CLEANCUBE
A Zero Debris CubeSat Platform

Clean Space Days 2026

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Industrial and Academic Consortium

Customer

Tyvak International: Prime Contractor, responsible for project coordination, system design, requirements management and future mission implementations

Prime Contractor

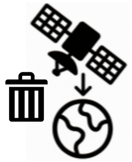
AIKO: Subcontractor responsible for the space and ground SW algorithms for collision avoidance and health monitoring

Università Di Torino: Subcontractor responsible for Space Debris Detector Camera development

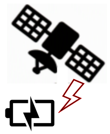
Sub-Contractors

Mission Objectives

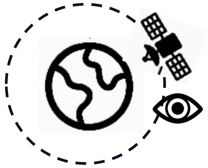
The CLEANCUBE mission concept aims to study an innovative CubeSat design to demonstrate and validate the ESA Space Debris Mitigation Requirements through an In-Orbit Demonstration (IOD) mission.



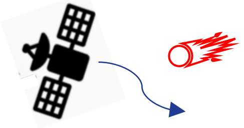
1. Reliable disposal at end-of-life
Ensuring satellite can safely clear the protected LEO region within the required timeframe.



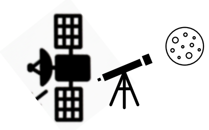
2. Reliable passivation
Guaranteeing the systematic deactivation of all onboard energy sources to prevent explosions.



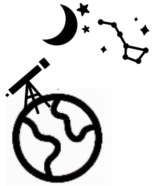
3. System Resilience and Monitoring
Health monitoring and fault management systems to detect and isolate anomalies for reliable disposal.



4. Collision risk reduction
Reducing in-orbit collisions probability enhancing collision avoidance capabilities and situational awareness



5. In Space Debris Detection
Contribution to Space Situational Awareness detecting orbital debris with photodetector camera system.



6. Assessment of Visual Brightness and impacts on radio astronomy
Visual magnitude assessment, reducing the impact of the satellite on astronomical observations.

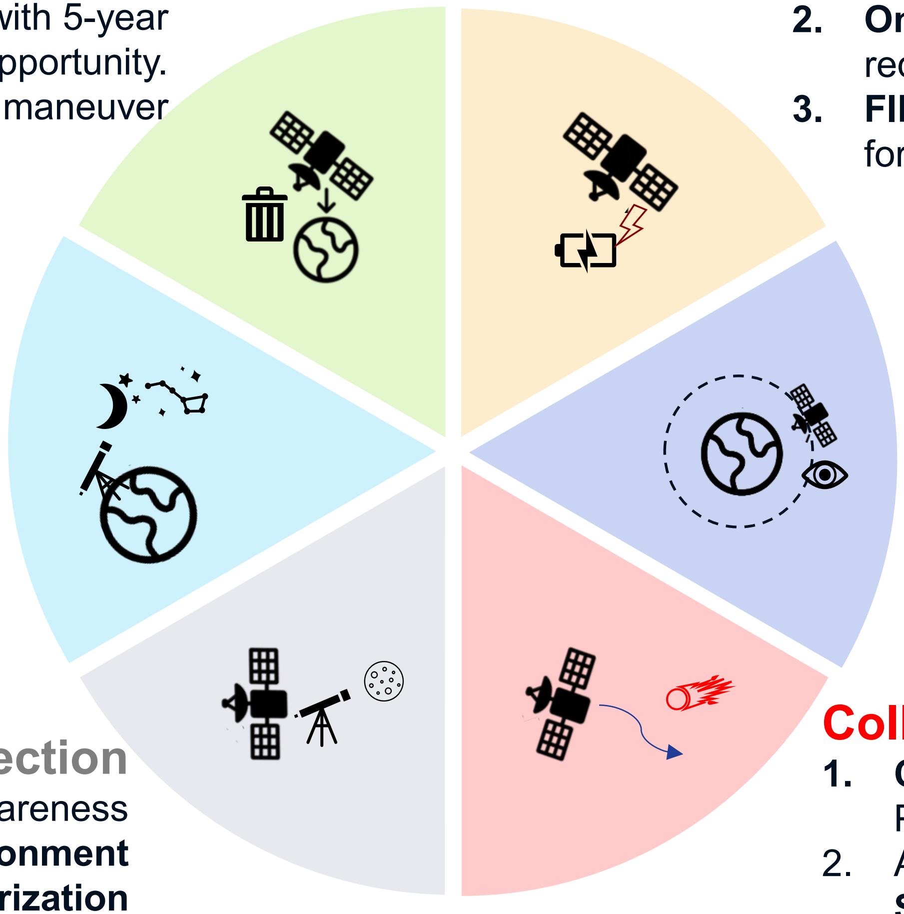
Selected approach to reach the main technical challenges

Reliable disposal at end-of-life

1. **Assessment** of potential deorbiting method solution
2. **Baseline identification** compatible with 5-year re-entry and rideshare launch opportunity.
3. **ΔV budget allocation** for a deorbiting maneuver

Reliable passivation

1. **Definition of Passivation strategy** (Batteries and Thruster)
2. **One fault tolerant passivation** (via functionality redundancy)
3. **FIDES Methodology** applied to a reference module for reliability assessment.



