IRoC-U

ISRO Robotics Challenge - URSC

Let's build a space robot

2026

Proposal Report

by

KALINGA
10468

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Kalinga institute of Industrial Technology,Bhubaneshwar-751024

Contents

1.Description of ASCEND:

The Autonomous Surveyor Challenge for Exploration, Navigation and Dynamics (ASCEND) is a competition designed to simulate future interplanetary swarm expeditions, specifically for Martian surface exploration. The core objective is to build a micro-UAV and a base station capable of executing complex scientific tasks autonomously, without reliance on external aids like GNSS (GPS), pseudolites, or reflector arrays.

Mission Objectives and Workflow

The UAV must demonstrate complete autonomy in a "no-GPS" environment through several distinct phases: .

- Seeding Phase: The UAV autonomously captures reference "seed" images (e.g., layered rock formations or reflective patches) provided by the base station.
- Search & Detection: The vehicle departs and searches a designated arena to locate unknown instances of these features. Upon detection, it must document coordinates and capture verification images.
- Return & Interface: The UAV autonomously returns to the base station, lands, and interfaces via wired or wireless modes for data transfer and recharging.
- Validation: The base station automatically validates the gathered data against the reference database to confirm a successful sortie.

Potential Rotorcraft Options and Selection

When selecting a rotorcraft for ASCEND, teams must balance payload capacity, endurance, and weight constraints (maximum 2 kg take-off weight).

- Mini Quadcopters (FPV style): Highly agile and lightweight but often lack the stability and payload mounting space required for advanced Al companion computers and multiple specialized sensors.
- Custom Professional Quadrotors: These allow for optimized component placement and larger, more efficient propellers. This approach is generally preferred for ASCEND to support the heavy computational load of real-time mapping and object identification while maintaining at least 5 minutes of flight time.

2.System Architecture

The architecture for ASCEND is designed to handle high-level mission intelligence and low-level flight stability through a modular, dual-processor approach.

