a **CubeSat-inspired 1U compartmentalization architecture**, allowing scalable subsystem integration, simplified avionics access, and future payload expansion.

This report presents the mission architecture, avionics systems, structural engineering, telemetry infrastructure, recovery systems, EuRoC compliance strategy, and preliminary subsystem cost estimations associated with Project NOCTURNA.

2. Mission Overview

2.1. Mission Objectives

The primary mission objective is the experimental evaluation of GNSS integrity, telemetry robustness, and autonomous avionics performance during high-altitude deployment and controlled atmospheric descent.

Secondary objectives include:

- validation of redundant avionics and recovery systems;
- evaluation of autonomous deployment architectures;
- telemetry-link verification during high-altitude operations;
- acquisition of synchronized inertial and GNSS datasets;
- validation of fault-tolerant embedded systems;
- demonstration of modular CubeSat-inspired payload integration methodologies.

The project additionally establishes a scalable aerospace research platform for future work involving resilient navigation systems, autonomous payload architectures, and redundancy-oriented avionics infrastructures.

2.2. Mission Profile

The payload is transported to approximately **9,000 meters altitude** using a high-power launch vehicle. During ascent, the avionics infrastructure continuously monitors acceleration, rotational dynamics, pressure evolution, telemetry quality, and GNSS consistency under realistic aerospace flight conditions.

Following autonomous separation from the launch vehicle, the payload deploys an independent parachute-assisted recovery system and transitions into a stabilized atmospheric descent phase representing the primary scientific operational window of the mission.

During descent, the payload continuously records and transmits:

- GNSS coordinates;
- inertial navigation data;
- telemetry metrics;
- altitude and pressure measurements;
- avionics and recovery-system status information.

The mission profile is divided into five operational phases:

- launch;
- ascent;
- payload separation;
- stabilized descent;
- recovery and post-flight data extraction.

2.3. Engineering Philosophy

Project NOCTURNA follows a modular and redundancy-oriented engineering philosophy emphasizing:

- operational reliability;
- fault tolerance;
- scalable avionics architectures;
- autonomous operational capability;
- simplified subsystem integration.

Critical subsystems including deployment electronics, telemetry infrastructures, avionics power systems, and recovery architectures incorporate independent and fault-tolerant methodologies intended to minimize single-point failures throughout all mission phases.

3. Structural and Mechanical Design

3.1. Structural Architecture

The NOCTURNA payload follows a modular elongated structural configuration inspired by CubeSat architectures.

Parameter	**Value**
Payload Length	50 cm
Payload Width	10 cm
Payload Height	10 cm
Structural Configuration	Modular 5U Architecture
Internal Segmentation	1U Compartmentalization

Table 1: Payload Overall Dimensions

The structure is internally segmented into standardized **1U compartments** approximately measuring:

10 cm × 10 cm × 10 cm

This architecture improves subsystem organization, cable routing, vibration isolation, maintenance accessibility, and future scalability.

3.2. Material Selection

The primary structural material is **Aluminum 6061-T6**, selected for its:

- high strength-to-weight ratio;
- machinability;
- corrosion resistance;
- dimensional stability;
- compatibility with CNC manufacturing.

The structural architecture consists of:

- four longitudinal structural rails;
- internal reinforcement bulkheads;
- front and rear end-cap structures;
- avionics mounting interfaces;
- M3 fastening systems.

The rail-and-bulkhead configuration provides efficient load distribution, high torsional rigidity, subsystem compartmentalization, and simplified avionics integration.