Visual Brightness

Analysis of the visual magnitude considering common external coatings solution

System Resilience and Monitoring

Based on enhance **real-time On-Board Health Monitoring** and on **ground predictive maintenance.**

In Space Debris Detection

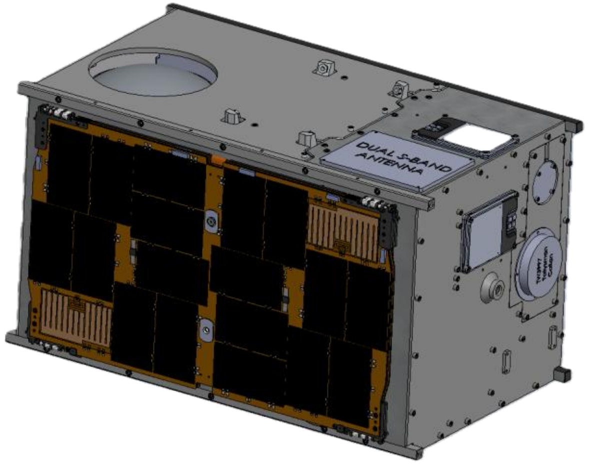
Enhancing Space Situational Awareness via **in orbit debris environment characterization**

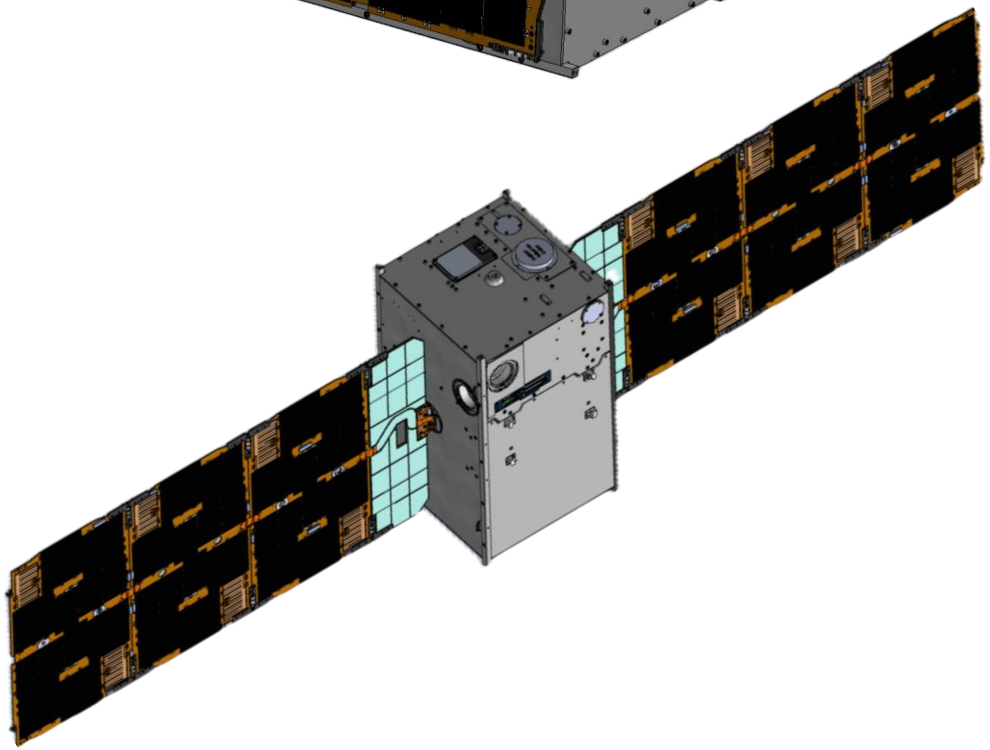
Collision risk reduction

1. **CAMs sequence** assessment based on selected Propulsion System
2. Assessment of **MCC and Space Surveillance Segment interaction**
3. Evaluation of the **Collision Avoidance module** added value

