ISRO Robotics Challenge - URSC

Let's build a space robot

Proposal Report

For IRoC-U 2025

by

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1 Description of ANAV:

The selected aerial vehicle complies with DGCA regulations and is a lightweight quadcopter drone that is easy to assemble (mass<2kg). Its modular architecture facilitates quick hardware upgrades. With limited resources and autonomy, the design is also robust in managing Martian-like environments. When the drone decides to carry out the previously mentioned self-flying tasks without human assistance, that is autonomy in this context. The smooth integration of the software and hardware allows for all of this. Its hardware includes high-resolution cameras that provide precise and real-time data for mapping and navigation, as well as parts like LiDAR and optical flow sensors. While the Raspberry Pi effectively handles computationally demanding tasks, the Pixhawk flight controller guarantees stability and responsiveness. This entire event flow can be easily controlled and comprehended using the block diagram and table below:

Sr.No	**Type**	**Description**
1.	Aerial Vehicle	A quadcopter drone that can fly efficiently and steadily thanks to four 2200KV brushless DC motors.
2.	Software Capabilities	The software integrates image processing techniques, such as optical flow, and algorithms for motion tracking, object detection, and environmental mapping, ensuring precise and efficient operation.
3.	Power Sources	5200mAh 3S LiPo battery, 200W Buck Converter for Raspberry Pi.
4.	Communication	A 2.4GHz transmitter and receiver for mode selection and emergency landings,
5.	Slope Landing Capab.	We are designing adaptive landing gear that can dynamically adjust to match the angle of the inclined surface, ensuring stable and secure contact during landing.

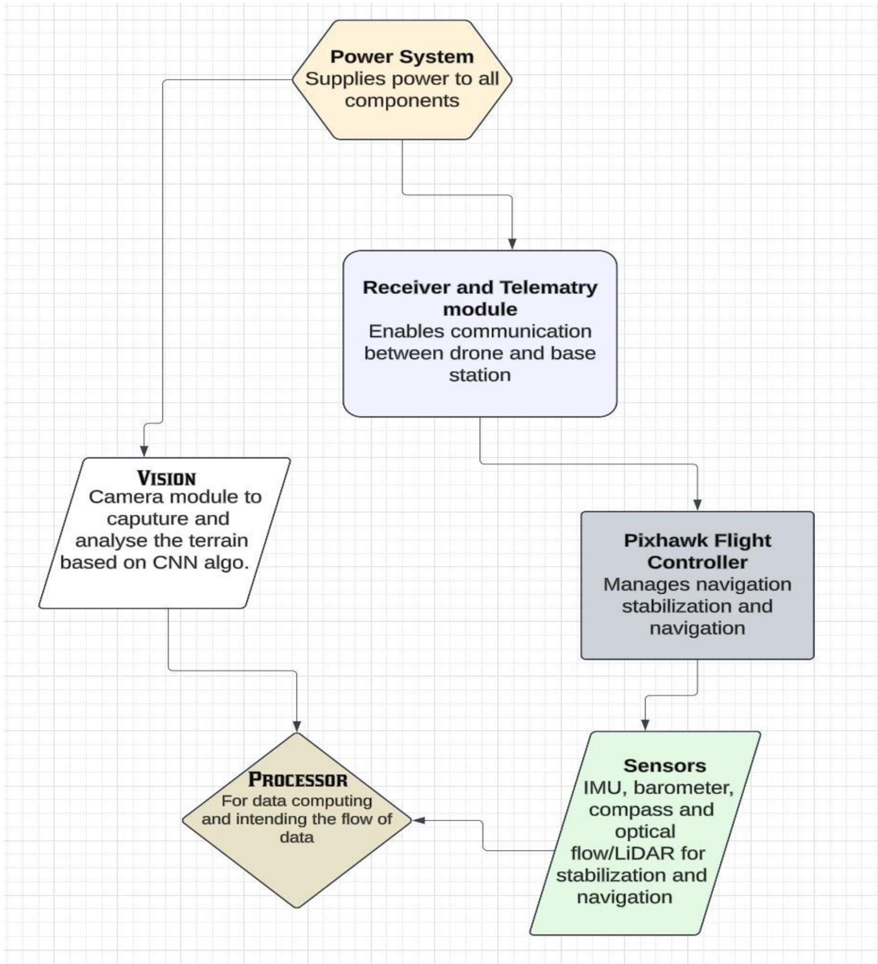
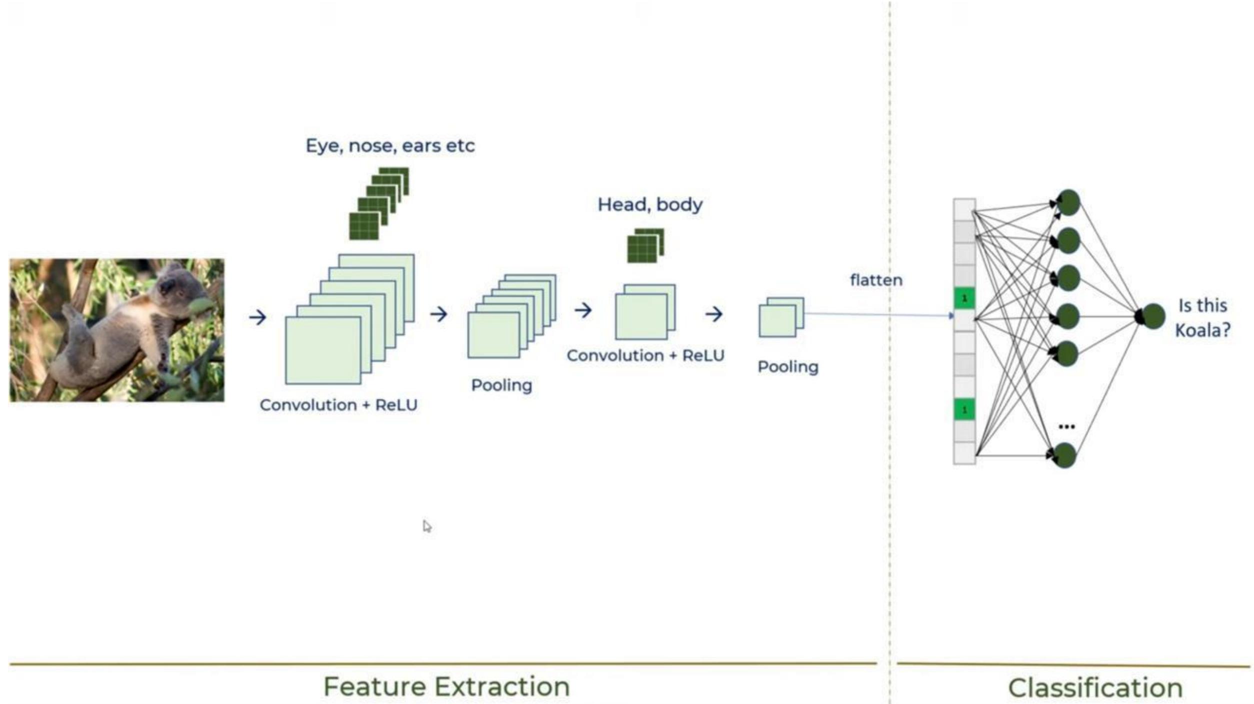