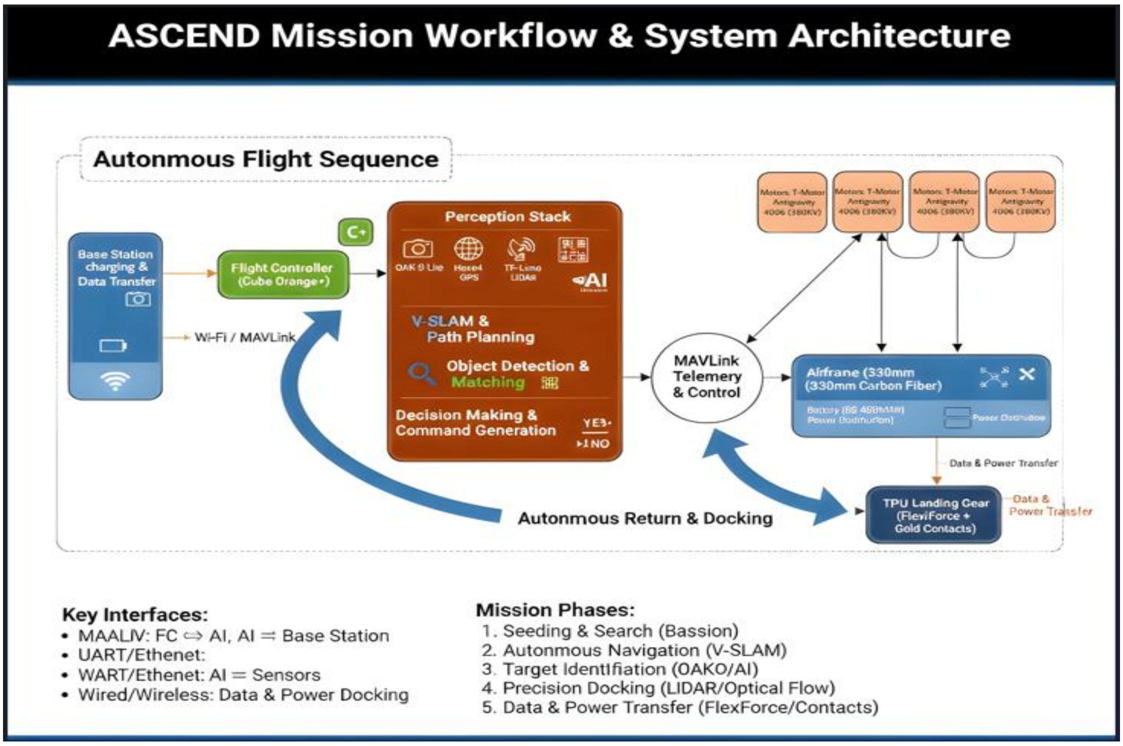
- **Block Schematic Components**

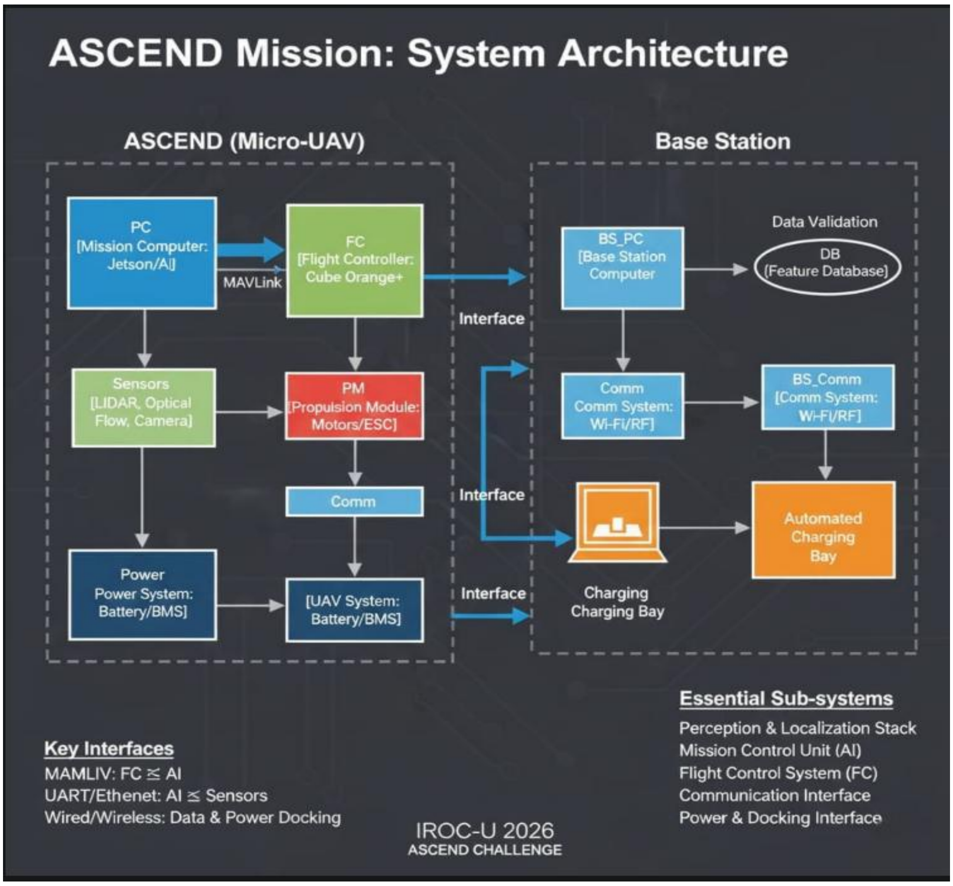
The following sub-systems are essential for meeting mission requirements:

1. <u>Mission Computer (High-Level</u>): A high-performance companion computer (e.g., NVIDIA Jetson or VOXL 2). It handles the "brain" tasks: real-time computer vision for feature detection, V-SLAM for GPS-denied navigation, and data validation.
2. Flight Control System (Low-Level): An embedded controller (e.g., Cube Orange+) running open-source firmware like PX4 or ArduPilot. It manages the physics of flight, stabilization, and motor actuation via MAVLink communication with the Mission Computer.
3. Perception & Navigation Sensors: Essential for non-GPS movement, including: . Vision Sensors: Stereo or RGB-D cameras (e.g., OAK-D) for object detection and visual odometry. . Distance Sensors: LiDAR or Ultrasonic sensors for terrain following and precise landing. . Optical Flow: For horizontal drift compensation in GPS-denied zones.
4. Power System: Integrated power management to sustain both the propulsion and high-draw Al hardware, with an automated docking/charging interface for "no-human" turnarounds.
5. Communication Interface: A robust link (typically Wi-Fi or RF) for exchanging mission status, telemetry, and image data with the base station.