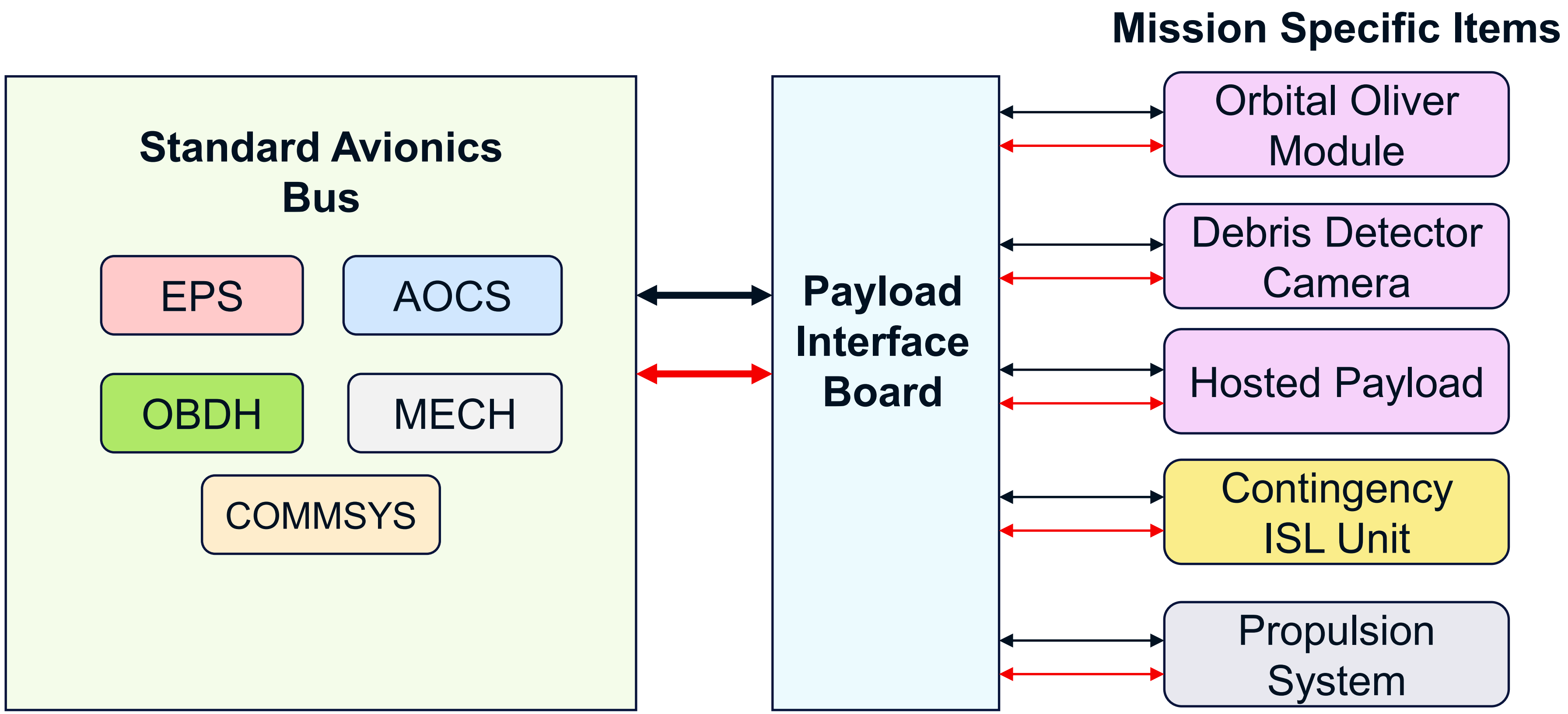
Mission Overview

TYVAK-CLEANCUBE MISSION	
Space segment	TYVAK 16U Platform
Target Launch Window	Q1-Q2 2028
Launch System	Compatibility proven with Vega C (Baseline), Falcon 9 and other commercial launchers
Baseline Orbit	SSO – 510 km – LTAN 10:30
Heritage	Based on flight-proven Tyvak and COTS avionics modules successfully operated in multiple Tyvak missions.





Space Segment System Architecture



Mission Specific Module (I) – Perseus Propulsion System

Propulsion System for this mission required:

- Recurrent **6 DOF manoeuvre capabilities**
- **High maneuver granularity**
- **Low time-to-fire**
- Δ**V** compliant with **CAMs and deorbiting maneuver**.

To achieve
Collision Risk reduction &
Reliable disposal at end-of-life

Baseline leverages on the **Perseus Thruster**, a Cold Gas propulsion module developed by Tyvak and T4i in the framework of the ASI-IPERDRONE mission, successfully flown in 2024.

