

ANRF MAHA Drones: Components & Sub-Assemblies Research & Innovation Program

In collaboration with the **ICMR and MoES**

1. Background and Rationale

Drone technology has become increasingly important across various defence and civilian sectors (e.g. military, security, agriculture, construction, logistics, etc.) due to its ability to perform tasks efficiently, safely, and cost-effectively. India's drone ecosystem is strong in applications and assembly of drones, but less developed in foundational technologies at the component & sub-assembly level. While domestic firms have advanced in assembling airframes and software solutions, critical components and subassemblies remain heavily import-dependent. These include motors, ESCs, high-C Li-ion cells, GNSS modules, secure radios, low cost EO/IR camera modules, Spectral imagers, LiDARs, Synthetic Aperture Radar (SAR) payloads, and advanced sensors.

With this basis, ANRF is launching a MAHA Program on Drones: Components & Sub-Assemblies Research & Innovation, intended to address potential Strategic, Economic, and Innovation challenges and to strengthen the national drone ecosystem, positioning India to build holistic, end-to-end capabilities in the drone sector.

2. Vision and Mission Objectives

This program aims to establish national capability in foundational drone technologies and transition India from an assembly-driven ecosystem to an innovation-driven, component-secure ecosystem.

The mission seeks to:

- Develop indigenous drone components and sub-assemblies across the full technology stack.
- Reduce strategic import dependence and build India's technological sovereignty.
- Foster innovation in propulsion, energy storage systems, advanced materials, autonomous navigation, communication, sensors, and safety systems.
- Deliver TRL-7 commercialisable demonstrators within 3 years.
- Build a competitive industrial base serving defence and civilian markets.

The program will catalyse collaboration between academia, national laboratories, deeptech startups, MSMEs, and industry through structured consortia comprising these entities with credible and compelling collaboration.

3. Scope of the Program

The mission will address problem statements that span the full life-cycle of drone subsystems: materials, design, integration, testing, and certification—within the six thematic domains outlined below. While a set of Key Problem Statements is provided, submissions are not restricted to these topics. Alternative problem statements may be considered, provided they define clear, measurable numerical targets and include a strong justification demonstrating how they achieve or surpass current global state-of-the-art standards.

- a) Propulsion and Energy Systems – advanced Li-ion cells, PEM fuel cells, hybrid propulsion units, cells with alternate architecture/chemistry with equivalent capabilities, and related domains.

Key Problem Statements

1.	Develop a high-C lithium-ion or silicon-anode cell (capable of 10C continuous and 20C pulse discharge, while maintaining a gravimetric energy density >300 Wh/kg) utilizing materials manufacturable at scale in India.
2.	Demonstrate a sub-2 kg lightweight PEM fuel cell stack capable of delivering >1 kW of continuous reliable power, enabling >4 hrs of continuous UAV flight endurance.
3.	Build a hybrid turbine-generator system (10–15 kW output) for heavy-lift UAVs achieving a 30% lower weight-to-power ratio compared to current state-of-the-art Internal Combustion Engine (ICE) alternatives.

- b) Smart Materials and Adaptive Airframes – morphing wings, self-healing polymers, lightweight composites, low-acoustic composite propellers, thermal isolation chamber, and related domains.

Key Problem Statements

1.	Develop an active morphing wing prototype for a <25 kg UAV that measurably increases aerodynamic endurance by >20% compared to rigid fixed-wing baselines under dynamic turbulent flight conditions.
2.	Design a self-healing composite material capable of autonomously repairing 1 mm structural micro-cracks at standard room temperature within 24 hours, subsequently restoring >85% of its original tensile strength.
3.	Demonstrate a bird-strike resistant composite UAV nose structure capable of successfully passing DO-160 certification tests at direct impact velocities of 250 knots.
4.	Fabricate low-acoustic composite propellers utilizing advanced aerodynamic geometries to achieve a >5 dBA overall noise reduction and a >10% increase in fatigue life compared to standard profiles.
5.	Design a cryogenic thermal management and vacuum-insulation cocoon (<80 g) for stratospheric UAV energy systems, enabling continuous battery operation at -70°C ambient temperatures while consuming <10% of total onboard power. (MoES Requirement)

- c) Assured Navigation and Autonomy – NavIC-enabled anti-jam GNSS receivers, swarm autonomy, reinforcement learning-based flight control, triple-redundant autopilot, and related domains.

Key Problem Statements

1.	Develop a NavIC-enabled GNSS receiver with robust hardware-level anti-jam capability at a mass-production cost of <\$300.
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2.	Create a neuromorphic chip-based SLAM (Simultaneous Localization and Mapping) module consuming <5 W of total power to enable rapid, real-time spatial mapping for onboard micro-swarm drones.
3.	Implement a decentralized blockchain-based flight logging system directly integrated with the national Digital Sky platform, mathematically optimized to scale securely to 100,000 daily concurrent flights.
4.	Design an open-architecture triple-redundant autopilot (less than 500g weight).

- d) Resilient Communications and PNT – detect-and-avoid millimeter-wave radar, secure SDR-based command-and-control links, post-quantum crypto stacks, anti-jam waveforms, and cognitive radios, and related domains.