- **Interface Identification**

The sub-systems are interdependent: the Mission Computer receives visual data from the Perception sensors, calculates waypoints, and sends navigation commands to the Flight Control System via a serial interface (UART/Ethernet). Simultaneously, the Base Station communicates with the Mission Computer to provide the "seed" images and receive verification logs upon landing.





3.Identification of components with their specifications:

1. Mechanical Components

The structural and propulsion systems are optimized for endurance and high stability during precision tasks like landing on a 5° slope .

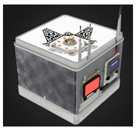
Structure/Frame: A custom **330mm carbon fiber frame** or a lightweight **3D-printed skeleton** is used to maintain a high strength-to-weight ratio. Carbon fiber is selected over plastic for its rigidity, which reduces IMU noise during high-torque maneuvers.

- **Propulsion**: .

1. Motors: T-Motor Antigravity 4006 (380KV) or similar high-efficiency brushless DC motors. Lower KV motors are chosen for their ability to spin larger propellers (12-15 inches) at lower RPMs, which is critical for extending the **5-minute typical flight time**

2.Propellers: 1245 Carbon Fiber propellers. These provide superior "grip" and efficiency for the required 2 kg take-off weight.

- **Docking Interface**: A mechanical "landing boot" with integrated charging pads for automated power transfer at the base station.

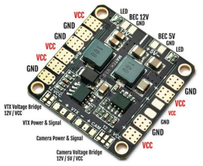


2.Electrical Components

Power and control systems are selected for redundancy and high-speed data processing without human intervention. ·

- **Power System**:
    1. **Battery: 4500mAh 6S LiPo.** This provides the necessary voltage for high-torque motors while remaining under the weight limit.

    2. **PDB/BMS:** An integrated Power Distribution Board with a **12V and 5V BEC** to power the AI computer and sensors.



- **Flight Controller (Low-Level): Cube Orange+** or similar industrial-grade controller. It features triple-redundant IMUs, which are essential for maintaining stable flight in the turbulent conditions of the simulated Martian arena.
- **Mission Computer (High-Level): NVIDIA Jetson Orin Nano.** Selected over emallor microcontrollers to handle intensive real-time Image Validation and **V-SLAM**

3. Sensors & Perception

Since GPS is prohibited, a robust suite of localized navigation sensors is mandatory.

- **Optical/Vision: Luxonis OAK-D Lite** or similar stereo depth camera. This is essential for the Search Task to locate target features like red-oxide patches and rock formations.

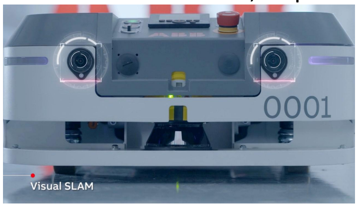
- **Time of Flight (ToF)/LiDAR**: **TF-Luna LiDAR** or similar for precise distance-to-ground measurements during the **Detection & Documentation Task.**

- **Inertial Sensors**: Redundant MEMS gyroscopes and accelerometers within the Cube Orange+.
- **Optical Flow:** For horizontal position hold in GPS-denied environments, mitigating drift during high-altitude hovering (up to 10m).

4. Algorithms & Logic

The software architecture is modular, using open-source foundations modified for indigenous navigation logic.

- **Software Platform: ROS 2 (Humble)** running on the Jetson Orin Nano, interfaced with **ArduPilot/PX4** firmware on the flight controller via MAVLink.
- **Navigation Logic:**

1. **V-SLAM (Visual Simultaneous Localization and Mapping)**: Used to create a local map of the arena in real-time, as pre-loading maps is strictly prohibited.


2. **Seeding Task**: Logic to capture and store 3-5 sample feature images via the base station interface.
3. **Search Task**: A sweep-pattern algorithm to detect and record coordinates of seeded feature instances.

- **Emergency Mode:** A failsafe logic that triggers a safe landing if communication with the base station is lost or abnormal behavior is detected.