Specification	Capabilities
Max Envelope	2.5U
Wet Mass	4 kg
Power	2 W during idle ; < 30 W during firing
MEOP	16.8 bar (tank + high-pressure lines) 1.5 bar (low-pressure lines)
Valves configuration	**10 nozzle valves**
Maximum Thrust (X/Y/Z)	9 /9 / 27 mN
Thrust Vectoring	**6 DOF**
MIB	**< 0.5 mNs**
Specific Impulse	> 40 s
Total Impulse	**450 Ns**
Pre-firing times	**60 s**

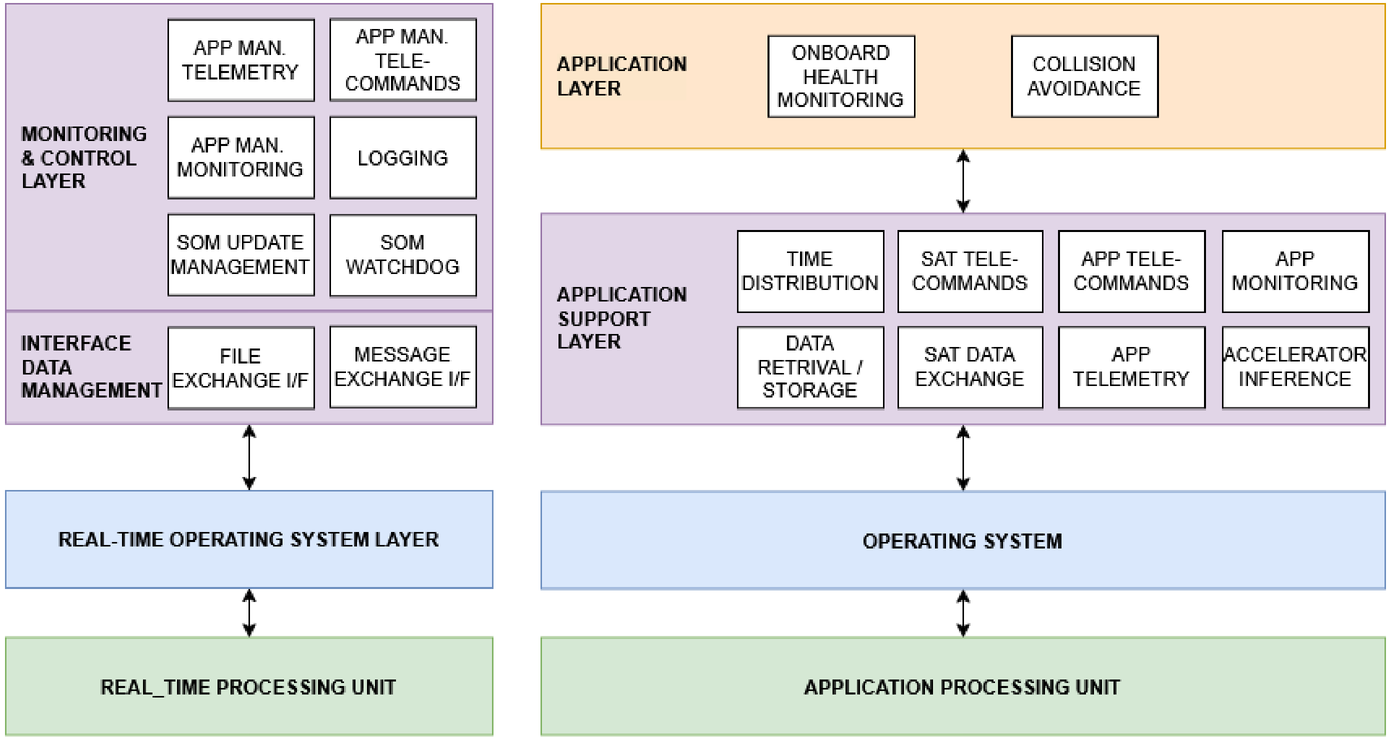
Mission Specific Module (II) – Orbital Oliver Module

The proposed zero debris platform relies on Orbital Oliver Module to enable onboard advanced AI-based FDIR and autonomous collision avoidance.

Advanced functionalities such as:

- machine learning-based telemetry analysis for platform health monitoring,
- goal-driven mission planning,
- reactive and proactive task scheduling,
- telecommand dispatching.

Orbital Oliver block diagram architecture



- The Onboard cognitive unit directly interfaces with the OBC, providing alerts, commands and operative plans.
- This architecture provides full configurability while keeping the OBC in control of all system functions and commands.