Key Problem Statements

1.	Develop a miniaturized detect-and-avoid millimeter-wave radar (<0.8 kg, >250 m detection range against small cross-section targets)
2.	Demonstrate a highly secure UAV C2 SDR link achieving a >150 km Line-of-Sight (LOS) range with 10 Mbps continuous data throughput, natively supporting AES-256 encryption with post-quantum cryptographic upgradeability.
3.	Prototype a ruggedized handheld ground control unit integrating SDR, Satcom telemetry, and automated LTE network fallback protocols with a unit cost of <\$2000.
4.	Create a 6G-compatible, self-healing UAV mesh network architecture capable of supporting up to 100 dynamic aerial nodes with <20 ms end-to-end packet latency.

- e) Advanced Sensors and Payloads – lightweight UAV SAR, chip-scale LiDAR, hyperspectral imagers, MEMS chemical/olfactory sensors, bio-secure medical payload carriers, fail-safe redundant high-altitude separation systems, and related domains.

Key Problem Statements

1.	Build a UAV-mounted hyperspectral imager (<2 kg) covering 400–1000 nm with 10 nm resolution.
2.	Develop a LiDAR-on-chip sensor with 200 m range, <0.6 kg, and <30 W power draw.
3.	Design a bio-inspired gas sensor array (e-nose) detecting ammonia, methane, and explosives at ppm levels.
4.	Develop a lightweight, bio-secure medical payload carrier (2–10 kg capacity) integrating hybrid active-passive thermal management to strictly maintain a 2–8°C cold-chain environment for >120 minutes during transit. (ICMR Requirement)
5.	Engineer an ultra-lightweight, dual-redundant balloon separation mechanism (<40 g) capable of fail-safe, autonomous high-altitude cut-down at 30 km AGL without mechanical binding or outgassing. (MoES Requirement)

6.	Produce Low-Cost EO-IR Camera Payloads (<500 g) incorporating a highly reactive 3-axis gyro-stabilization system, featuring a 4K EO visual resolution.
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f) Safety, Certification, and UTM Systems –parachute recovery modules, UAV structural health monitoring, UTM 2.0 integration, and related domains.

Key Problem Statements

1.	Create a certified UAV parachute recovery system for >2 kg drones at <\$2000 per unit.
2.	Demonstrate onboard prognostics software that predicts motor/battery failure with 90% accuracy.
3.	Develop a UTM-compliant Specialized Medical Emergency Identifier hardware module (<50 g) enabling automated Priority Access routing and forced airspace deconfliction with <1 second network communication latency. (ICMR Requirement)

Technical Specifics of the problem statements mentioned above are placed in **Annexure I**.

Disclaimer: The quantitative targets and performance metrics set out in the problem statements are indicative and may be subject to change or evolve over time.

4. Program Framework and Implementation Approach

A mission-mode, stage-gated framework will be adopted:

Stage 1: Pre-Proposal Submission

Interested consortia will submit short concept notes for initial evaluation. This should have an outline of the credible and compelling translation plan and identified partners in the consortium and their roles.

Stage 2: Full Proposal Submission

Applicants shortlisted from Stage 1 will be invited to submit detailed technical and financial proposals. This must include a letter of intent (LoI) from the identified industry partner(s), presenting a detailed, credible and compelling plan for translation along with the research team as part of the consortium. The letter must explicitly state the partner’s role, commitment, resources (facilities, manpower, or test equipment, etc.) and interest in co-developing and/or in-cash co-funding as necessary to complement/support the translation plan.

Multiple teams may be supported at early TRLs (1–3). Progression to TRLs 5–7 will be based on milestone achievements, technical performance, and competitive down-selection. This means that through the program, several research teams may be funded in the early, exploratory phase, but only the most promising ones will continue to receive support at later stages.

Funding will be linked to:

- TRL progression
- Intellectual property creation
- Demonstrated collaboration and translation through the Open License framework

Strategic collaboration with relevant government ministries, departments, and agencies—such as DRDO, ISRO, MoCA, the Armed Forces, MeitY, and other related bodies—may be pursued to ensure alignment with domain priorities and to enable broader impact across application areas.

Important Note:

- A. This MAHA program will strongly encourage and require collaboration in proposals between academia/national research labs and industry, as outlined above, to support translation. Individual or purely academic/national laboratory/S&T organisations without industry partner(s) and/or startup partner(s), or proposals without a credible and compelling translational plan, WILL NOT be prioritised.
- B. In addition to the research proposed, the proposal MUST clearly articulate the translation pathway for how research outputs will be converted into deployable technologies. Each proposal must have at least one industry and/or startup partner who is part of the consortium, who will demonstrate commitment to the proposal translation plan.
- C. Intellectual property generated using ANRF funding will vest with the ANRF grantee institutions from an ownership standpoint. However, the foreground IP created in this program (software, models, data sets, patents, designs) will be subject to the Open License. ANRF's IP policy and open licensing are published in <https://serb.gov.in/page/english/policies>

5. Funding

Funding may be allocated to collaborative consortia of academia, R&D labs, industry and recognised & registered startups / registered MSMEs / section-8 companies / DSIR SIRO recognised organisations. While industry entities may not receive direct funding, they may leverage open-source outputs of the mission. This approach aims to ensure that advanced research is transformed into scalable, manufacturable solutions while encouraging broad participation across the ecosystem.