Component Selection Summary & Justification

Component	Selected Approach	Potential Options	Justification
Struture	Carbon Fiber Frame	3D Printed / Plastic	Carbon Fiber handles the 2kg load with minimal flex,crucial for sensor accuracy
Processor	Jetson Orin Nano	Rasberry Pi 5	Only the Jetson provides GPU acceleration for real-time automatic image matching.
Navigation	V-SLAM + Optical Flow	Pure IMU Dead Reckoning	GPS-denied environments require visual confirmation to prevent cumulative drift.
Communication	Wifi/RF 2.4GHz	Bluetooth/5.8GHz	Wi-Fi allows for high-bandwidth "Seeding" and "Validation" data transfer.

4.ASCEND Realization plan

1. Description of ASCEND & System Overview

The ASCEND mission requires a micro-UAV to perform autonomous exploration in a simulated Martian terrain without external aids like GNSS or reflector arrays. The drone must autonomously:

- **Capture "Seed" Images** from the base station (3–5 sample feature types).
- **Navigate & Search** the arena to find instances of these features (rock formations, red-oxide patches, etc.).
- **Return & Interface** with the base station for autonomous landing, data transfer, and power recharging.
- **Validation** is performed by the base station computer through automatic image-matching.
- **Selected Rotorcraft Justification:** A **Custom Quadrotor** approach is selected over off-the-shelf FPV drones to balance the strict **2 kg weight limit** with the heavy onboard AI processing requirements. This allows for optimized component placement for V-SLAM and autonomous docking stability.

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2. System Architecture

The architecture follows a dual-controller model to ensure mission reliability.

- **Mission Computer (High-Level):** NVIDIA Jetson Orin Nano for V-SLAM, real-time feature detection, and coordinate documentation.
- **Flight Control System (Low-Level):** Cube Orange+ with PX4/ArduPilot firmware for flight stabilization and MAVLink communication.
- **Interfaces:** Communication is handled via high-speed Wi-Fi (for seeding/data transfer) and a physical wired/wireless docking interface for charging.

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3. ASCEND Realization Plan (Hardware Tabulation)

Hardware is classified into **Procured**, **Fabricated**, and **3D Printed** sources to meet the specific technical performance measures (TPMs).

No.	Hardware Details	Procurement Source	Specifications / Realization Plan	Quantity
1	**Motors**	Market (Procured)	Brushless DC (BLDC), 380-400 KV (T-Motor style) for high efficiency.	4
2	**Frame**	Fabrication (Custom)	Carbon fiber sheets (3mm) CNC machined for weight optimization (Goal: < 2kg).	1
3	**Flight Controller**	Market (Procured)	Cube Orange+ with triple-redundant IMU for stable hover.	1
4	**AI Computer**	Market (Procured)	NVIDIA Jetson Orin Nano for autonomous image validation.	1
5	**Sensors**	Market (Procured)	OAK-D Lite (Camera), TF-Luna (LiDAR), Optical Flow.	1 Set
6	**Docking Port**	3D Printing / Fab	Custom mechanized landing "feet" with gold-plated power contacts.	1
7	**Propellers**	Market (Procured)	Carbon fiber 1245 propellers for max lift-to-weight ratio.	4

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4. Software Implementation Strategy

- **Navigation Logic: Real-time scanning and mapping will be done using Visual SLAM as preloading arena maps is strictly prohibited.**

- **Feature Recognition:** YOLOv5/v8 models will be deployed on the Jetson for target detection during the Search Task.
- **Autonomous Docking:** A vision-based precision landing algorithm will identify the base station marker to initiate the charging interface.
- **Failsafe (SAFE Mode):** Hard-coded emergency logic triggers a gradual descend and land command if communication is lost.

5. Testing Plan

a) Identification of Required Tests

Testing is categorized into three stages to bridge the "sim-to-real" gap and ensure mission success. 1. Sub-System Level Tests: . IMU & Sensor Calibration: Verifying the noise levels and accuracy of the redundant IMUs in the Cube Orange+ Vision Accuracy Test: Confirming the OAK-D camera's ability to match "seed" images to arena features. . ToF/LiDAR Distance Verification: Validating altitude measurements for precision landing. 2. System Level Integration Tests: . V-SLAM Stability Test: Checking the accuracy of real-time mapping while hovering between 3m and 10m. . Communication & Data Link Test: Ensuring reliable Wi-Fi/RF data transfer for seed images and coordinate logs. . Safe Mode/Emergency Failsafe: Verifying the "hard-coded" SAFE mode triggers a gradual descent upon command or link loss. 3. Mission Profile (Task) Tests: . Seeding & Search Sortie: Full autonomous flight to detect 2-3 instances of rock or reflective features. . Autonomous Docking & Charging: Precision landing on a 5° slope and initiation of power transfer.