Fig 1: Basic flow chart for ANAV.

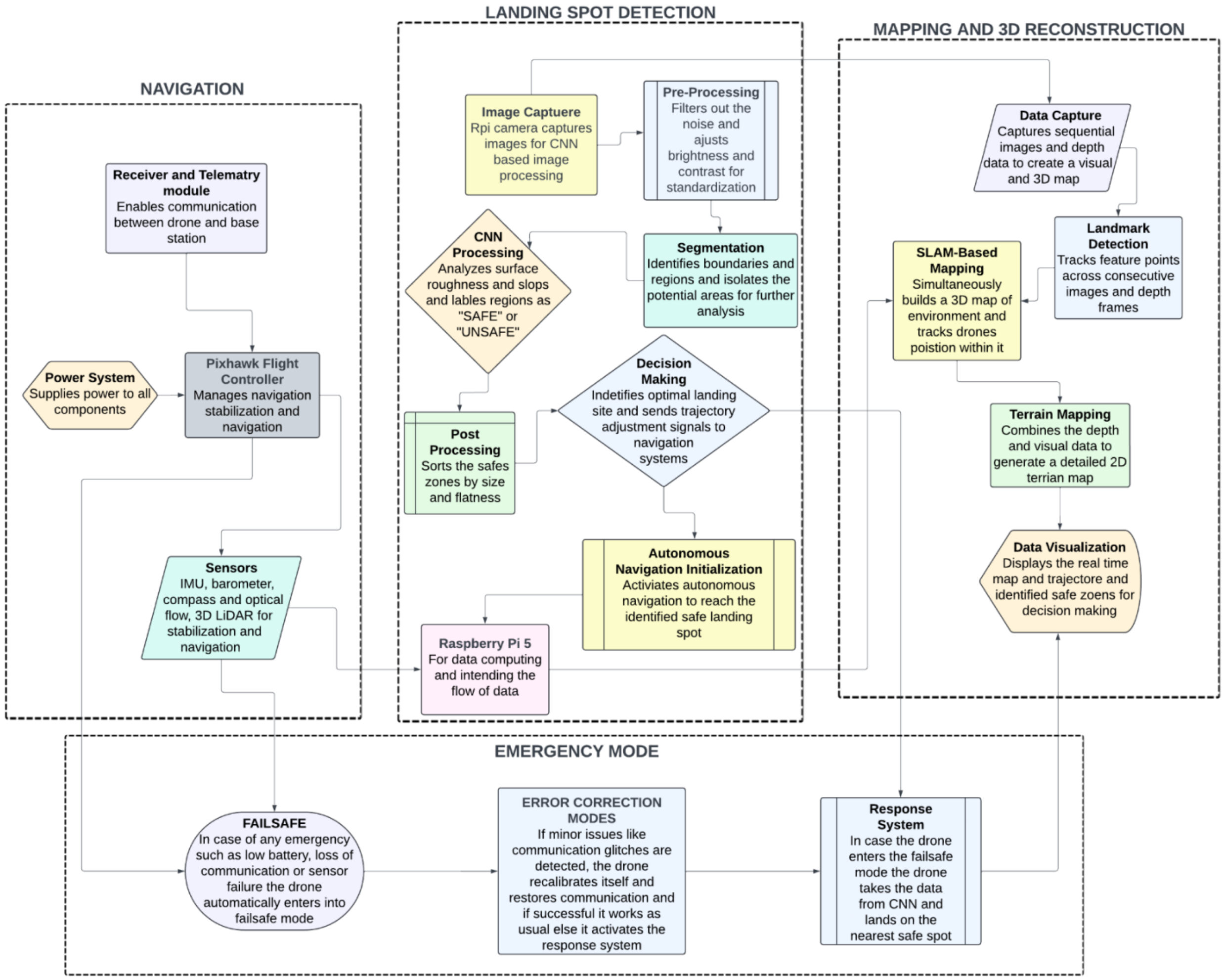
Additionally, the software would translate the complex sensor data with the aid of a Convolution Neural Network (CNN) to facilitate accurate landing, terrain mapping, and intelligent decision-making. Additionally, the high-precision hardware guarantees performance and dependability in dynamic environments, guaranteeing autonomous navigation that satisfies mission requirements. In the event that there is insufficient data, an external drive module can be added to store the images used to train the model.