The maximum financial support from ANRF permissible for a single project shall be **Rs. 50 Cr for 3 years**.

6. Licensing Terms

The programme will mandate the use of ANRF Open License frameworks, as outlined below:

- ANRF Open License for software, models, and datasets
- ANRF Open License for patents and designs

All contributors must operate under these licensing models. Detailed information on the licenses is available [here](#) (adapted from the MIT License).

7. Expected Outcomes

- Development of indigenous, validated drone subsystems achieving TRL 7, suitable for commercial and civilian & defence-oriented applications
- Decreased reliance on imports for critical drone-related technologies
- Strengthening of national supply chains and domestic manufacturing capabilities
- Improved collaboration and knowledge exchange among academia, national research laboratories, and industry
- Establishment of an open, modular, and scalable innovation ecosystem for drone technologies

Note: Assessment of Technology Readiness Levels (TRLs) may be carried out using the [TRL framework](#) developed under the supervision of the Office of the Principal Scientific Adviser to the Government of India.

8. Integrator Partner & Technical Program Management Unit (TPMU)

To ensure subsystem technologies transition into deployable drone platforms, ANRF will involve a central **Multi-Stage Integrator (MSI)** (*separate to this call*) who will be responsible for –

- To act as a multi-stage integrator for the technologies developed under the mission.
- Providing access to advanced testing facilities (such as wind tunnels, propeller rigs, composite testing, environmental and EMI/EMC tests, flight ranges, motor testing, etc.).
- Supporting subsystem integration onto common drone platforms for verification.
- To undertake drone development project(s) resulting in suitable drones for the purpose of testing various payloads and novel design concepts.
- Facilitating design reviews, certification pathways, and safety compliance.
- Operating a collaborative digital portal for academia–industry interaction.
- Enabling an **Open-Source Drone Platform Initiative (OSDPI)** for modular, indigenous UAV development.
- Shall be responsible for the end-to-end system integration and for delivering a fully integrated and tested drone platform in accordance with the technical and operational requirements specified by the user agencies / departments.

9. Submission Guidelines and Evaluation

- Under the Mission, a lead PI is eligible to submit only one proposal during a given call.
- Information to be provided for pre-proposal:

Section A: Objectives, Team, Technical efficacy benchmarks including TRLs, planned contributions, deliverables, impacts, and milestones with a clear deployment pathway (maximum 3 pages).

Section B: Budget Requirements - Details of Non-recurring, Consumables, Travel, Contingency, Research Personnel, Other Charges and Overheads (Maximum 1 page).

Full proposals will be invited by ANRF, based on the evaluation of the pre-proposals.

The proposals will be evaluated by a domain-specific Technical Advisory Committee (TAC), and applicants may be invited for presentations or discussions as part of the selection process.

10. Who can Apply?

- Project proposals are invited in consortium mode, bringing together multiple Principal Investigators (PIs) and institutions/laboratories from academia, research organisations, industry, and startups.
- Each proposal must be submitted by a lead institution and will be headed by a Lead PI (LPI).
- The LPI will be from the academic institution or a National Research Laboratory, and must hold a regular position in the institution.
- PIs should hold a regular academic / research position in a recognised academic institution, national laboratory, or any other DSIR-SIRO recognised research organisation eligible to receive grants-in-aid from the Government of India.
- Applicants must be Indian citizens or OCI holders.
- Applicants must have a PhD in Science, Mathematics, Engineering, or other relevant S&T disciplines.
- LPI should have at least three years of service remaining before superannuation at the time of proposal submission.
- Each proposal must designate one Lead Principal Investigator (LPI) and may include up to six Principal Investigators (PIs). PIs may be from the same institution as the LPI or from multiple collaborating institutions. This structure is designed to encourage the development of strong, interdisciplinary, and multi-institutional research teams capable of achieving the intended outcomes.
- A person from industry, startups, or an international faculty member/researcher, or industry partner may be formally designated as an “Honorary PI” in collaboration with an LPI based in India; however, the role and responsibilities of the Honorary Investigator must be clearly defined in the proposal.

Note:

- The lead institution will be responsible for the financial and administrative management of the project.
- Post selection of the project, funds will be allocated to the lead institution, which will in turn be distributed to other academic/ R&D lab partners, as required.
- Collaboration: Startups and Industry partners may participate in the mission as collaborating partners with academic institutions/ R&D labs and can aim to leverage applicable open-source/open licensing frameworks/outputs of the mission to drive their innovation. No financial support will be provided for industry and startups by ANRF in this mission.

11. How to Apply

Proposals must be submitted through www.anrfonline.in and will be evaluated under ANRF's standard procedures, aligned with the implementation strategies of this Mission. Applicants should carefully review the detailed PI guidelines on the portal to ensure full compliance with submission requirements and formats.

The opening of online submission will be updated soon.

Frequently Asked Questions

Q1: Can an applicant submit multiple proposals

A1: No, an applicant can submit only one proposal under a given call. Also, an investigator is permitted to be linked with only one project.

Q2: Can there be multiple proposals from a host institution

A2: Yes, multiple proposals in different thematic areas can be submitted from different applicants.

Q3. Who is eligible to apply under this program?

A3. Only collaborative consortia comprising academic institutions and/or national research laboratories, along with at least one industry and/or startup/MSME partner, are eligible to apply. Proposals without industry or startup participation will not be prioritised.