b)Text Plans For identification Texts

Test Name	Methodology/Tools	Test Environment	Success Criteria
Pixel-to- Meter Accuracy	**Compare camera-estimated distance vs. Physical tape measurement**	**Indoor Laboratory**	**Error <5% at 5m altitude**
V-SLAeM Loop Closure	**Fly a circular path; check if the starting/ending points on the map match**	**GPS-Denied Arena**	**Drift < 0.5m over 50m path**
Feature Detection Precision	**Test YOLOv5 models on the Jetson Orin Nano with sample rock/patch image**	**Varied Lighting Arena**	**>90% mAP (Mean Average Precision)**
Precision Landing (5° Slope)	**Autonomous landing on a tilted base station using ArduPilot/PX4 PLND mode**	**Tilted Base Station**	**Touchdown within 10cm of center**
Automatic Power Interface	**Physical engagement of the charging bay upon successful landing**	**Base Station Dock**	**Charging initiated within 5 seconds**

c) Expected Outcome of All Identified Tests

Sub-System Tests: Expected to confirm that individual hardware components (T-Motors, LiDAR, Sensors) meet the provided performance specifications.

Navigation & Logic: The UAV should generate a 3D point cloud or topological graph of the arena in real-time without pre-loaded maps.

Safety Outcomes: The Failsafe Controller must successfully intercept any SLAM health failure and initiate an emergency landing to protect the 2kg hardware.

Mission Goal: The system achieves a successful "Sortie" by matching seeded images and returning to base for data validation.

6. Brief of System Specification

The following table summarizes the baseline design and capabilities of the ASCEND micro-UAV. These specifications are tailored to meet the challenges of autonomous seeding, searching, and docking within a Martian-simulated arena.

Sl. No.	Description	Specification Details
1.	Overall Mass	≤ 2.0 kg (Inclusive of all flight elements, battery, sensors, and AI companion computer).
2.	Overall Dimensions	Approx. 330mm to 450mm (Diagonal wheelbase); optimized for stability in the 10m altitude arena.
3.	Power Requirements	6S LiPo Battery (Approx. 4500mAh - 5000mAh); configured to power high-torque motors and the NVIDIA Jetson Orin Nano simultaneously.
4.	Flight Time per Charge	Min. 12–15 minutes (Designed to complete multiple search and return sorties in a single mission).
5.	Number of Propellers	4 Propellers (Quadrotor); Diameter: 12 inches; Pitch: 4.5 (Carbon fiber reinforced for high lift-to-weight ratio).
6.	Key Features	GPS-Denied Navigation: Fully autonomous V-SLAM and Optical Flow integration. Autonomous Interface: Wired/Wireless docking for automated data transfer and charging. Vision Intelligence: Real-time feature matching (rock formations, reflective patches) using AI-on-the-edge.
7.	Others	Max Landing Slope: 5 degrees (with precision autonomous docking). Max Hover Height: 10 meters (Operating range: 3m to 10m). Comm. Protocol: 2.4GHz Wi-Fi/RF for "Seeding" and "Validation" data exchange.

Technical Justification for Specifications

- Mass Compliance: The 2 kg limit is the most critical constraint. By utilizing a carbon fiber frame and high-density 6S batteries, the system maintains enough "payload budget" for the OAK-D camera and LiDAR sensors required for the Search and Detection tasks.
- Propulsion Selection: 12-inch propellers are selected to provide the necessary "grip" for precision landing on sloped safe-spots without the aid of GPS.

Autonomous Intelligence: The inclusion of an NVIDIA Jetson module allows for the Validation Task to be performed onboard, matching seeded images from the base station against discovered instances in the arena in real-time.