3.3. CAD Development and Structural Validation

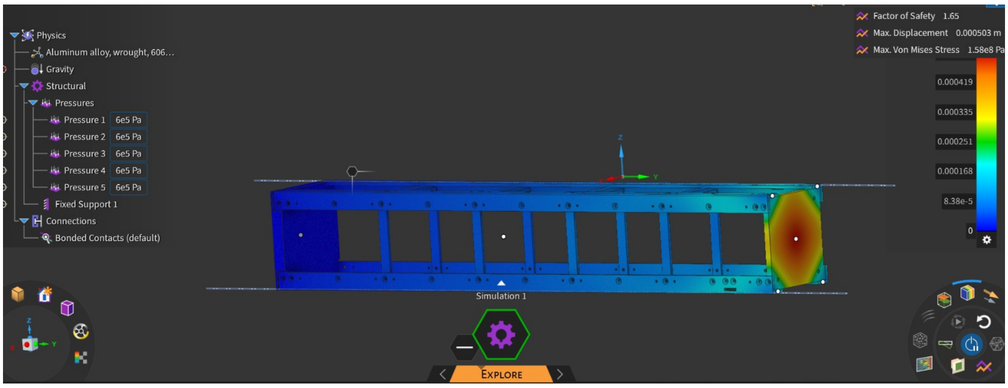
The payload was developed using **SolidWorks CAD software** with emphasis on manufacturability, structural rigidity, subsystem accessibility, and modular integration.

Finite-element validation was performed using **ANSYS** to evaluate:

- stress distribution;
- structural deformation;
- fastening-point loading;
- compressive resistance;
- global rigidity.

The simulations confirmed structural resistance against compressive loads approaching:

6000 N



Aluminum alloy, wrought, 606...
Pressure 1 6e5 Pa
Pressure 2 6e5 Pa
Pressure 3 6e5 Pa
Pressure 4 6e5 Pa
Pressure 5 6e5 Pa
Factor of Safety 1.65
Max. Displacement 0.000503 m
Max. Von Mises Stress 1.58e8 Pa

Figure 1: ANSYS structural validation results.

3.4. Structural Components

The payload integrates multiple independently manufactured structural elements optimized for rigidity, manufacturability, and modular assembly compatibility.

3.4.1 Longitudinal Rail Structure

The longitudinal rails form the primary load-bearing skeleton of the payload and provide structural rigidity, bending resistance, torsional stability, and avionics mounting capability.

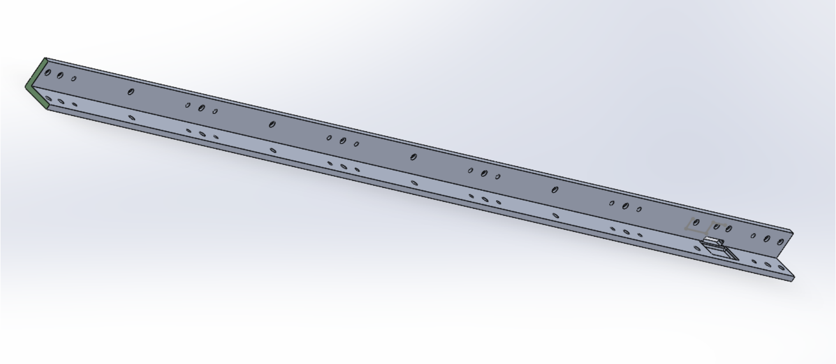


Figure 2: Longitudinal structural rail component.

3.4.2 Bulkhead Reinforcement Structure

Internal bulkheads provide structural reinforcement, subsystem isolation, vibration reduction, and CubeSat-inspired compartmentalization.

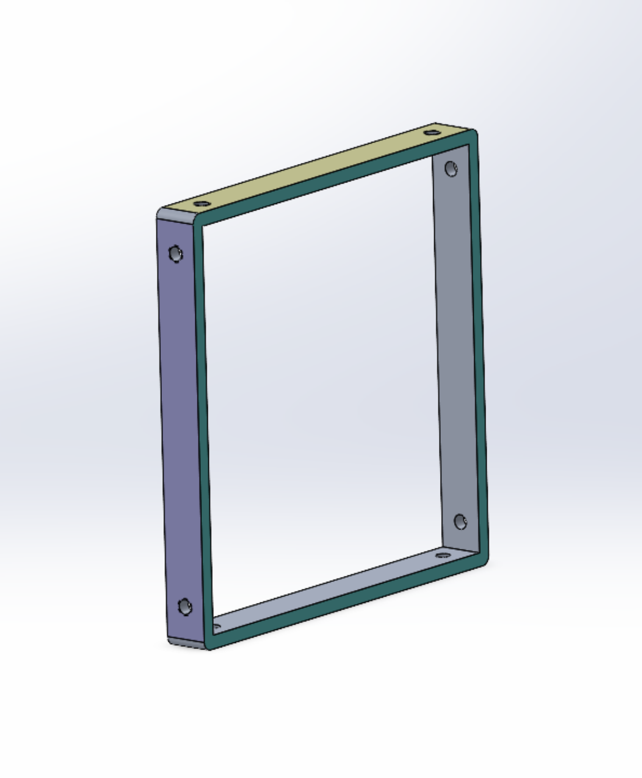


Figure 3: Bulkhead reinforcement structure.