Q4. Is industry participation mandatory?

A4. Yes. Industry and/or startup participation is mandatory. Each proposal must demonstrate a credible and compelling translation plan supported by committed industry or startup partners.

Q5. What constitutes a credible and compelling translation plan?

A5. A translation plan must clearly outline how research outputs will be converted into deployable and manufacturable technologies. It should define partner roles, commitments, access to resources, and pathways for commercial or strategic deployment.

Q6. What is the proposal submission process?

A6. The program follows a two-stage, mission-mode, stage-gated framework. Stage 1 involves submission of short pre-proposals (concept notes). Stage 2 involves submission of detailed technical and financial proposals by shortlisted applicants, including mandatory Letters of Intent from industry or startup partners.

Q7. Can industry or startups receive direct funding from ANRF?

A7. No. Industry entities and startups/MSMEs may participate as consortium partners but will not receive direct funding from ANRF. They may leverage open-source/open licensing frameworks/outputs of the mission to support translation and commercialisation.

Q8. How is funding linked to performance?

A8. Funding allocation and continuation are linked to TRL progression and also progression towards the technical targets for the specific components/subassemblies, achievement of technical milestones, intellectual property generation, and the strength of industry participation and commitments.

Q9. Is there a provision for a central integrator under the program?

A9. ANRF may involve a central Multi-Stage Integrator with proven capabilities in UAV development, testing, certification, and subsystem integration to support platform integration and validation.

Q10: Is there a limit on the number of PIs in a consortium?

A10: Yes. Up to 6 PIs are allowed.

Q11. How will proposals be evaluated?

A11. Proposals will be evaluated by a domain-specific Technical Advisory Committee (TAC). Applicants may be invited for presentations or technical discussions.

Q12. Will there be additional cycles of the R&D call under the MAHA Drone Program?

A12. There may be additional cycles of the R&D call under the MAHA Drone Program. Any further calls or new cycles will be announced through official notifications in due course.

Q13. Is it permissible to submit a proposal under this call if similar or related work has been submitted elsewhere or is being funded by another agency?

A13. Proposals under this call must not duplicate or substantially overlap with any project that is already funded, under review, under consideration, or previously submitted to any other Ministry, Department, or Government funding organisation, nor shall they overlap with or fall within the scope of the ongoing scheme mandates of any other government agency.

Q14: I belong to a Private Limited Company. Am I eligible to apply as an LPI/PI under the MAHA DRONE?

A14: No. Individuals affiliated with a Private Limited Company are not eligible to serve as a Lead Principal Investigator (LPI) or Principal Investigator (PI) under the MAHA Drones Program. However, they may participate in the project as an Honorary Investigator, subject to the applicable guidelines.

Q15: How do startups and industry benefit from collaborating with academia and national labs?

A15: They gain access to advanced research, national testing infrastructure, validation platforms, and open-licensed IP, enabling faster time-to-market, rapid national-scale adoption, and competitive advantage.

Q16: Why are startup and industry partners required in proposals?

A16: Startups enable rapid innovation and product development, while industry provides market access, risk reduction, and scaling capability. Their participation ensures a credible translation pathway from research to commercialisation, supporting national-scale deployment and delivering tangible national impact.

Problem Statement 3 a) 1. : High-Power, High-Energy-Density Li-Ion Cell

Target Exit TRL: 7

Technical Context: Electric VTOL drones require a contradictory battery profile: high specific energy for endurance (cruise) and high specific power for takeoff/landing (hover). Current commercial cells generally trade one for the other. This project seeks a cell chemistry that bridges this gap while ensuring the supply chain relies on domestic materials or processing capabilities.

Scope of Work: Research proposals must focus on the development of a Lithium-ion or silicon-anode cell chemistry capable of sustaining continuous discharge rates of 10C and pulse discharge of 20C while maintaining a gravimetric energy density exceeding 300 Wh/kg at the cell level. Innovations may involve silicon-anode doping, advanced cathode architectures, or novel electrolyte formulations. Crucially, the manufacturing process must be validated on pilot-scale equipment available in India, moving beyond coin-cell research to cylindrical or pouch cell formats.

Key Performance Indicators: Cycle life must exceed 500 cycles at 1C charge/5C discharge to 80 percent capacity retention. Safety testing must demonstrate resistance to thermal runaway under nail penetration standards. The 10C discharge capability must be sustained for at least 60 seconds without voltage sag dropping below the safe cutoff, simulating a heavy-lift takeoff scenario.

Deliverables:

- Batch of 50 pilot-production cells.
- Standard cycling data sheets and impedance spectroscopy reports.
- Manufacturing process document for gigafactory transfer.

Problem Statement 3 a) 2. : Lightweight PEM Fuel Cell Stack

Target Exit TRL: 6

Technical Context: Hydrogen Proton Exchange Membrane (PEM) fuel cells offer significantly higher energy density than batteries for long-endurance missions. However, the balance of plant (cooling, humidification, valves) typically adds excessive weight, making them unviable for small (<25 kg) tactical UAVs.

Scope of Work: The objective is to miniaturize the PEM stack and its ancillary systems. Innovations should eliminate heavy liquid cooling loops, and lightweight bipolar plates. The system must deliver 1 kW continuous power.