A feature map is created to determine the available landing spots after the entire region is represented as a binary matrix as part of the model training procedure. ReLU operations are repeatedly performed, and pooling techniques are employed to shrink the feature map's size and further reduce the computational demands of this process. Calculations will be performed using fixed-point arithmetic for testing and time efficiency optimization. The use of ResNet is contingent upon your weighting and data limitations. ResNet's residual block functionality is excellent at managing vanishing gradients and performs well with moderate data; however, overfitting may happen if the dataset is too small or undiversified. Deeper ResNet models can also be computationally demanding, which presents difficulties when weighting is strictly limited. Simpler models might be more appropriate, and the statement regarding ResNet's use should be removed, but if these limitations are manageable, ResNet can be adopted for increased efficiency. The diagram below illustrates how an image could be instantly processed and recognized.



Lastly, a high-level neural network API in Python can be used to integrate the hardware and software using Keras with a Tensor Flow backend.

2 System Architecture:



DESCRIPTION:

The system is engineered for accuracy and flexibility to address the challenges of autonomous navigation, secure descent, and real-time decision-making on Martian terrain. It integrates technologies like SLAM, Convolutional Neural Networks (CNN), and a backup system to ensure reliability in critical situations.

1. Navigation Subsystem

The Navigation Subsystem ensures precise movement, stability, and communication, serving as the backbone of drone operation. It integrates sensors, a flight controller, and telemetry systems for smooth, reliable navigation.

- **Stage 1:** Data Acquisition and Power Management Focuses on capturing real-time data and maintaining consistent power supply. Power System: Ensures steady performance even under high demand. Sensor Data Acquisition: Collects real-time data for navigation and stabilization using IMU, optical flow, and 3D LiDAR.
- **Stage 2:** Navigation and Stability Control Ensures accurate navigation and stability. Sensor Integration: Combines data from 3D LiDAR, optical flow, and IMU for obstacle detection. Flight Path Adjustment: Adjusts altitude, trajectory, and velocity in real-time. Stability Management: Maintains smooth operation during turbulence or sudden trajectory changes.
- **Stage 3:** Communication and Real-Time Feedback Ensures seamless communication with the base station. Receiver and Telemetry Module: Sends and receives real-time updates. Command Execution: Processes and executes navigation commands, ensuring responsiveness.
- **Stage 4:** Flight Control and Decision Making Executes navigation commands and coordinates system functions. Pixhawk Flight Controller: Analyzes sensor data to maintain trajectory, altitude, and stability. Autonomous Adjustments: Adapts to mid-flight changes for smooth operation.
- **Subsystem Outputs The Navigation Subsystem provides real-time outputs for effective operation:** Stability Metrics: Data on roll, pitch, yaw, and altitude to maintain balance. Obstacle Avoidance Feedback: Continuous updates for safe navigation. Telemetry Data: Position, velocity, and trajectory feedback for operator guidance.
- **Significance and Advantages Autonomous Navigation:** Enables fully automated operation with precise control. Real-Time Communication: Maintains constant operator link for decision-making. High Stability and Reliability: Ensures stable operation in diverse environments. Adaptability: Navigates complex terrains under dynamic conditions.

2. Landing Spot Detection Subsystem

The Landing Spot Detection Subsystem (LSDS) ensures safe, precise drone landings in extraterrestrial environments during planetary exploration. Using advanced deep learning and pose estimation, LSDS identifies potential landing zones while avoiding hazards like craters, rocks, and uneven terrain. It is essential for autonomous landings on the Moon, Mars, and similar surfaces.

System Architecture

Stage 1: Detection Using Deep Prior Convolutional Detection Network (DPCDN) This stage employs DPCDN, a real-time deep learning algorithm, to analyze terrain data from onboard cameras during descent.

Key Processes:

- Input Data Acquisition: Captures continuous surface frames during descent.
- Feature Extraction: Identifies flat zones, craters, and boulders, creating a Feature Detection Map (FDM).
- Hazard Identification: Classifies zones as hazardous or safe using pre-trained models.
- Output: Marks safe and hazardous zones on the FDM.

Stage 2: Recognition and Pose Estimation Refines detected features and validates them for safe landings.

Key Processes:

- Noise Reduction: Kalman Filter removes sensor/environmental noise.
- Keypoint Matching: Compares detected features with known terrain models.
- Pose Estimation: EPnP algorithm calculates drone position and orientation.
- Projection and Validation: Ensures safe zones remain optimal for landing.

Subsystem Outputs LSDS provides real-time outputs essential for landing:

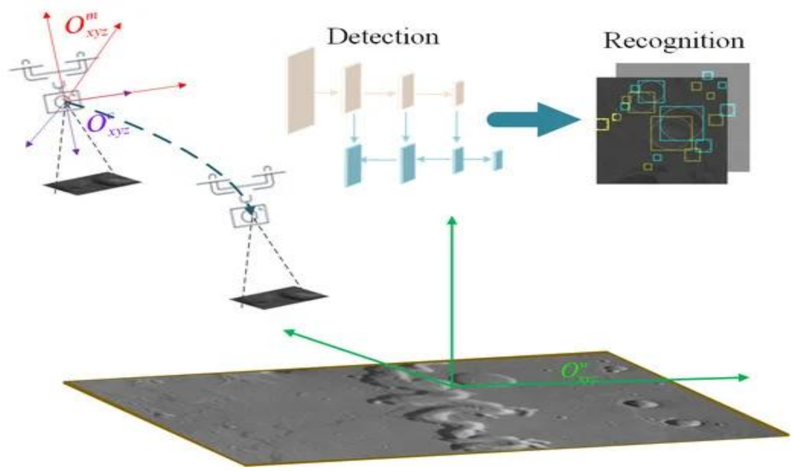
- Safe Landing Zone Coordinates: Accurate 1.5 sq. m landing zone.
- Hazard Zones: Marked areas to avoid.
- Telemetry Updates: Real-time position, velocity, and alignment data for corrections.