3.4.3 Front End Cap Structure

The front end-cap improves rigidity, structural alignment, load transfer, and avionics protection.

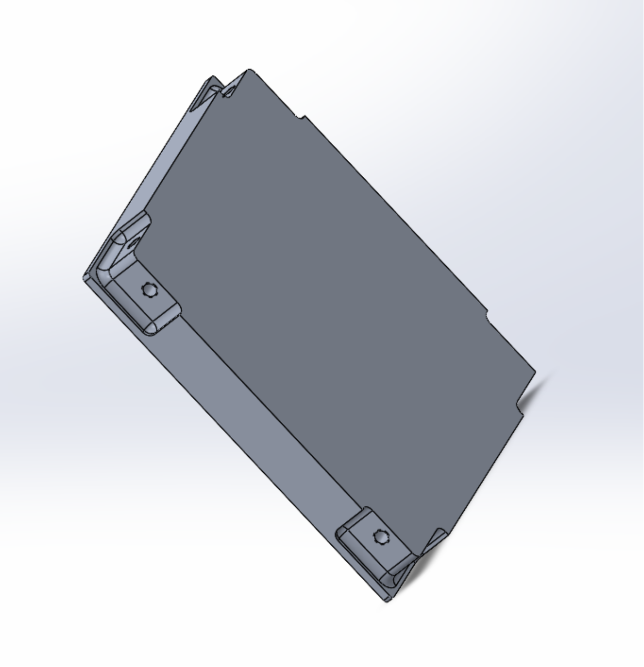


Figure 4: Front end-cap structure.

3.4.4 Rear End Cap Structure

The rear end-cap provides subsystem mounting interfaces, assembly stabilization, and structural closure for the payload architecture.

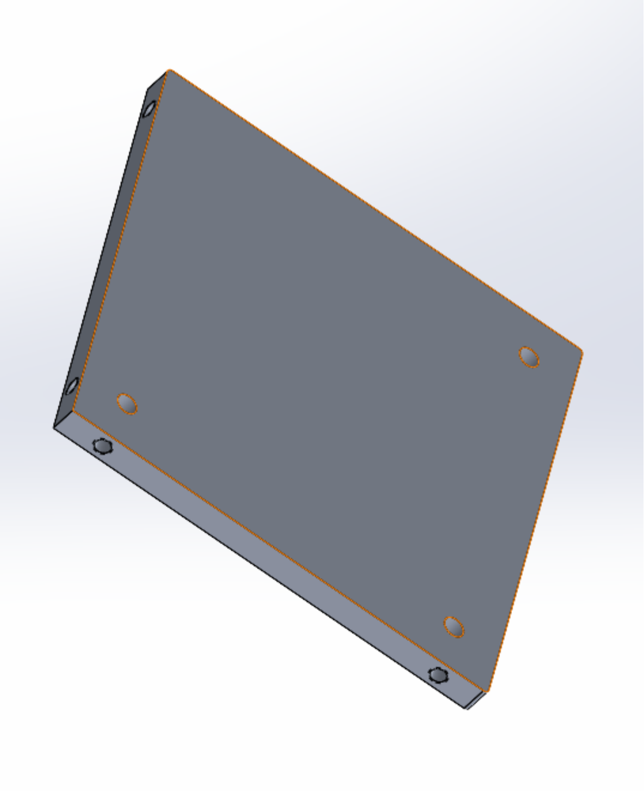


Figure 5: Rear end-cap structure.