Key Performance Indicators: The total system mass (excluding hydrogen cylinder) must not exceed 2 kg. The stack must demonstrate stable operation for a 4-hour duration under variable load profiles typical of drone flight. Thermal management must be passive or strictly air-cooled.

Deliverables:

- Integrated 1kW Fuel Cell Power Module.
- Polarization curves and durability test report.
- Integration manual for hybrid battery-FC configurations.

Problem Statement 3 a) 3. : Hybrid Turbine-Generator

Target Exit TRL: 5

Technical Context: Heavy-lift logistical drones require propulsion architectures with exceptionally high power-to-weight ratios to offset the weight of the payload and maximize operational endurance.

Scope of Work: Develop a micro-turbine generator system (10-15 kW output) for heavy-lift logistical drones. The focus is on increasing power density to surpass existing Internal Combustion Engine (ICE) alternatives. The target is a 30% weight reduction compared to a comparable piston engine-generator set.

Key Performance Indicators:

- Achieve a 30% lower weight-to-power ratio compared to a comparable piston engine-generator set.
- Provide continuous 10-15 kW output.

Deliverables: Prototype turbine engine with integrated generator; Fuel consumption analysis; Specific power validation.

Problem Statement 3 b) 1. : Morphing Wing Prototype

Target Exit TRL: 4

Technical Context: Fixed-wing UAVs possess high cruise efficiency but lack agility, whereas multi-rotors excel at hovering but suffer from poor range. Active wing morphing bridges this gap by altering aerodynamic profiles mid-flight.

Scope of Work: Investigate compliant mechanisms or shape-memory alloy actuators to create a wing that changes profile in flight to optimize for both loiter (high lift) and dash (low drag) phases. Target platform is a <25 kg tactical UAV.

Key Performance Indicators:

- Measurably increase aerodynamic endurance by >20% compared to rigid fixed-wing baselines.

Deliverables: Wind tunnel test model; aerodynamic performance data showing 20% endurance gain; actuation durability report.

Problem Statement 3 b) 2. : Self-Healing Composite Material

Target Exit TRL: 4

Technical Context: Structural micro-cracks induced by fatigue and high-frequency vibration significantly degrade the lifespan of composite airframes.

Scope of Work: Formulate a polymer matrix composite containing microcapsules of healing agent. The material must automatically repair minor structural cracks caused by fatigue or minor impact.

Key Performance Indicators:

- Autonomously repair 1 mm width micro-cracks.
- Healing must occur at standard room temperature within 24 hours without external intervention.
- Restore >85% of original tensile strength post-healing.

Deliverables: Composite test coupons; Mechanical strength recovery test reports (pre- and post-healing).

Problem Statement 3 b) 3. : Bird-Strike Resistant Nose Structure

Target Exit TRL: 5

Technical Context: High-speed BVLOS drones operate in airspace populated by avian wildlife, making high-velocity kinetic impacts a primary cause of catastrophic airframe failure.

Scope of Work: Design a UAV nose cone and forward fuselage optimized for impact resistance. The structure must protect critical internal electronics during a collision.

Key Performance Indicators:

- Successfully pass DO-160 certification tests at direct impact velocities of 250 knots.

Deliverables: Finite Element Analysis (FEA) impact simulation; Physical impact test results (gas gun test).

Problem Statement 3 b) 4. : Low-Acoustic Composite Propellers

Target Exit TRL: 6

Technical Context: High-frequency tonal noise generated by propeller blade passage creates distinct acoustic patterns that limit the covert operation of tactical drones and societal acceptance of urban aerial mobility.

Scope of Work: Integrate Carbon Nanotubes (CNTs) or advanced composite matrices to fabricate low-acoustic composite propellers utilizing advanced aerodynamic geometries (e.g., toroidal loops, serrated trailing edges).

Key Performance Indicators:

- Achieve a >5 dBA overall noise reduction compared to standard profiles.
- Demonstrate a >10% increase in fatigue life.

Deliverables: Prototype propeller set; Acoustic anechoic chamber testing data; Vibration fatigue test comparison data.

Problem Statement 3 b) 5. : Stratospheric Thermal Management for Energy Systems

Target Exit TRL: 5

Technical Context: Stratospheric drones (MoES) must operate in extreme cold, reaching -70°C. At these temperatures, the ionic conductivity of standard Li-ion batteries drops to near zero, causing instant system failure. Current battery heaters are often inefficient and drain the flight battery faster than they preserve it.

Scope of Work: The objective is to develop a specialized thermal cocoon for high-altitude UAV energy systems. This includes ultra-lightweight vacuum insulation and an intelligent, low-density heating mesh. The system must utilize an adaptive energy redistribution logic that harvests waste heat from the flight controller or motors to supplement the battery heater. Research should also explore the use of vacuum-jacketed battery housings to minimize convective heat loss in the low-pressure stratosphere.

Key Performance Indicators: The system must maintain the internal battery temperature above 5°C while the exterior is at -70°C for at least 90 minutes. The thermal management system's power consumption must not exceed 10% of the drone's total energy capacity. The total mass of the insulation and heating assembly must be under 80g to comply with the overall 600g mass limit.

Deliverables:

- A functional stratospheric battery housing prototype.
- Thermal stability test data from a cryogenic vacuum chamber simulation.