7.Overview of the Emergency response system

7.1 Identification of Emergency Situations

Based on the IRoC-U 2026 challenge constraints (GPS-denied environment, 2kg mass limit), the following critical emergency situations have been identified:

Emergency Scenario	Description	Risk to Mission
Loss of Communication (Failsafe)	Interruption of the RF/Wi-Fi link between the UAV and the Base Station.	Loss of real-time command ability and "Seeding" data flow.
Critical Power Failure	Sudden drop in battery voltage below the threshold required for safe flight (~3.5V per cell).	Uncontrolled descent or "crash-landing" in the arena.
V-SLAM / Navigation Drift	Degradation of visual-inertial odometry resulting in inaccurate position mapping in the GPS-denied arena.	Potential collision with arena boundaries or failure to locate the Base Station.
Abnormal Flight Behavior	Deviations from the flight path due to motor failure, ESC desync, or high wind gusts.	Physical damage to the UAV or injury to arena observers.
Obstacle / Arena Boundary Conflict	The UAV leaves the designated yellow-border zone or detects an unexpected obstacle.	Automatic disqualification or impact damage.

7.2 Description of the Response System

The ASCEND system employs a multi-layered response architecture, utilizing both Hard-Coded Flight Logic on the Cube Orange+ and AI-Driven Failsafes on the Jetson companion computer.

A. Automated Failsafe Responses

Every identified situation is justified with a specific, pre-programmed response protocol:

1.Communication Failsafe (Link Loss):

- Response: If the link is interrupted for >3 seconds, the UAV enters "Return-to-Base" (RTB) mode.
- Justification: Since the UAV uses local coordinates, it can autonomously retrace its path back to the last known Base Station coordinates using Visual Odometry without needing a pilot.

2.Low Battery Management:

- Response: At Level 1 (Low), the UAV returns to the base for docking. At Level 2 (Critical), it initiates an immediate vertical landing at its current spot.
- Justification: This preserves the hardware by ensuring the drone does not fall out of the sky mid-sortie, protecting the 2kg investment.

3.V-SLAM Health Monitor:

- **Response:** If the companion computer detects high drift (>1.0m error), it triggers a "Hover and Re-localize" command.
- **Justification:** This pauses the mission to prevent the drone from flying into the yellow border, giving the sensors time to re-align with the environment.

4.Physical Emergency Call-Off (Manual Failsafe):

- **Response:** A command sent via a **physical button** on the Base Station or a software trigger on the terminal.
- **Justification:** Mandated by IRoC-U rules, this allows for immediate "Safe Mode" activation during any abnormal behavior that the autonomous logic might not detect.

B. Redundancy Systems

- **Triple Redundant IMUs: The Cube Orange+ uses three sets of sensors; if one fails, the flight controller "votes" on the most accurate data to maintain stability.**
- **Dual Landing Identification:** If primary vision matching fails, the UAV uses secondary **Optical Flow** and **LiDAR** to identify a flat, safe-spot for landing.

C. Working Principle of the SAFE Mode

When an emergency is triggered, the system initiates a **"Graceful Degradation"** strategy. It sheds non-critical AI tasks (like feature searching) and focuses all computational power on **Flight Stabilization** and **Landing Guidance** using the Optical Flow magnitude map for collision-free touchdown.

- Propulsion System(The Heavy Lifters)

COMPONENT	Sub-Category	UNIT WT(gm)	Qty	Total Wt(gm)
MOTORS	T-Motor MN4006 380KV	68	4	272
PROPELLERS	1245 Carbon Fiber(12”)	18	4	72
ESC	Hobbywing XRotor 60A 4-In-1	15	1	15
Sub-Total				359

- The “Brain” & “Eyes”

Components	Sub-Category	Unit Weight(gm)	Qty	Total Weight
AI Computer	Jetson Orin Nano(Module+Heatsink)	176	1	176
Carrier Board	Mini Carrier Board(Airbot)	19	1	19
Main Camera	Oak-D Lite(Spatial AI)	61	1	61
Storage	(Western Digital SN580)	7	1	7
Sub-Total				263

- Navigation & Guidance Suite(Ego-Centric Sensing)

Components	Sub-Category	Unit Weight	Qty	Total Weight
Flight Controller	Cube Orange+ (ADSB)	33	1	33

Altimeter	TFmini Plus LiDAR	12	1	12
Optical Flow	PMW3901 (Matek LOX)	2	1	2
IMU	BNO085	3	1	3
Beacon Sensor	IR-Lock Sensor	14	1	14
Sub Total				64

- Structure and Energy (The Chasis)

Components	Sub-Category	Unit Weight	Qty	Total Weight
Main Frame	330 mm Carbon Fibre Quad Frame	185	1	185
Main Battery	4500 mAh 6S LiPo (25 C)	650	1	650
Landing Gear	Bio-Mimetic Damping Legs (Custom)	20	4	80
Power board	Matek PDB-HEX	20	1	20
Sub total				935