Integration and Decision-Making LSDS integrates advanced algorithms for efficient decision-making:

- DPCDN: Detects surface features and terrain variations.
- Kalman Filter: Reduces noise for consistent detection.
- KM Matcher: Validates features against terrain models.
- EPnP: Calculates position and orientation efficiently.

Significance and Advantages LSDS enhances landing safety by:

- Autonomous Landing: Ensures safe landings without human input.
- Real-Time Hazard Detection: Continuously monitors landing areas.
- High Precision and Reliability: Uses deep learning and pose estimation for accuracy.
- Terrain Adaptability: Ensures safe landings on diverse surfaces.



Graphical Abstract

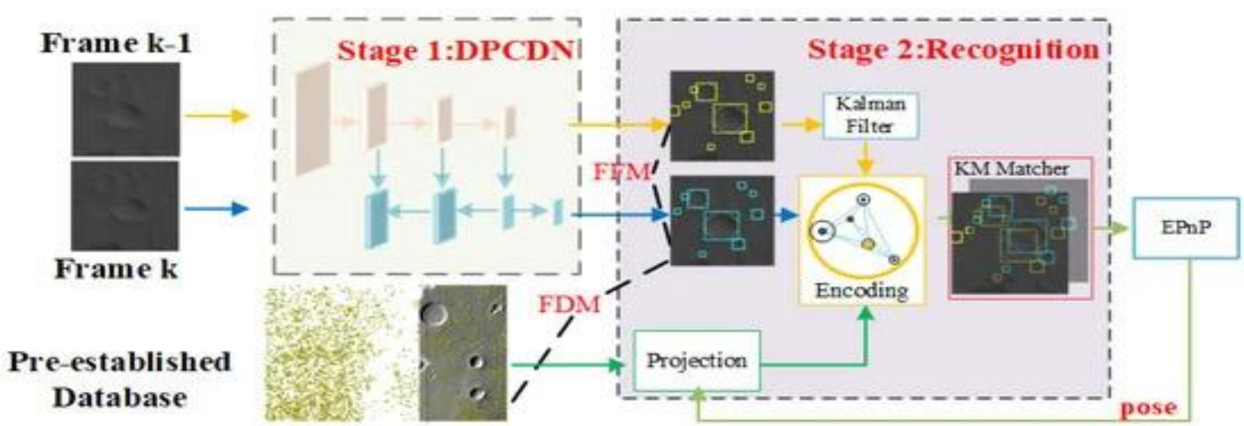


Fig 2: Crater detection and recognition system workflow. The whole workflow consists of two stages. In stage 1, a dense point crater detection network obtains craters in the frame k and frame k − 1. Then, in stage-2, we use the KM algorithm to match k's craters with k − 1′s craters or the pre-established database.

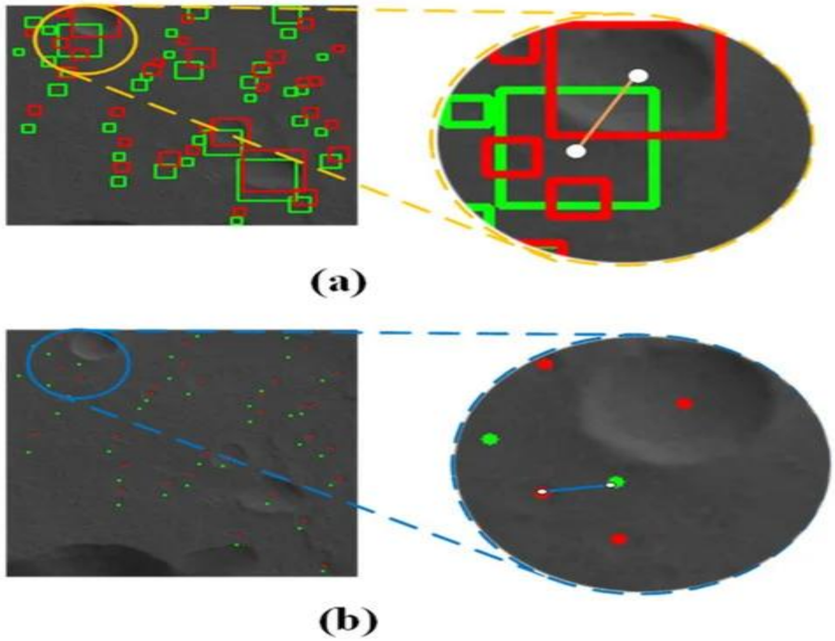


Fig 3: Matching (**a**) with bounding box and (**b**) with the center of craters.

3. Localization and Mapping Subsystem

Precise localization and environmental awareness are crucial for drone operation in GPS-denied areas. The Localization and Mapping Subsystem combines sensor data, SLAM, and terrain mapping to ensure real-time positional accuracy and situational awareness.

Stage 1: Data Capture Relies on visual and depth data for accurate mapping and localization.

- IMU: Records angular velocity and acceleration for movement and orientation.
- Camera: Captures high-resolution images for visual mapping and object recognition.
- LiDAR: Provides depth data for 3D mapping and obstacle detection.

Stage 2: Landmark Detection Tracks static features to estimate position and movement.

- Position and Orientation: Detects and calculates motion changes.
- Landmark Identification: Tracks static points across frames.
- Motion Estimation: Analyzes landmark movement to determine trajectory.

Stage 3: SLAM-Based Mapping SLAM algorithms integrate sensor inputs to create and update 3D maps.

- 3D Map Construction: Builds detailed environmental maps.
- Real-Time Localization: Updates drone position within the map.

Stage 4: Terrain Mapping Combines visual and depth data for navigation and decision-making.

- Obstacle Detection: Identifies hazards like craters and slopes.
- Dynamic Updates: Continuously updates terrain maps.
- Safe Zone Identification: Highlights flat, obstacle-free areas.