Problem Statement 3 c) 1. : Low-Cost NavIC-Enabled GNSS Receiver with Anti-Jamming

Target Exit TRL: 7

Technical Context: Standard commercial drones currently rely heavily on single-frequency GPS/GLONASS modules which are susceptible to spoofing and jamming. The strategic imperative is to migrate the national drone fleet to the Indian Constellation (NavIC). The challenge lies not in the receiver design itself, but in achieving robust anti-jamming capabilities while suppressing the cost to commodity levels suitable for civilian mass adoption.

Scope of Work: The objective is to design and fabricate a multi-constellation GNSS receiver module centered on NavIC L5 and S-band signals. The architecture must integrate RF front-ends, digitizers, and baseband processing on a compact PCB. Critical

functionality includes the rejection of in-band interference and mitigation of spoofing attacks through signal authentication or null-steering techniques. The proposed solution must demonstrate a clear path to mass manufacturing where the unit price needs to be below 300 USD at volumes exceeding 1,000 units (Bill of Materials must support the cost structure).

Key Performance Indicators: The module must support simultaneous reception of GPS (L1/L2) and NavIC (L5/S) bands. Time-to-First-Fix should remain under 45 seconds for cold starts. Anti-jamming performance must withstand interference power levels of at least 40 dB relative to the noise floor without loss of lock. The physical footprint is restricted to standard drone UART/CAN form factors, with power consumption not exceeding 1.5 W during active tracking.

Deliverables:

- Hardware prototype (Form Factor Compliant).
- RF performance test reports (Anechoic chamber results for antenna pattern and jamming resilience).
- Firmware source code and ICD for autopilot integration.

Problem Statement 3 c) 2. : Neuromorphic SLAM Module

Target Exit TRL: 5

Technical Context: Simultaneous Localization and Mapping is computationally expensive, draining battery on small drones. Neuromorphic computing offers a paradigm shift in power efficiency for event-driven processing.

Scope of Work: Design a navigation module using neuromorphic hardware. The system must perform real-time SLAM in GPS-denied environments. The primary constraint is power consumption, which is capped at 5 Watts.

Key Performance Indicators: The module must map an unknown indoor corridor and maintain position estimate with <1% drift over the distance travelled. Processing latency must support control loops at 50 Hz.

Deliverables:

- Hardware PCB with neuromorphic chip integration.
- SLAM algorithm benchmarking report against standard GPU baselines.

Problem Statement 3 c) 3. : Blockchain-Based Flight Logging System

Target Exit TRL: 6

Technical Context: As drone density increases, centralized UTM (Unmanned Traffic Management) databases become single points of failure and trust. A distributed ledger system is needed to create immutable records of flight paths, pilot identities, and maintenance logs.

Scope of Work: Develop a private or permissioned blockchain architecture compatible with India's Digital Sky framework. The ledger must handle high transaction throughput corresponding to 100,000 daily flights without significant validation latency.

Key Performance Indicators: Consensus mechanism efficiency (energy per transaction) is critical. Query latency for regulatory auditing must be under 2 seconds. The system must run on lightweight nodes suitable for ground control stations.

Deliverables:

- Software stack (Blockchain core + API).
- Simulation report scaling to 100k nodes.

Problem Statement 3 c) 4. : Open-Architecture Triple-Redundant Autopilot

Target Exit TRL: 7

Technical Context: High-value BVLOS and defence operations demand absolute fault tolerance against acute hardware failure, which single-IMU commercial flight controllers cannot provide.

Scope of Work: Design an open-architecture triple-redundant (3X) autopilot featuring dissimilar microprocessors, enabling asynchronous voting logic that isolates faulty nodes without physical flight disruption.

Key Performance Indicators:

- Weight must be strictly <500 g.
- Demonstrate verifiable compliance up to DO-178C (Software) and DO-254 (Hardware) Design Assurance Level (DAL) B.
- Maintain a Mean Time Between Failures (MTBF) exceeding 100,000 hours.
- Sensor voting switchover latency must be <50 ms.
- Manufacturable for domestic users at a unit cost of <\$1000.

Deliverables: Fully assembled triple-redundant flight controller hardware; Asynchronous voting logic software stack; Stress-test certification logs.

Problem Statement 3 d) 1. : Miniaturized Detect-and-Avoid (DAA) Radar

Target Exit TRL: 7

Technical Context: For Beyond Visual Line of Sight (BVLOS) operations, drones require non-cooperative sense-and-avoid capabilities. Optical cameras fail in low light or fog; thus, radar is essential. Existing automotive radars are too heavy or lack the vertical field of view required for aerial manoeuvring.

Scope of Work: The project entails the development of a lightweight millimeter-wave radar optimized for aerial collision avoidance. The system must process returns onboard

to classify obstacles (wires, other aircraft, structures) and output vector corrections to the flight controller. The strict mass limit of 0.8 kg includes the antenna array, processing unit, and housing.

Key Performance Indicators: The sensor must detect a 0.5 square meter RCS target at a range of 250 meters with a false alarm rate lower than one per hour. Field of View requires at least ± 45 degrees azimuth and ± 20 degrees elevation. The target unit cost of 4000 USD necessitates the use of commercial off-the-shelf MMIC components rather than custom military-grade silicon.