3.4.5 Integrated Structural Assembly

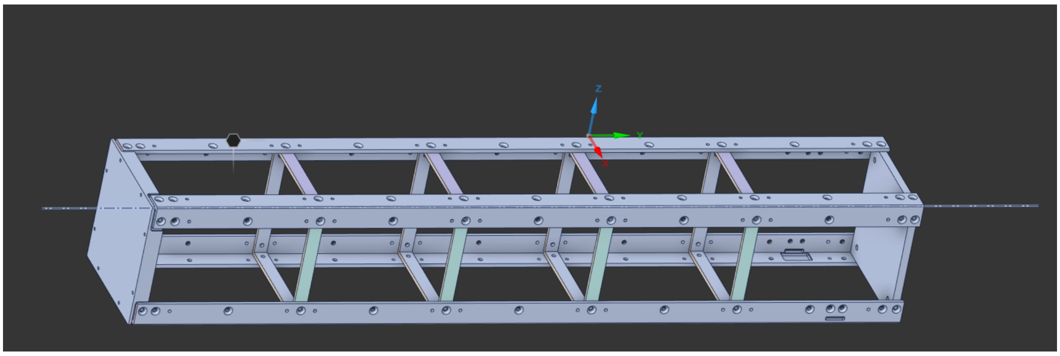


Figure 6: Final integrated structural assembly of the NOCTURNA payload architecture.

The final structural platform combines lightweight construction, modular compartmentalization, redundancy-oriented subsystem integration, and aerospace-grade mechanical rigidity optimized for high-altitude deployment and autonomous recovery operations.

4. Recovery and Deployment Systems

4.1. Recovery Architecture

The NOCTURNA recovery system was designed as a fully autonomous deployment and stabilization architecture optimized for high-altitude atmospheric descent operations.

Unlike conventional timer-based systems, the payload uses an infrared proximity-based separation-detection methodology. While integrated within the launch vehicle, the infrared sensor continuously detects surrounding structural surfaces and inhibits parachute deployment authorization. Following payload ejection, the absence of nearby surfaces confirms successful separation and authorizes deployment logic activation.

The deployment architecture integrates:

- infrared separation-detection sensors;
- autonomous deployment electronics;
- CO2 deployment actuation systems;
- parachute stabilization hardware;
- redundant avionics supervision.

4.2. CO2 Deployment System

The parachute deployment mechanism is based on an electronically controlled CO2 actuation system.

Once separation is validated, the avionics infrastructure activates a MOSFET-controlled puncture mechanism which perforates a pressurized CO2 cartridge. The generated gas expansion deploys the parachute system and stabilizes the payload during descent.

Compared to pyrotechnic systems, the CO2 architecture reduces thermal loading, ignition complexity, and structural shock exposure while maintaining rapid deployment characteristics.

4.3. Recovery Electronics

The recovery subsystem is integrated within the centralized avionics architecture and operates primarily on a 3.3V electrical bus with auxiliary regulated 5V support where required.

The system integrates:

- STM32F405 primary avionics;
- Fluctus backup flight computer;
- telemetry subsystems;
- deployment-control electronics;
- infrared separation sensors;
- CO2 actuation hardware.