Stage 5: Data Visualization Outputs interactive terrain maps to guide navigation.

- Terrain Map Display: Marks safe zones, hazards, and paths.
- Decision Support: Enhances situational awareness for accurate actions.

4. Emergency Mode Subsystem

The Failsafe and Response Subsystem ensures drone safety and reliability during unexpected events through failsafe mechanisms and response protocols.

Stage 1: Failsafe Mechanism Continuously monitors operational parameters to prevent critical failures.

- Error Detection: Identifies low battery, communication loss, or sensor failure.
- Self-Correction: Recalibrates sensors or restores communication to resume normal operation.
- Failsafe Mode: Activates protective mode if issues persist.

Stage 2: Response System Executes safety actions for critical errors.

- Return-to-Home (RTH): Automatically returns to the starting point when possible.
- Hover Mode: Maintains a stationary position to avoid further complications.
- Emergency Landing: Lands safely at a designated spot to prevent severe damage in extreme cases.

3 Identification of components with their specifications:

1. Drone Assembly

The following section describes the mechanical and structural components of the drone to be used. This includes the frame, propellors, motors, ESCs, battery, Flight controller.

1.1. Frame

F450 Drone Frame

The main frame of the drone will use off the shelf f450 drone frame. The selection of this frame work was guided by the following considerations-

- Modularity – Easily swappable components allowing rapid prototyping.
- Ease of availability – Widely available in the Indian Market.
- Strength and Rigidity – Made from glass fiber and polyamide nylon making it light, durable and impact resistant.
- Payload Combability – Should allow placement of various payloads such as cameras, lidars and compute modules.

The F450 Drone frame satisfies all of these requirements and hence it is being used.

1.2. Landing Legs

We decided to go with 3d printed TPU landing Legs for the following reasons-

- Topple Protection – Less prone to toppling over when landing at an angle.
- Impact Absorption – Absorbs forces during a harsh landing, protecting the drone from damage.
- Enhanced Grip – Provide greater grip enabling the drone to land on slopes.

1.3. Motors, Props, ESCs

A2212 6T 2200KV

The following requirements were taken into account –

- Cell Compatibility – Should be compatible with 3S batteries.
- Current Limit – Should consume up to 30A continuous current.
- Thrust to weight Ratio – A minimum thrust to weight ratio of 1.5:1.

The A2212 6T 2200KV motor satisfies all these requirements and hence was selected.

- Technical Specifications –

Max Efficiency	80%
Number of Cells	2-3s Lipo
Load Current	21.5A
Weight	49g
Minimum Recommended ESC	18A

1.4. Propellors

- Diameter – 10 inch, larger the diameter, more thrust but there is a tolerable trade off in higher power draw.
- Blade Count – 2 Blade, more efficient, less drag, higher rpms.

1.5. ESC

30A ESC

The following requirements were taken into account -

- Cell Compatibility - Should be compatible with 3S batteries.
- Pole Compatibility – 6 Pole (for A2212 6T 2200KV motors)
- Heat Dissipation – Ability to safely and effectively get rid of the heat generated along with thermal protection in case of emergencies.
- Safety Features – Short Circuit Protection, Over/Under Voltage Protection, Thermal Protection.

1.6. Flight Controller

Pixhawk 2.4.8

The following requirements were taken into account –

- Redundant IMUs –
  Should have multiple inertial measurement units which can reference each other and work individually too when needed.
- Barometer – Should have a high-resolution barometer for height measurement.
- Expandability – Should have the provision to attach external compute models and peripherals.
- Data Logging and Analysis – Should save the flight data in a SD card for post flight analysis and optimization.
- Communication Protocols – Should be compatible with MAVLink for telemetry and control and communication with Raspberry Pi.
- Processing Power – Arm Cortex M7 for handling multiple control loops.
  Pixhawk 2.4.8 satisfied all these requirements and hence it is chosen.
- Technical Specifications-

Main FMU Processor	STM32F765
IO Processor	STM32F100
Accel/Gyro 1	ICM-20689
Accel/Gyro 2	BMI055
Magnetometer	IST8310
Barometer	MS5611
Interfaces	- 16 PWM servo outputs - 5 general purpose serial ports - 3 I2C Buses - 4 SPI Buses
Max Input Voltage	6V
Weight	15.8g

1.7. Battery

The following requirements were taken in to account-

- Voltage – 11.1V(3S) Lipo
- Capacity – 5000 mah minimum (about 25 minutes of flight time)
- Discharge Rate – High discharge rate allowing greater current draw.
- Weight – not more than 500 grams.

- Safety features – Overcharge protection, short circuit protection, under voltage protection, thermal protection.

Orange 11.1V 5200mAh 40C 3S Lipo satisfied all these requirements and hence was selected.

Voltage	11.1V
Max Continuous Discharge	40C (208A)
Max Burst Discharge	80C (416A)
Weight	360g

1.8. Buck Converter –

To supply the Raspberry Pi and other navigation and mapping hardware(explained in further sections), a 5V supply is needed. This is achieved by using a buck converter which steps down the ~12V supplied by the battery to 5V.
The following considerations were kept in mind when selecting the buck converter-

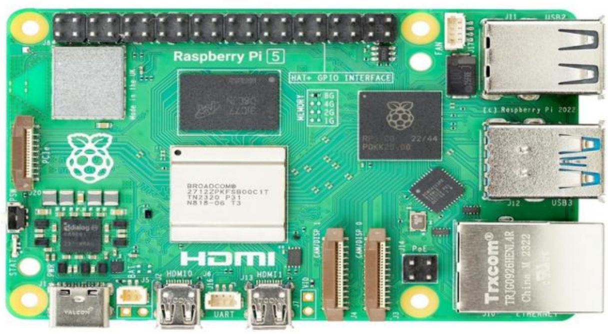
- Input Voltage Range – 10V to 15V
- Output Current Capacity – 10A
- Efficiency - >90%
- Thermal Performance – Should be able to effectively dissipate the generated heat loss.
- Soft Start to prevent large inrush currents during startup.
  The 200W buck converter from Robu.in fit all these requirements and hence it is selected.