- Miscellaneous (The "Hidden" Grams)

Components	Sub-Category	Total weight
Wiring	14AWG Power and 22AWG Signal wires	45
Connectors	XT60, JST-GH, USB-C	15
Hardware	M3 Steel screws, Standoffs,Zip-Ties	25
Failsafes	Low-ESR Capacitor (35V 1000 micro Farad)	8
Sub Total		93

- Final Weight Calculation

Category	Wt(g)	Percentage
Propulsion		
Intelligence(Brain)		
Sensors		
Structure & Battery		
Misscellaneous		
Total Drone Wt		

<u>BASE STATION</u>

- The structure and Landing interface

Components	Sub-Category	Purpose	Qty	Weight (gm)
Main Chassis	Aluminium 6061 Frame	Structural rigidness for 5° slope	1	2500
Landing Surface	PTFE-Coated Funnel	Passive Self-Centering Geometry	1	1200
Alignment Magnets	N52 Neodymium Discs	Physical"Final Pull"For docking	4	15
Sub-Total				3715

- The power And charging bay(High Current)

Components	Sub-Category	Purpose	Qty	Weight (gm)
Power supply(PSU)	Industrial 24V 15A	Converts AC Grid to 6S DC	1	1200
Charge Controller	Smart BMS/INA219	Logic for current drop Detection	1	45

Pogo pin Array	Gold Plated Spring Pins	High Current Electriccal Interface	1	12
Sub Total				1257

- The Logic Hub("Ground Brain")

Components	Sub-Category	Purpose	Qty	Total Weight
Base Station PC	Jetson Orin Nano Kit	Image Matching & mission logic	1	130
Storage(Data-base)	512GB NVme SSD	Stores seed images and logs	1	9
Cooling	Active Fan/Heatsink	Prevents CPU Throttling during AI	1	45
Sub-Total				184

- Communication & Safety

Components	Sub-Category	Purpose	Qty	Weight (gm)
Wifi 6 Router/Card	Intel AX210 kit	High-speed Image transfer	1	35
Emergency Switch	Physical Kill-Switch	Immediate autonomous safe-land	1	150
Visual Beacon	ArUcoIR LED Ring	Precision visual guide for drone	1	65
Sub-Total				250

- Miscellaneous & Assembly

Components	Sub-Category	Purpose	Weight(gm)
Internal Wiring	12AWG Power & Signal	Connectivity between components	350
Connectors/Bus Bars	XT60,Bus bars,Ports	Power and data distribution	150
Enclosure/Fasteners	M4/M5 Bolts Bars,ports	Final protective housing	1344
Sub-Total			1844

- Total Base Station Weight Summary

Category	Weight(gm)	
Mechanical Structure	3715	
Power & charging	1257	
Intelligence(pc)	184	
Communication & Safety	250	
Assembly & Misc	1844	
Grand Total	7250	

8. PROJECT MANAGEMENT:

The project management strategy for ASCEND is designed to ensure the delivery of a high-performance autonomous surveyor within a tight 7-month development window. Our approach focuses on a modular system breakdown, clear individual accountability, and a strictly defined timeline to meet the milestones set by ISRO.

a) Identification of Responsibilities and System Breakdown Structure

The project is divided into five core sub-systems. Each team member is assigned a primary area of responsibility while maintaining secondary support roles to ensure cross-functional resilience.

No.	Task / System Component	Main Responsibility	Deadline for Completion	Secondary Responsibility
1	Hardware Procurement & Frame	Team Member 1	12-02-2026	Team Member 4
2	Navigation Algorithms (V-SLAM)	Team Member 2	15-03-2026	Team Member 3
3	Vision Systems & Target Matching	Team Member 3	25-03-2026	Team Member 2
4	Base Station & Power Interface	Team Member 4	01-04-2026	Team Member 5
5	Flight Dynamics & SAFE Mode	Team Member 5	10-04-2026	Team Member 1

- System Breakdown:
    1. **Perception Unit:** Responsible for OAK-D integration and feature detection.
    2. **Navigation Controller:** Manages non-GPS movement and coordinate logging.
    3. **Base Station Hub:** Manages automated data validation and the physical charging interface.