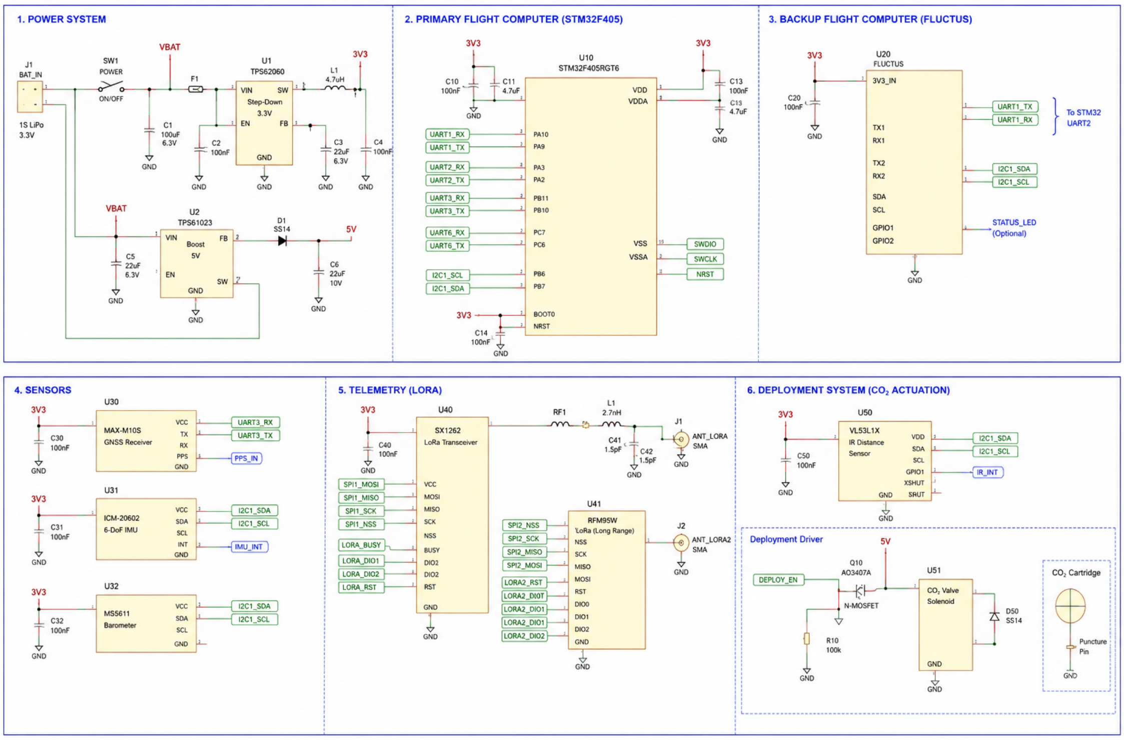


Figure 7: High-level electrical architecture of the avionics and deployment systems.

The layered deployment methodology significantly improves redundancy, deployment reliability, and EuRoC compliance regarding autonomous recovery-system architectures.

4.4. Manufacturing and Integration Status

Project NOCTURNA is currently undergoing final conceptual and preliminary engineering development. Manufacturing, subsystem integration, and verification activities will begin following official competition acceptance and will be conducted in collaboration with the project's academic and industrial partners.

5. Preliminary Payload Cost Estimation

Component	**Qty**	**Category**	**Cost (€)**
Front End Cap Structure	1	Structure	21.75
Rear End Cap Structure	1	Structure	13.87
Bulkhead Structures	4	Structure	99.05
Structural Rails	4	Structure	84.00
Fastening Hardware	1 Set	Structure	25.00
Manufacturing Shipping	1	Structure	27.00
STM32F405 Flight Computer	1	Avionics	35.00
Fluctus Backup Flight Computer	1	Avionics	230.00
Professional GNSS Module	1	Avionics	550.00
SX1262 LoRa Module	2	Avionics	32.00
RFM95W Telemetry Module	1	Avionics	18.00
Sensors and IMU Systems	1 Set	Avionics	65.00
Flash Storage	1	Avionics	12.00
Voltage Regulation Electronics	1 Set	Avionics	35.00
PCB Manufacturing	1 Set	Avionics	80.00
Connectors and Wiring	1 Set	Avionics	40.00
RAPTOR CO2 Deployment System	1	Recovery	185.95
12g CO2 Cartridge	1	Recovery	8.00
Valve Actuator	1	Recovery	35.00
Infrared Sensor	1	Recovery	12.00
Deployment Electronics	1 Set	Recovery	18.00
Parachute Recovery System	1	Recovery	65.00
Recovery Harness	1 Set	Recovery	25.00
3.3V LiPo Battery System	2	Power Systems	40.00
Battery Protection Circuitry	1 Set	Power Systems	18.00
Voltage Regulation Modules	1 Set	Power Systems	20.00
Power Distribution Hardware	1 Set	Power Systems	15.00
Charging Electronics	1 Set	Power Systems	20.00
TOTAL ESTIMATED PAYLOAD COST			**1829.62**

Table 2: Preliminary subsystem-level payload cost estimation.