- Technical Specifications –

Input Voltage Range	6 – 40V
Max Output Current	20A
Efficiency	97%
Switching Frequency	180Khz

2. Compute Module

Raspberry Pi 5 8gb



2.1. Ideal for Image Processing

- Our system requires data two high resolution cameras to be processed at a reasonable rate for stereo vision and depth information. A high-performance compute device with a dedicated gpu is required for this task.
- Raspberry PI 5 has a powerful Cortex A76 CPU making it well suited for intensive image processing tasks. It also has a modestly powerful GPU, which aids in hardware accelerated image processing.
- It has two Camera Serial Interface Ports allowing a quick and simple connection for two cameras.
- Its small form factor and less power consumption makes it ideal for space and battery constrained applications like ours.
- It has multiple I2C, SPI, UART interfaces for our sensors.

2.2. Ideal for Pixhawk Integration

The Raspberry Pi 5 can communicate seamlessly with Pixhawk via MAVLink using MAVROS enabling smooth control of the drone and integration with the flight controller.

3. Localization and Navigation Hardware

As mentioned in previous sections, our approach fuses data from IMU and Optical Flow Sensor for localization. Details about the hardware to be used for implementing this is mentioned below.

3.1. Inertial Measurement Unit

BNO055 IMU

BNO055 integrates a triaxial 14-bit accelerometer, an accurate close-loop triaxial 16-bit gyroscope, a triaxial geomagnetic sensor and a 32-bit microcontroller running the BSX3.0 FusionLib software. It significantly smaller than comparable solutions. By integrating sensors and sensor fusion in a single device, the BNO055 makes integration easy.

Reasons for using a separate IMU instead of the onboard ones on Pixhawk-

- **BNO055's Fusion Algorithm**: BNO055's onboard microcontroller runs the BSX3.0 FusionLib software which implements an Extended Kalman Filter, reducing the computational load on Pixhawk and Raspberry Pi.
- **Magnetic Interference Reduction:** Unlike the Pixhawk's onboard IMUs, which are fixed to the flight controller and susceptible to magnetic interference from nearby power electronics, the BNO055 can be placed away from such interference sources, ensuring more accurate heading data.
- Specifically designed for applications subject to vibrations.

Accelerometer	Programmable functionality	- Acceleration ranges ±2g/±4g/±8g/±16g - Low-pass filter bandwidths 1kHz - <8Hz

Gyroscope	Programmable functionality	- Ranges switchable from ±125°/s to ±2000°/s - Low-pass filter bandwidths 523Hz - 12Hz
Magnetometer	Flexible functionality	- Magnetic field range typical ±1300µT (x-, y-axis);±2500µT (z-axis) - Magnetic field resolution of ~0.3µT

3.2. Optical Flow Sensor

PX4 Optical Flow Sensor

- The **PX4 Optical Flow Sensor** is a lightweight, high-precision motion tracking sensor designed for drones and robotics. It measures relative motion between the sensor and a surface, providing accurate velocity data, which is particularly useful for position hold, navigation, and stabilization in GPS-denied environments. This is achieved by analyzing image patterns captured by its onboard camera.
- It comprises of a STM32F407 168Mhz CPU, 752 × 480 MT9V034 image sensor and a 16mm M12 lens.

- Data Processing is done at 250Hz.

4. Mapping hardware

For 3D mapping, the drone uses a stereo camera setup and 3D LiDAR. While the cameras use disparity to estimate depth, the LiDAR provides precise spatial data. To improve mapping precision and obstacle detection in intricate environments, these complementary data sources will be combined. The details about hardware to be used to implement this system are given below.

4.1. Stereo Cameras

Two OV5647 5MP 1080P Cameras

- OV5647 is a CMOS Image Sensor with a resolution of 5MP, and an active pixel area of 2592×1944. It supports upto 1080p 30 fps video output. It has a wide field of view of about 54 degrees.
- These attributes make it ideal for use in a dual camera setup like ours where high resolution, high frame rate and wide field of view are required.

Technical Specifications –

Active Array Size	2592 x 1944
Power Supply	- core: 1.5 V ±5%(internal regulator) - Analog: 2.6 ~ 3.0 V - I/O: 1.7 ~ 3.0 V
Temperature Range	- operating: -30°C to 70°C - stable image: 0°C to 50°C
Output formats	8-/10-bit raw RGB data

Lens size	1/4"
S/N ratio	36 dB
Field Of View (with Lens)	54°
Sensitivity	680 mV/lux-sec
Maximum Image Transfer Rate	- QSXGA (2592x1944): 15 fps - 1080p: 30 fps - 960p: 45 fps - 720p: 60 fps - VGA (640x480): 90 fps - QVGA (320x240): 120 fps
Dark current	- 16 mV/sec @ 60°C

4.2. 3D Lidar

CS20 Dual-Resolution 3D TOF Solid-state LiDAR

CS20 is a compact and light weight solid state 3D lidar with a resolution of 640 * 480. Unlike a spinning LIDAR, it has no moving parts making it ideal for high vibration environments like a drone.

Technical Specifications –

Depth Resolution	640×480
Range Ability	0.1-5m, indoor
VCSEL Wavelength	940nm
Data Transmission	USB 2.0, Type C Interface
Power Dissipation	1.2W

5. Communication hardware-

This section describes the hardware for the communication system of our proposition. This system will be used to send commands to the drone for mode selection and emergency landing. It will not be used for general flying.