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b) Strategy for Schedule Management

The project follows the official IRoC-U 2026 milestones. Our strategy involves a "Sim-to-Real" approach: initial 4 weeks for simulation-based algorithm testing, followed by 12 weeks of iterative hardware testing.

- **Phase 1: Preliminary Design (Jan 2026):** Finalizing the micro-UAV architecture and submitting the initial proposal
- **Phase 2: Qualification Round (Feb – April 2026):** Development ofindigenous navigation algorithms and submission of design videos.
- **Phase 3: Elimination Round (April – June 2026):** On-field autonomous testing without GPS or telemetry aids.

- **Phase 4: Final Field Round (July 2026):** Deployment at Bengaluru for the final task evaluation.

c) Cost Estimation

The budget is strictly optimized to build a micro-UAV under the 2 kg mass limit while ensuring all autonomous task requirements are met.

Component Category	Key Items	Estimated Cost (INR)
Propulsion	BLDC Motors (4x), ESCs (4x), 12" Propellers	₹35,000
Processing	NVIDIA Jetson Orin Nano, Cube Orange+ FC	₹65,000
Perception	OAK-D Lite Camera, TF-Luna LiDAR, Optical Flow	₹25,000
Base Station	Charging Bay, High-Gain Wi-Fi Hub, Validation PC	₹45,000
Power & Misc	6S LiPo Batteries (3x), Fabricated Carbon Fiber Frame	₹30,000
TOTAL		**₹2,00,000**

9. Novelty in the Overall Proposal

9.1 Originality in System Design

The proposed system design moves beyond simple navigation to a **hierarchical swarm-ready architecture**. While the current mission involves a single micro-UAV, the architecture is built to support the future vision of autonomous aerial swarms that can deploy, survey, and share data without human intervention.

- **Integrated Base Station Ecosystem:** Unlike standard drone setups, our system treats the **Base Station** as an active intelligent partner. The originality lies in the **automated "Seeding-to-Validation" loop**. The base station does not merely act as a landing pad but as a data-transfer and energy-replenishment hub, validating scientific data against a reference database automatically.
- **GPS-Denied Swarm Localization:** The system implements **Collective Localization** principles, allowing for the establishment of a system of local coordinates entirely relative to the Base Station frame, eliminating cumulative drift during repeat sorties.

9.2 Hardware Selection Originality

To meet the rigorous **2 kg weight constraint** while ensuring high computational throughput, our hardware selection prioritizes **Edge AI acceleration**.

- **Hybrid Perception Suite:** We integrate **LiDAR** with **Stereo Visual Odometry** (e.g., OAK-D Lite) to provide a 360º-aware system that compensates for the inherent weaknesses of individual sensors (like IMU drift) without external aids.
- **Dual-Interface Docking:** Our hardware design features a novel **physical landing interface** that supports both high-speed wired data transfer and simultaneous charging. This "drone-in-a-box" approach is optimized for Martian simulation where reliability and ease of autonomous interface are critical.

9.3 Software and Algorithmic Originality

The core innovation in our software stack is the elimination of all pre-loaded maps and external aids.

- **Real-time Feature Matching (Validation Task):** We employ a **Deep Learning-based Target Identification** algorithm (e.g., Tiny YOLO) optimized for the onboard Mission Computer to match "seeded" feature types (layered rock formations, oxide patches) in real-time.
- **Adaptive Exploration Planner:** Our waypoint generation uses a novel **Frontier-Based Exploration** sequence. Instead of pre-programmed paths, the UAV prioritizes new frontiers to minimize back-and-forth movement, ensuring maximum arena coverage within the limited **5-minute flight window**.
- **Autonomous Slope Landing Logic:** The software utilizes high-frequency **LiDAR and Vision-Aided Navigation** to identify stable landing spots on surfaces with up to a **5-degree slope**, adjusting the drone’s pose in real-time during the Return Task.

10.Conclusion

The registration for **Team KALINGA** from the **Kalinga Institute of Industrial Technology** is officially documented for the **ISRO Robotics Challenge - URSC 2026**. Led by **Aurosri**

Arman Panigrahi and mentored by Dr. Anish Pandey , the team consists of 10 members from the Computer Science and Engineering department. The institute has certified that this is the sole team representing them in this challenge.

For further information regarding the team's progress and project details, please visit the site: kalinga26.netlify.app