Mission Specific Module (III) – Debris Detector Camera Payload

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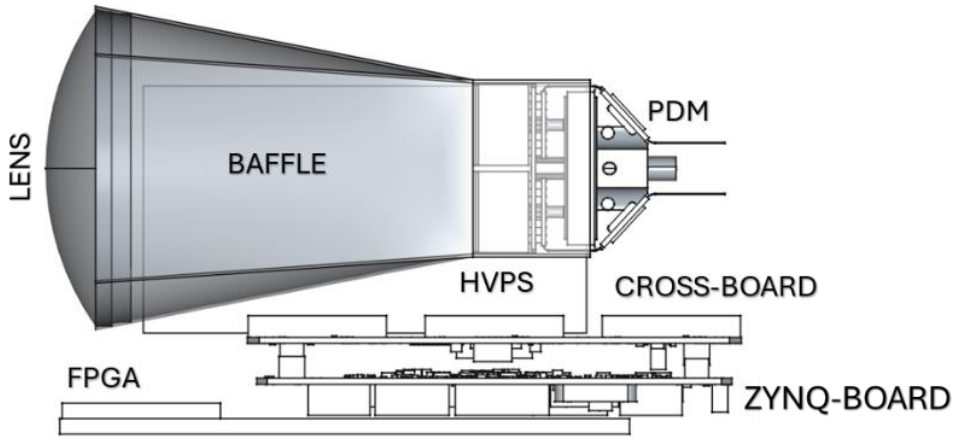
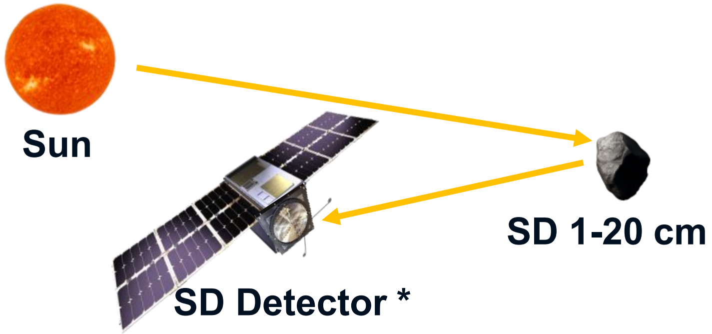
A TERRAN ORBITAL COMPANY
AIKO
UNIVERSITA DEGLI STUDI DI TORINO

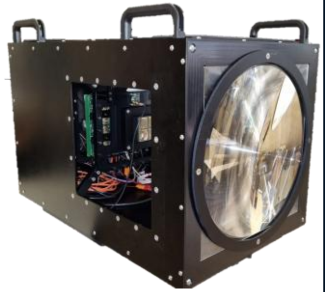
- **Debris Detection method** based on albedo reflection, developed by the University of Turin and adapted from JEM-EUSO collaboration for the Mini-EUSO experiment, onboard the ISS since 2019.
- **Principle of detection**: based on the albedo effect, light reflected from the debris could be observed at twilight/sunrise.





Debris Detector Prototype
used for ground testing.

UNIVERSITÀ DI TORINO
JEM-EUSO Joint Exploratory Missions Extreme Universe Space Observatory
INFN



Main Characteristics	
Total envelope	22x15x14 cm
Fresnel Lens diameter	10 cm
Focal length	13.5 cm
Photo detector sensing element	2×2 matrix of Multi Anode Photo Multipliers (8×8-pixel array each)
Sub-system Modules	FPGA Processing and Control Board
Main operational modes	- CONTINUOUS ACQUISITION - TRIGGER ACQUISITION

