SIH 2025 - Disaster Response Drone Complete Roadmap

Problem Statement Analysis (PS ID: 25047)

Organization: Government of Odisha
Department: Electronics & IT Department
Theme: Robotics and Drones
Category: Hardware

Objective: Develop a drone-based system to deliver medical supplies and communication devices to remote areas during natural disasters, with AI-powered real-time navigation and obstacle avoidance, 5kg payload capacity, reducing response time by 20% in inaccessible regions.

Phase 1: Research & Planning (Week 1-2)

1.1 Market Research & Analysis

- Study existing disaster response drone systems (DJI Matrice series, Zipline medical drones)
- Analyze Odisha's geographical challenges and disaster patterns
- Research regulatory requirements (DGCA guidelines for drones in India)
- Study similar implementations globally (Rwanda's medical drone network)

1.2 Technical Requirements Analysis

- **Payload Requirements:** 5kg capacity with secure mounting system
- **Flight Range:** Minimum 50km radius for remote area coverage
- **Flight Time:** 60+ minutes for effective operations
- **Weather Resistance:** IP65 rating for monsoon conditions
- **Navigation:** GPS + Visual SLAM for GPS-denied environments
- **Communication:** 4G/5G connectivity with satellite backup

1.3 Team Structure & Role Assignment

- **Hardware Lead:** Drone assembly, payload mechanisms
- **Software Lead:** Flight control, navigation algorithms
- **AI/ML Developer:** Computer vision, obstacle detection
- **Mobile App Developer:** Ground control station, user interface

- **System Integrator:** Overall coordination, testing

Phase 2: System Design & Architecture (Week 3-4)

2.1 Hardware Architecture

Drone Platform Selection:

- Custom quadcopter/hexacopter design

- Frame: Carbon fiber for weight reduction

- Motors: High-efficiency brushless motors (4x or 6x)

- Propellers: Foldable for transport efficiency

- Battery: LiPo 6S, 22000mAh for extended flight time

2.2 Payload System Design

- **Drop Mechanism:** Servo-controlled release system
- **Parachute Deploy:** Automatic deployment for fragile items
- **Compartments:** Modular design for different supply types
- **Weight Distribution:** Centered mounting for stability

2.3 Sensor Integration

- **Primary Camera:** 4K gimbal-stabilized for navigation
- **Depth Sensors:** LiDAR for 3D mapping
- **IMU:** 9-axis for flight stability
- **GPS Module:** Dual-frequency for precision
- **Ultrasonic Sensors:** Ground proximity detection
- **Weather Sensors:** Wind speed, humidity monitoring

2.4 Software Architecture

Ground Control System (Mobile App)

├── Mission Planning Interface

├── Real-time Monitoring Dashboard

├── Emergency Override Controls

└── Data Logging & Analytics

Flight Control System

├── ArduPilot/PX4 based autopilot

├── Custom navigation algorithms

├── AI obstacle avoidance

└── Emergency landing protocols

Communication Layer

├── 4G/LTE primary connection

├── LoRaWAN for long-range backup

├── Satellite communication fallback

└── Mesh networking capability

Phase 3: Development Sprint 1 - Core Systems (Week 5-8)

3.1 Hardware Development

Week 5-6: Frame & Power System

- Assemble drone frame with motor mounts
- Install electronic speed controllers (ESCs)
- Integrate battery management system
- Test basic flight capabilities

Week 7-8: Sensor Integration

- Mount and calibrate IMU, GPS modules
- Install camera and gimbal system
- Integrate LiDAR and ultrasonic sensors
- Complete wiring and EMI shielding

3.2 Software Development

Week 5-6: Flight Control Foundation

- Set up ArduPilot/PX4 firmware

- Configure basic flight modes
- Implement safety protocols
- Test manual flight controls

Week 7-8: Navigation System

- Develop waypoint navigation
- Implement GPS failover systems
- Create emergency return-to-home
- Test autonomous flight modes

3.3 Mobile App Development

Week 5-8: Ground Control Station

- Design user interface mockups
- Implement mission planning features
- Create real-time telemetry display
- Develop communication protocols

Phase 4: Development Sprint 2 - AI & Advanced Features (Week 9-12)

4.1 Computer Vision & AI Development

Week 9-10: Object Detection

- Train models for obstacle detection (trees, buildings, power lines)
- Implement real-time image processing
- Develop landing zone identification
- Create weather condition assessment

Week 11-12: Navigation AI

- Implement SLAM for GPS-denied navigation
- Develop dynamic path planning algorithms
- Create collision avoidance system
- Test AI decision-making in simulated environments

4.2 Payload Delivery System

Week 9-10: Mechanical Systems

- Design and 3D print payload containers
- Implement servo-controlled drop mechanism
- Develop parachute deployment system
- Test payload release accuracy

Week 11-12: Smart Delivery

- Implement GPS-coordinate based dropping
- Develop visual confirmation system
- Create delivery status reporting
- Test with various payload types

4.3 Communication Systems

Week 9-12: Multi-layered Communication

- Implement 4G/LTE connectivity
- Develop LoRaWAN backup system
- Create mesh networking capability
- Test communication range and reliability

Phase 5: Integration & Testing (Week 13-16)

5.1 System Integration

Week 13-14: Hardware-Software Integration

- Integrate all sensors with flight controller
- Calibrate AI algorithms with real hardware
- Test end-to-end communication systems
- Resolve integration issues