5.1. Transmitter

FS-i6 6CH 2.4GHz AFHDS RC Transmitter

The following requirements were kept in mind –

- Frequency Band – Preferably 2.4 Ghz, providing long range, legal in almost every region.
- Range – Should be able transmit data with minimal losses up to distances of 200 ft with multiple obstacles in the transmission path.
- Channels – at least 4 channels for throttle, yaw, pitch and roll with additional channels for auxiliary features.
- Antenna – High Gain, multidirectional

FS-i6 6CH 2.4GHz AFHDS RC Transmitter was selected because it met all the aforementioned requirements.

- Technical Specifications –

Channels	6
Frequency Range	2.40 – 2.48 Ghz
Bandwidth	500 Khz
Code Type	GFSK
2.4 Ghz System	AFHDS 2A and AFHDs
Range	500m (ideal conditions)

5.2. Receiver

FS-iA6B Receiver

- Frequency Compatibility – Should be compatible with 2.4 Ghz transmitter
- Interference Rejection – Should be able to resist interference in noisy environments.
- Range – Comparable to the range provided by the transmitter.

FS-iA6B Receiver fulfilled all these requirements and was hence selected.

- Technical Specifications –

Channels	6
Frequency Range	2.4055 – 2.475 Ghz
RF Receiver Sensitivity	-105dbm
2.4 Ghz System	AFHDS 2A
Weight	14.9g

Sr. No.	**Component Name**	**Sub – System**	**Procurement Source**	**Quantity**
1.	F450 Drone Frame	Drone Assembly	Online - link	1
2.	Landing Legs		TPU 3d Printed	4
3.	A2212 6T 2200KV Motors		Online - link	4
4.	10 inch Propellors		Online - link	4
5.	30A ESC		Online – link	4
6.	Pixhawk 2.4.8 Flight Controller		Online – link	1
7.	5200 mAh 3S Lipo battery		Online - link	1
8.	200W Buck		Online - link	1

	Converter			
9.	Raspberry Pi 5 8GB	Compute Module	Online – link	1
10.	BNO055 Imu	Localization and Navigation	Online – link	1
11.	PX4 Optical Flow Sensor		Online – link	1
12.	OV5647 Cameras	Mapping	Online – link	2
13.	CS20 3D Lidar		Online – link	1
14.	FS-i6 Transmitter, FS-iA6B Receiver	Communication	Online – link	1

4 Outline the plan for realization of ANAV:

Concise description of the software implementation plan for navigation and guidance.

Integrates sensor fusion, SLAM, terrain analysis, and real-time decision-making. Sensor data from IMU, LiDAR, optical flow, and cameras is processed using a **Kalman Filter** for precise state estimation (position, velocity, orientation). **SLAM** builds a 3D map and localizes the drone in GNSS-denied environments, enabling obstacle detection and path planning.

Sensor Data Acquisition:

- Collect real-time data from IMU, LiDAR, optical flow sensors, and onboard cameras.
- Fuse sensor data using a Kalman Filter for accurate state estimation (position, orientation, velocity).

SLAM (Simultaneous Localization and Mapping):

- Build and update a 3D map of the terrain while continuously tracking the drone's position within the environment.
- Use SLAM for obstacle detection and real-time localization.

Path Planning and Guidance:

- Plan trajectories using algorithms like RRT* or *D Lite** for obstacle avoidance and efficient navigation to target waypoints.
- Dynamically adjust flight paths based on real-time updates from SLAM and terrain analysis.

Flight Control:

- Use the Pixhawk flight controller to execute high-level commands for stable takeoff, hover, landing, and navigation.
- Maintain stability and responsiveness through tight integration of control loops.

Failsafe Mechanisms:

- Monitor battery health, communication status, and sensor functionality.
- Trigger emergency landing or return-to-home (RTH) in case of critical failures.

Return-to-Home (RTH):

- Navigate back to the home position after completing tasks or during emergencies using the same SLAM-based navigation pipeline.

5 Test Plan:

Subsystem Tests:

Navigation System

- **Test**: SLAM Accuracy in Simulated Martian Terrain
- **Plan**: Evaluate SLAM in a simulated Martian environment with uneven surfaces and obstacles, testing map accuracy and real-time position tracking.
- **Expected Outcome**: Precise terrain mapping and reliable obstacle detection for efficient path planning.

Control System

- **Test**: Stability During Takeoff, Hover, and Landing
- **Plan**: Assess stability in varied conditions, including wind disturbances, to ensure steady hover, ascent, and landing.
- **Expected Outcome**: Smooth and stable flight with effective compensation for external forces.

Sensing System

- **Test**: Data Accuracy from LiDAR and Optical Flow Sensors
- **Plan**: Compare sensor readings to known measurements in controlled settings under varied light and surface conditions.

- **Expected Outcome**: Accurate obstacle detection and surface mapping with consistent performance.

System Tests:

Autonomous Flight

- **Plan**: Perform a complete mission in a simulated environment, covering takeoff, obstacle navigation, and landing.
- **Expected Outcome**: Autonomous mission completion with seamless subsystem integration, obstacle avoidance, and precise landing.

Failsafe Scenarios

- **Plan**: Simulate critical failures such as power or communication loss to evaluate emergency response mechanisms.
- **Expected Outcome**: Controlled emergency landing to minimize damage and ensure mission integrity under adverse conditions.

6 System specification:

Sl. No.	Description	Specification
1.	Overall mass	≤ 2 kg
2.	Overall dimensions	30 x 30 x 15 cm
3.	Power requirements	5200mAh 3S LiPo Battery
4.	Flight time per charge	20–25 minutes per charge
5.	Number of propellers and their size	4 (6-inch diameter)
6.	Features	Trajectory Recall, Experience based Adaptive Planning, Self adaptive model for crater detection and safe spot detection
7.	Total Torque	3.74 Nm
8	Telemetry range	Upto 2Km
9.	Thrust per motor (assuming 2200kV)	750 g
10.	Thrust to weight ratio (assuming 2 kg)	1.5

7 Overview of the Emergency Response System:

The **Emergency Landing System (ELS)** makes sure the space drone lands safely in the event of an emergency, such as a low battery, a communication breakdown, a sensor failure, or a collision risk. By using a sequence of automated reactions to reduce danger and safeguard the drone, this system enables a safe landing without the need for human assistance.