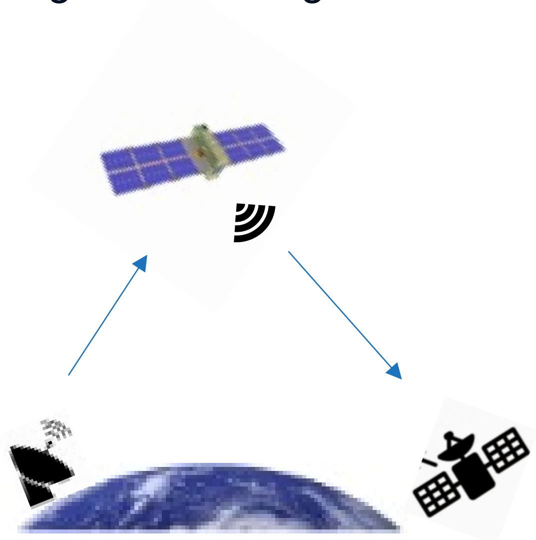
Mission Specific Module (IV) – ISL Link

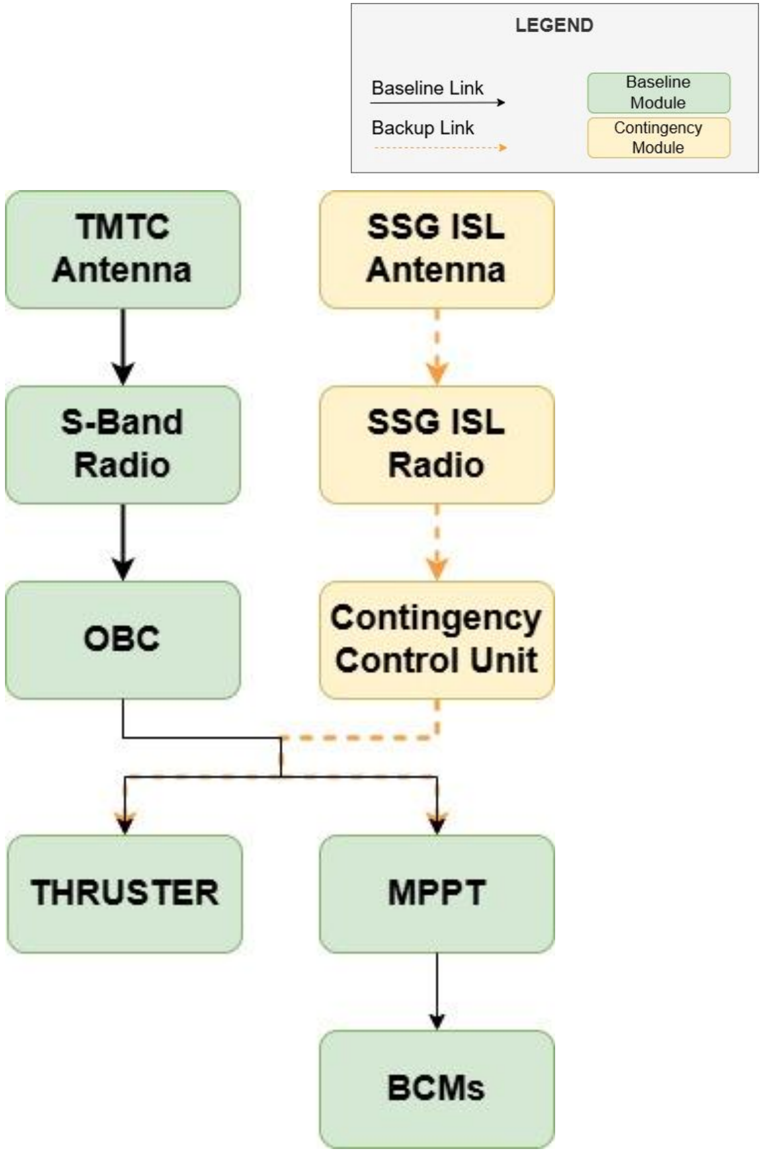
Integration of an Inter-Satellite Link to decouple the communication chain:

- To ensure the **One fault tolerant functional chain for end-of-life disposal operations**
- To **command passivation sequences (**by-passing traditional TMTC link**)**
- To provide a **faster response for CAMs**, even when the spacecraft is not in direct visibility with the selected ground station.

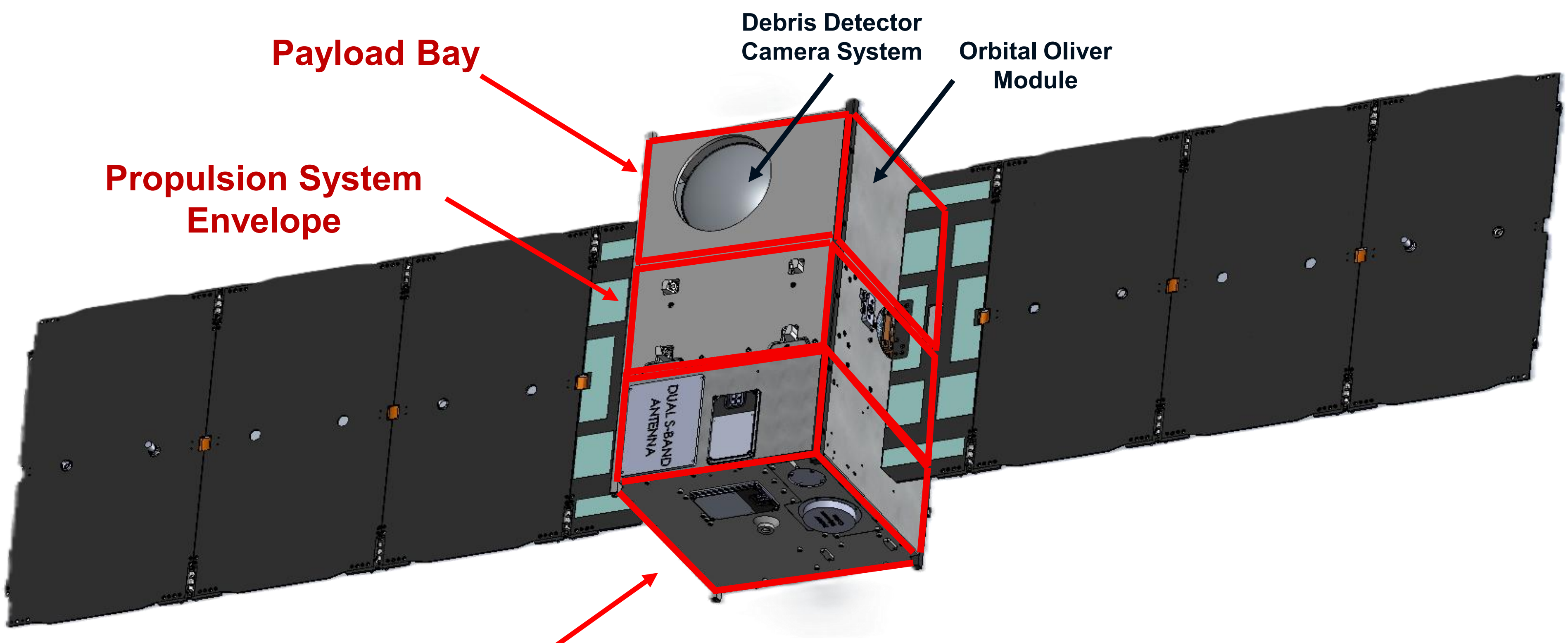
Baseline leverages on **COTS Space-Space-Ground (SSG) ISL Radio**