5.2 Field Testing

Week 15: Controlled Environment Testing

- Test in simulated disaster scenarios
- Validate payload delivery accuracy

- Test obstacle avoidance in controlled space
- Measure flight performance metrics

Week 16: Real-world Validation

- Conduct tests in actual remote locations
- Test various weather conditions
- Validate 20% response time improvement
- Gather performance data

5.3 Safety & Compliance Testing

- DGCA compliance verification
- Fail-safe mechanism testing
- Emergency protocols validation
- Risk assessment documentation

Phase 6: Optimization & Final Preparation (Week 17-20)

6.1 Performance Optimization

Week 17-18: System Tuning

- Optimize flight algorithms for efficiency
- Improve AI model accuracy
- Enhance battery life and flight time
- Streamline user interface

6.2 Documentation & Presentation Prep

Week 19-20: SIH Preparation

- Create technical documentation
- Develop presentation materials
- Prepare demonstration scenarios
- Create video documentation

6.3 Final Testing & Validation

- Complete system stress testing

- Validate all performance metrics
- Prepare backup systems
- Final safety checks

Technical Implementation Details

Hardware Stack

Flight Controller: Pixhawk 4 / Cube Orange

Companion Computer: Raspberry Pi 4 / Jetson Nano

Communication: 4G module + LoRa + WiFi

Sensors: GPS RTK, IMU, Magnetometer, Barometer

Vision: RealSense D455 depth camera

Motors: T-Motor U8 Pro (6x for hexacopter)

Battery: 6S 22000mAh LiPo

Software Stack

Flight Software: ArduPilot / PX4

Companion Software: Python/ROS2

Computer Vision: OpenCV, TensorFlow/PyTorch

Mobile App: Flutter/React Native

Backend: Node.js/Django with PostgreSQL

Cloud Services: AWS/Google Cloud for ML training

AI/ML Components

- **Object Detection:** YOLOv8 for real-time obstacle detection
- **Path Planning:** A* algorithm with dynamic updates
- **Image Recognition:** CNN for landing zone identification
- **Predictive Modeling:** Weather pattern analysis for route optimization

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Key Performance Indicators (KPIs)

Primary Metrics

- **Response Time Reduction:** Target 20% improvement over traditional methods
- **Payload Accuracy:** 95% successful deliveries within 10m radius
- **Flight Reliability:** 99% successful mission completion rate
- **Battery Efficiency:** 60+ minute flight time with 5kg payload

Secondary Metrics

- **Weather Adaptability:** Operations in 25+ km/h winds
- **Communication Range:** 50+ km reliable connectivity
- **AI Accuracy:** 95+ % obstacle detection accuracy
- **User Experience:** <5 minute mission setup time

Risk Management & Mitigation

Technical Risks

- **Battery Life:** Implement swappable battery system
- **Communication Loss:** Multi-layer backup communication
- **Weather Conditions:** Advanced weather monitoring and planning
- **Regulatory Issues:** Early DGCA consultation and compliance

Project Risks

- **Timeline Delays:** Modular development approach
- **Component Availability:** Maintain backup supplier list
- **Team Coordination:** Regular daily standups and weekly reviews
- **Budget Constraints:** Prioritize core features first

Budget Estimation

Hardware Costs (₹80,000 - ₹1,20,000)

- Drone frame and motors: ₹25,000
- Flight controller and sensors: ₹20,000
- Camera and gimbal: ₹15,000
- Communication modules: ₹10,000

- Batteries and chargers: ₹15,000
- Miscellaneous components: ₹10,000

Software & Development

- Cloud services: ₹5,000
- Development tools: ₹3,000
- Testing and validation: ₹5,000

Innovation Highlights

Unique Features

1. **Multi-Modal Communication:** 4G + LoRaWAN + Satellite backup
2. **Weather-Adaptive AI:** Dynamic route planning based on real-time weather
3. **Modular Payload System:** Quick-change containers for different supplies
4. **Mesh Network Capability:** Drones can relay communications
5. **Visual Confirmation:** AI-powered delivery confirmation
6. **Emergency Override:** Ground control emergency intervention

Technology Differentiators

- Advanced computer vision for GPS-denied navigation
- Machine learning for predictive maintenance
- Real-time weather integration for safe operations
- Automated mission planning with minimal user input

Post-SIH Development Roadmap

Short-term (6 months)

- Production-ready prototype refinement
- Pilot deployment with Odisha government
- User feedback integration
- Regulatory approvals

Medium-term (1-2 years)

- Scale to other states and disaster-prone regions
- Integration with existing emergency response systems
- Advanced AI features and autonomous swarm coordination
- Commercial partnerships for sustainable deployment

Long-term (3-5 years)

- National disaster response network
- International expansion
- Advanced medical capabilities (blood transport, defibrillators)
- Integration with IoT sensors for predictive disaster response

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Success Criteria for SIH

Technical Demonstration

- Live demonstration of autonomous flight
- Real payload delivery with accuracy measurement
- AI obstacle avoidance in action
- Multi-communication system demonstration
- Mobile app functionality showcase

Presentation Requirements

- Clear problem-solution fit
- Technical innovation explanation
- Scalability and impact demonstration
- Business model and sustainability
- Team expertise and execution capability

This roadmap provides a comprehensive path to developing a winning solution for SIH 2025 while addressing the real-world needs of disaster response in challenging terrains like Odisha.