Deliverables:

- Radar sensor unit integrated with a standard drone autopilot.
- Algorithm description for object classification and tracking.
- Flight test video demonstrating autonomous avoidance of a static obstacle.

Problem Statement 3 d) 2. : Secure Long-Range UAV Communication Link

Target Exit TRL: 7

Technical Context: Standard ISM band telemetry links are power-limited and insecure. Military-grade links are export-controlled. An indigenous Software Defined Radio (SDR) solution is required to provide high-bandwidth data for video streaming while maintaining command and control (C2) integrity over long distances.

Scope of Work: Development of a dual-link communication system operating on licensed or unlicensed bands capable of 150 km Line-of-Sight range. The waveform design must be resilient to multipath fading and intentional jamming. The cryptographic layer must support AES-256 for current security standards and include a transition path to Post-Quantum Cryptography (PQC) algorithms to future-proof against quantum decryption threats.

Key Performance Indicators: Throughput must be adaptive, maintaining at least 10 Mbps at maximum range for video, and falling back to a robust low-rate C2 channel (50 kbps) under heavy interference. The system must demonstrate link stability with a total latency under 100 milliseconds.

Deliverables:

- Air unit and Ground Control Station (GCS) radio modules.
- Bit Error Rate (BER) vs. Range test logs.
- Security audit report of the cryptographic implementation.

Problem Statement 3 d) 3. : Handheld Ground Control Unit (GCU)

Target Exit TRL: 7

Technical Context: Disparate control interfaces for telemetry, video, and overrides create high cognitive loads for operators during field deployments.

Scope of Work: Design a ruggedized, ergonomic handheld controller that consolidates multiple radio links (SDR, Satellite, LTE). The unit must run mission planning software on an embedded OS. The Bill of Materials must be optimized to keep production costs below 2000 USD.

Key Performance Indicators:

- Integrate SDR, Satcom telemetry, and automated LTE network fallback protocols.
- Unit production cost must be kept below <\$2000.

Deliverables: Functional prototype unit; environmental test report (drop, dust, water resistance).

Problem Statement 3 d) 4. : 6G-Compatible UAV Mesh Network

Target Exit TRL: 5

Technical Context: Future swarm operations require ad-hoc networking where drones relay data between each other without relying on ground infrastructure. 5G-ready and 6G-compatibility standards will prioritize ultra-low latency and high reliability.

Scope of Work: Prototype a mesh networking protocol stack designed for highly mobile nodes (high Doppler shift). The network must self-heal when nodes drop out and support a swarm size of 100 nodes.

Key Performance Indicators: End-to-end latency across 3 hops must remain below 20 milliseconds to support real-time swarm coordination. The network must demonstrate stable routing convergence within 500 milliseconds of a topology change.

Deliverables:

- SDR-based mesh network implementation.
- Demonstration of video relay across a 5-node linear chain.

Problem Statement 3 e) 1. : Compact Hyperspectral Imager

Target Exit TRL: 6

Technical Context: Hyperspectral imaging is critical for precision agriculture and mineralogy but is traditionally limited to large, manned aircraft platforms due to size and data processing requirements.

Scope of Work: Develop a hyperspectral sensor within a 2 kg mass budget. The optical design must cover the Visible to Near-Infrared range (400–1000 nm). The core challenge involves developing a lightweight spectrometer assembly and an onboard processing unit capable of handling the high data rate.

Key Performance Indicators: Spectral resolution must be 10 nm or finer. Spatial resolution should achieve ground sampling distances compatible with low-altitude drone flight.

Deliverables:

- Flight-ready hyperspectral camera payload.
- Data calibration software (radiometric and geometric correction).
- Sample data cubes from flight trials.

Problem Statement 3 e) 2. : LiDAR-on-Chip Sensor

Target Exit TRL: 4

Technical Context: Traditional mechanical LiDAR arrays are bulky, power-hungry, and prone to mechanical vibration failure.

Scope of Work: Develop a solid-state LiDAR using silicon photonics or MEMS steering to eliminate moving parts. The sensor must achieve a 200-meter range for mapping applications while keeping power draw under 30 Watts and mass under 0.6 kg.

Key Performance Indicators:

- Achieve a 200 m effective point-cloud mapping range.
- Overall weight <0.6 kg.
- Operational power draw strictly <30 W.

Deliverables: Packaged sensor chip; point cloud data sample; power consumption analysis.

Problem Statement 3 e) 3. : Bio-Inspired Gas Sensor Array (E-Nose)

Target Exit TRL: 5

Technical Context: Detecting chemical trace elements from an aerial platform is exceedingly difficult due to the massive signal-to-noise ratio degradation caused by rotor downwash.

Scope of Work: Create a highly sensitive chemical sensor array capable of detecting trace amounts (ppm level) of ammonia, methane, and explosive precursors from a flying platform. The sensor must overcome the signal-to-noise ratio issues caused by rotor downwash.

Key Performance Indicators:

- Detect ammonia, methane, and explosive precursors at parts-per-million (ppm) levels.
- Response latency of <2 seconds.

Deliverables: Sensor payload; sensitivity and selectivity test reports; flight trial data in a controlled plume.