- L-Band Communication
- Leveraging on the Iridium constellation network
- To extend global coverage without disruptive pointing or pass planning.





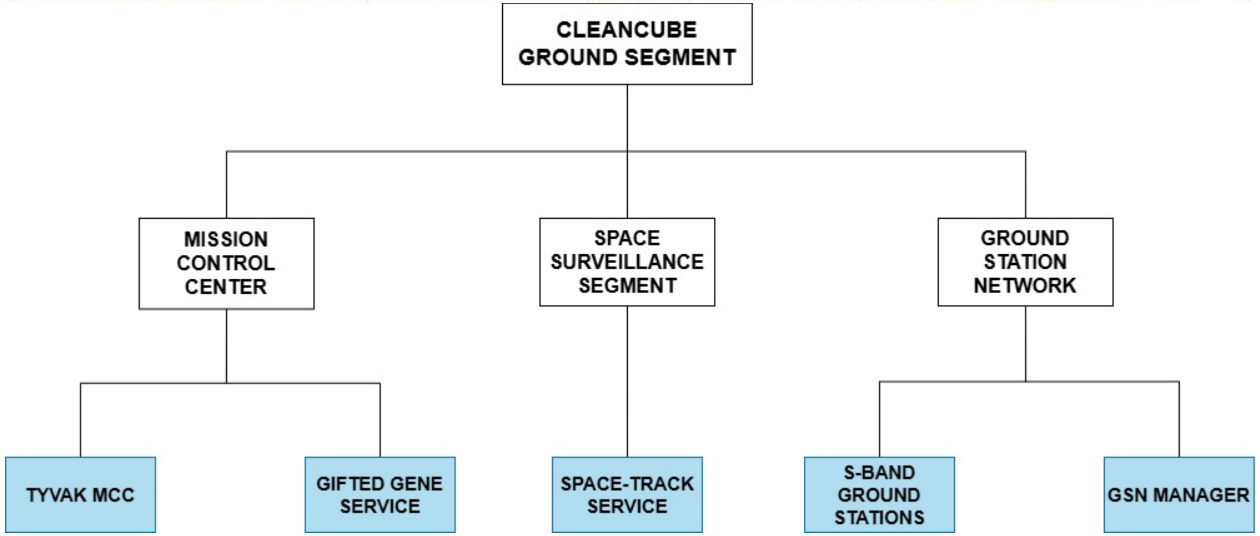
Spacecraft CAD – Preliminary Internal Accommodation



Ground Segment

- The **Tyvak MCC** is based on a proven software infrastructure, leveraging a command, control, data handling, and dissemination suite with **heritage from 18 flown satellite missions**.
- The MCC is fully integrated with **Tyvak's extensive global ground station network (TGN)**, comprising both company-owned stations and third-party operated assets.
- Complementing the MCC, **gifted_GENE suite**, provided by AIKO Space, delivers predictive maintenance and anomaly detection capabilities using historical and near-real-time telemetry data.
- A **Space Surveillance Segment** is integrated, as third part entity, in the baseline Ground Segment architecture, to ensure the tracking, the unambiguous identification of the spacecraft, and to support all collision avoidance procedures.