1. The following essential elements form the basis of the **Emergency Landing System's operation**:

- **Sensors**: The system employs various sensors, including battery monitors, altitude sensors, proximity sensors, and IMU (Inertial Measurement Unit) sensors, to collect critical data for decision-making.
- **Control Algorithm**: A state-machine-based algorithm manages different emergency scenarios. It ensures safe transitions between modes such as safe mode, error correction mode, and landing mode, guaranteeing the drone's secure operation during emergencies.

2. Operating Modes

The system's state machine operates through several stages, adapting to the drone's condition. These modes include:

- **Safe Mode**:
  This mode is activated when the drone encounters critical issues, such as a dead battery or communication failure. Once stabilized, the drone initiates a controlled descent to a safe altitude.
- **Error Correction Mode**:
  In this mode, the drone attempts to resolve minor issues like misaligned sensors or communication disruptions. If the system successfully recalibrates sensors and restores communication, the drone resumes normal operation. Otherwise, it transitions to Safe Mode.
- **Landing Mode**:
  When the drone nears the ground, the system uses crush pads to enable a soft landing. The drone descends at a reduced speed to minimize impact forces.

4. Control Algorithm

The control algorithm is a decision-making process that checks the drone’s status and triggers actions based on specific emergency conditions.

Decision Logic:

- The system continuously monitors: Battery level, communication status, sensor health, altitude, and proximity to the ground.
- Upon detecting an emergency (e.g., low battery or communication loss), the system switches to **Safe Mode**.
- If the issue is minor, the system attempts **Error Correction** (recalibration or restoring communication).
- When nearing the ground, the system switches to **Landing Mode** and deploys airbags or crush pads for a soft landing.

5. Hardware Requirements

To practically implement this system, the following hardware components are required:
Sensors:

- **IMU (Inertial Measurement Unit)**: Monitors the orientation of the drone.
- **Altitude Sensors (Barometer)**: Measure the altitude to trigger landing actions.
- **Proximity Sensors (LiDAR)**: Detect obstacles or proximity to the ground.
- **Battery Monitoring System**: Monitors battery levels and triggers safe landing if critical.

Actuators:

- **Landing Legs**: Provide structural stability during landing and absorb some of the impact.

Flight Controller: A **flight controller** (e.g., Pixhawk) will manage the sensors and execute the algorithm. This will also ensure that the drone follows the prescribed behaviours during emergencies.

8 Project management:

No.	Task	Main Responsibility	Deadline for Completion	Secondary Responsibility
1	Hardware Procurement	Dharmik Nakum	31-01-2025	Dhairya Panchal
2	Navigation	Meet Jain	21-02-2025	Harshid Rawal
3	Algorithm	Smit Shah	10-03-2025	Achyut Savaliya
4	Sensor Fusion	Khushi Thakkar	01-03-2025	Moulik Shaparia
5	Assembly	Meet Patoliya	15-02-2025	Sankalp Parikh

STRATEGY FOR SCHEDULE MANAGEMENT:

To ensure timely project completion, a detailed schedule management strategy has been adopted:

1. **Task Prioritization**: Tasks are prioritized based on dependencies. For example, hardware procurement and assembly must be completed before sensor fusion and navigation testing
2. **Milestone Deadlines:** Deadlines are assigned to each task based on project phases and interdependencies.
3. **Regular Updates:** Weekly progress meetings are scheduled to evaluate task completion and address bottlenecks. Task owners will provide updates and ensure transparency regarding challenges or delays.
4. **Contingency Planning:** Buffer times are allocated for critical tasks to account for unexpected delays, especially in hardware procurement and algorithm testing.
5. **Documentation and Reporting:** A project management tool will trace the task progress, deadlines and dependencies. Detailed documentation for each milestone will be developed to ensure traceability and clarity for all team members.

9 Novelty in the overall proposal:

The proposed drone system features a self-learning crater detection mechanism, diverging from traditional static datasets by adapting detection algorithms in real-time. This ensures exceptional adaptability and precision.

Key Innovations: Dynamic Data Acquisition: Onboard cameras capture high-resolution terrain frames during descent and navigation, ensuring real-time monitoring for processing.

Advanced Feature Extraction: A Deep Prior Convolutional Detection Network (DPCDN) extracts key surface features—flat zones, craters, and hazards—forming a Feature Detection Map (FDM) for navigation and hazard analysis.

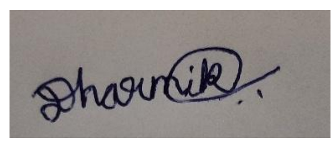
Real-Time Hazard Identification: Pre-trained models classify FDM regions as hazardous (e.g., crater rims, rocky areas) or safe, enhancing decision-making and achieving 80% detection accuracy.

Advantages: The system’s adaptive algorithms enable effective navigation in unknown terrains. High-speed real-time processing ensures precise hazard identification, making it ideal for extraterrestrial exploration, where adaptability is crucial.

10 Declaration format:

<u>Declaration</u>

We hereby declare that the aerial vehicle (rotorcraft) built/procured by team <u>Sky Grid</u>, Dharmsinh Desai University, College Road, Nadiad, Gujarat, India, complies to Drone rules-2021, issued by Ministry of Civil Aviation as per the Gazette of India CG-DL-E-26082021-229221 or the latest version.



Team lead: Dharmik Nakum

Mentor-1: Dr. Ashish B. Pandya

Mentor-2: Prof. Pinkesh V. Patel