Problem Statement 3 e) 4. : Bio-Secure & Temperature-Controlled Payload Modules

Target Exit TRL: 7

Technical Context: Medical logistics, particularly for vaccines, blood products, and diagnostic specimens, require strict Cold-Chain maintenance between 2°C - 8°C. Conventional insulated boxes are bulky and lack the structural integrity required for drone flight. There is a need for an integrated, lightweight payload carrier that combines high-performance insulation with active thermal regulation and bio-containment.

Scope of Work: Research must focus on the development of a modular, biosecure payload carrier with a capacity of 2–10 kg. The carrier must utilize advanced insulation materials, such as vacuum insulation panels or aerogels, to minimize wall thickness. The thermal management system should ideally be a hybrid of Phase Change Materials for passive stability and low-power thermoelectric cooling for active regulation. The housing must be contamination-proof, airtight, and equipped with sealed-container security features.

Key Performance Indicators: The carrier must maintain an internal temperature of 2°C -8°C for a minimum flight duration of 120 minutes in ambient temperatures up to +45°C. The total mass of the empty carrier (including cooling systems and battery) must not exceed 25% of its rated payload capacity. The system must include real-time temperature and tamper-evident logging via the drone's telemetry.

Deliverables:

- Prototype of a 5 kg capacity biosecure carrier.
- Thermal performance validation report across variable ambient profiles.
- Bio-containment and crash-resilience test certification.

Problem Statement 3 e) 5. : Fail-Safe Redundant High-Altitude Separation Systems

Target Exit TRL: 6

Technical Context: For balloon-assisted UAVs (MoES), the transition from ascent to glide is a single point of failure. If the cut-down mechanism fails to release the drone from the balloon at 30 km, the entire payload is lost. Existing mechanisms often freeze or experience mechanical binding in stratospheric conditions.

Scope of Work: Develop a dual-redundant, ultra-lightweight separation mechanism capable of reliable operation at 30 km AGL. The system must incorporate two independent triggering methods. The design must ensure zero outgassing and no risk of the cut-down line entangling with the UAV's propulsion or control surfaces during the separation sequence.

Key Performance Indicators: The mechanism must demonstrate a 99.9% reliability rate in separation trials at -70°C and 10 mbar pressure. The total mass for the dual-redundant assembly must be less than 40g. It must interface directly with a standard flight controller.

Deliverables

- 10 units of the separation mechanism for destructive and flight testing.
- Fail-safe autonomous decision logic source code.

Problem Statement 3 e) 6. : Low-Cost EO-IR Camera Payloads

Target Exit TRL: 7

Technical Context: High-resolution EO/IR gyro-stabilized gimbals are essential for tactical surveillance but remain highly expensive and import-dependent.

Scope of Work: Engineer an indigenous micro-gimbal housing both an Electro-Optical (EO) lens and an uncooled radiometric Infrared (IR) core.

Key Performance Indicators:

- Total payload weight strictly <500 g.
- Incorporate a 4K EO visual resolution sensor and a minimum 640x512 IR thermal core resolution.
- Maintain highly reactive 3-axis gyro-stabilization with <0.1° angular accuracy.
- Unit production cost optimized to <\$2000.

Deliverables: Fully functional EO/IR gimbal prototype; Video stabilization and thermal calibration logs.

Problem Statement 3 f) 1. : Certified UAV Parachute Recovery System

Target Exit TRL: 7

Technical Context: Operations over populated areas demand reliable physical flight termination systems.

Scope of Work: Engineer a ballistic parachute deployment system featuring independent power and trigger logic.

Key Performance Indicators:

- Optimized for drones >2 kg MTOW.
- Unit cost engineered to <\$2000.
- Ensure a safe descent rate of <4 m/s.

Deliverables: Deployment mechanism prototype; drop test reliability report; reaction time analysis.

Problem Statement 3 f) 2. : Onboard Prognostics Health Management (PHM)

Target Exit TRL: 6

Technical Context: Unpredictable hardware degradation leads to catastrophic mid-air failures.

Scope of Work: Develop an edge-computing software module that monitors motor vibration, battery voltage sag, and ESC temperature in real-time. Using machine learning models, the system must predict impending component failure with 90% accuracy before catastrophic loss of control occurs.

Key Performance Indicators:

- Predict impending component failure with 90% accuracy prior to loss of control.

Deliverables: Software library/SDK; validation report using seeded fault datasets.

Problem Statement 3 f) 3. : Integrated Emergency Priority Identifiers for UTM

Target Exit TRL: 7

Technical Context: Medical drones (ICMR) must be distinguishable from commercial traffic to be granted priority safety corridors during time-critical missions. Standard strobe lights are insufficient for integrated Unmanned Traffic Management (UTM) awareness.

Scope of Work: Research and develop a dual-mode Medical Emergency Identifier system. This includes an active electronic signature that flags the drone as a Priority-1 Medical asset to the UTM framework, and a passive/visual high-intensity distinctive identifier. The system must be tamper-proof to prevent unauthorized use of priority status.

Key Performance Indicators: The electronic ID must be recognized by standard UTM 2.0 protocols with zero latency. Visual identifiers must be visible from a distance of 1.5 km in clear daylight. The entire module must weigh less than 50g and consume under 2W of power.

Deliverables:

- Integrated Priority ID module (Hardware + Firmware).
- Protocol definition for Priority Request handshaking with UTM systems.