Tyvak International Mission Control Room, Torino (Italy)



System Design Open Trade-offs to Achieve Mission Objectives

Deorbit Effectiveness to ensure reliable end-of-life disposal

The current baseline orbit (~510 km) enables uncontrolled re-entry compliant within the 5-years requirement.

For higher operational altitudes, the baseline propulsion system supports active deorbit maneuvers, providing ~30 km of orbit reduction.

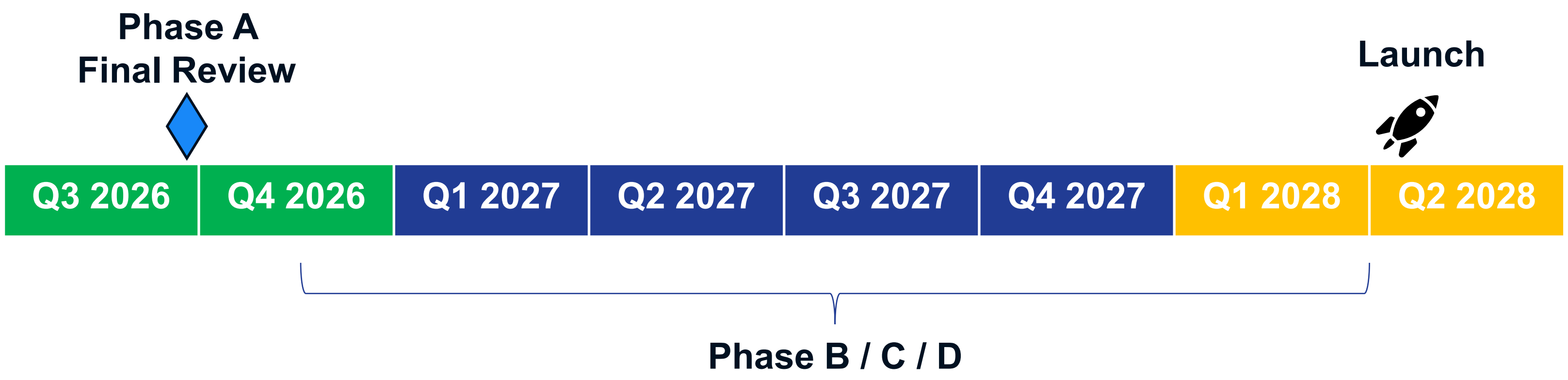
- A **propulsion system trade-off** remains open to assess alternative thrusters with enhanced deorbit capability (>30 km altitude reduction).
  - Support missions at higher baseline orbits, ensuring compliance with the 5-year re-entry requirement through end-of-life orbit reduction.
  - Preserve the high reliability of the baseline design.
  - Ensure proven capability to execute Collision Avoidance Maneuvers (CAM)

- Orbital decay with **dedicated drag sail trade-off** is ongoing, in order to:
  - Assess reliability and overall system robustness
  - Evaluate compatibility and integration with the platform (Mass and Envelope availability)
  - Perform quantitative analysis of increased collision risk due to larger cross-sectional area
  - Assess the orbit decay effectiveness

Next steps and Path Forward

- **Consolidation and closure of the open design trade-offs**
- **Finalization of the overall system design and definition of platform–payload interfaces**
- **Working on Reliability Assessment to ensure compliance with the quantitative reliability requirements for passivation of critical subsystems and end-of-life disposal**

  Phase A Status: FIDES Methodology applied to a reference Standard Avionics Module
  - ✓ To benchmark results against available in-orbit data
  - ✓ To Assess benefits and potential limitations of extending FIDES to system-level analysis
- **Refinement of the model philosophy, currently foreseeing a PFM at system level**



The Tyvak CLEANCUBE program is on a clear and ambitious path toward launch by 2028, supported by a strong flight heritage and proven platform capabilities with the goal to deliver an innovative CubeSat design compatible with the Zero Debris strategies and adaptable to future mission frameworks.

Flawless Execution Sustains Growth

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Back-up Slides

Gifted_GENE Module

- Complete suite of services to support **predictive maintenance, anomaly detection and root cause analysis,** leveraging on ground-based machine learning models trained on historical and near-real-time telemetry.

- Core functionalities:
  - Performance trend monitoring over time
  - Early detection of degradation indicators
  - Lifecycle-aware mission planning and adjustment
  - Determination of optimal EOL initiation timing
  - Validation of critical onboard diagnosis reports

- The key innovation lies in the tight integration between the onboard health monitoring application of Orbital Oliver and the ground-based predictive maintenance software suite of Gifted_GENE, designed to work in tandem to support robust, zero-debris operations in LEO.
- They form a unified system resilience layer that supports autonomous anomaly management, extends the satellite's operational life, and ensures the safe and timely execution of EOL procedures.