*Project Proposal Titled*

# Maharashtra Drone Mission

## Establishing a World Class Drone Hub

## Bringing Together Academic and Research Institutions, Government, Industries, and Youth for Development of Maharashtra through Drone Technology

*Submitted to*

**the Government of Maharashtra**

*By*

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*October 2023*

## Content

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## 1. Introduction and Motivation

Drone or unmanned aerial vehicle (UAV) is an aircraft without a human pilot on board and also comprises of mission planning and control hardware and software. Drones can be rotorcraft, fixed wing, hybrid/vertical take-off and landing (VTOL), balloon systems, and many other configurations. UAVs revolutionize industries worldwide by tackling challenging, costly, and time-consuming tasks. Recognizing their significance, the Government of Maharashtra is launching the "***Maharashtra Drone Mission***". This program aims to make Maharashtra self-reliant and a global leader in drone technology. It brings together academic institutions, R&D institutes, industries, government, and youth to foster indigenous research, development, and large-scale commercialization of drones and allied technologies, which can be used for development of Maharashtra. The mission focuses on establishing drone centres, developing a safe and reliable integrated autonomous drone ecosystem (which can be used for both urban and rural areas) and counter drone technology, carrying out impactful pilot R&D projects in coordination with the functionaries of various departments of the Maharashtra government, and providing necessary technical expertise to the departments. Startup support, training, awareness, outreach programs will be carried out, support for Maharashtra drone policy and academic programs will be provided, and the mission will engage the wider community to nurture talent and innovation. This mission will also focus on job creation, economic growth, and revenue generation for self-sustenance.

### 1.1. Potential Use Cases in Various Sectors

Drones can be used for various applications as shown in Figure 1. Drone, in combination with the right technology and/or equipment, will be a mighty technology. Currently drone technology has used for several applications, and interestingly, it will continue to grow in the future.


Figure 1: Some of use cases of drones

Potential benefits and estimates of cost savings due to the use of drones in agriculture, construction monitoring, and planning surveys and mapping are given in Table 1 [1].

Table 1: Potential benefits and estimates of cost savings for the use of drones in agriculture, construction monitoring, and planning surveys and mapping

| Areas | Existing Process | Potential Benefits of Drones | Saving Details (Approximate Values) |
|---|---|---|---|
| Agriculture crop monitoring and spraying | • Manual applications– unsafe, in-efficient and limited access to skilled labor<br>• Erroneous, single point-decision making | • 10x faster turnaround, efficient and cost-saving<br>• Automated analysis and collaborative decision making | • Existing cost: Rs. 1500-1800 per acre for spraying<br>• Potential cost: Rs. 300-400 per acre<br>• Cost Savings: 75% |
| Construction monitoring | • Excel-based progress tracking without visual verification | • Automated object recognition, counting and progress tracking on drone maps<br>• 80% faster and improved transparency and on-site governance | • Existing cost: Rs. 2500 per km for road construction survey<br>• Potential cost: Rs. 1500 per km<br>• Cost Savings: 40% |
| Planning surveys and mapping | • Ground-based manual data collection<br>• Manual analysis and single-point decision-making | • Automated analysis and collaborative decision-making<br>• 10x faster and 10000x more data points on a digitized base for better plans | • Existing cost: Rs.10,000-12,000 per sq. km<br>• Potential cost: Rs. 6,000 per sq. km<br>• Cost Savings: 45% |

Till now multiple ministries / departments of Maharashtra government have provided us their potential use cases of drones (which are also attached in ***Appendix D***, and Drone based solutions to some of these use cases are proposed in the short proposals in ***Appendix A***) as follows:

- **Agriculture**
  - Spraying fertilizers/ pesticides, crop/ soil nutrients, insecticides
  - Mapping crop type and acreage
  - Crop and soil health, stress, treatments monitoring
  - Crop phenological stage mapping
  - Crop yield estimation/forecasting
  - Identifying presence of pests, soil condition or any crop damage
  - Irrigation estimation and crop water use
  - Post-disaster damage assessment

- **Public Health**
  - Drug delivery to remote location
  - Vaccine delivery to remote location
  - Anti-snake venom and anti-rabies shot delivery
  - Emergency reconnaissance: with VIDEO camera, 2-way audio communication, Loudspeaker

    - Construction tracker / monitoring

- **Disaster Management, Relief, and Rehabilitation**
    - Pre-Disaster
        - Periodical monitoring and mapping of drought prone areas
        - Pre-monsoon mapping flood prone areas
        - Detection of forest fire hotspots
        - High resolution terrain mapping for land use and land cover mapping
        - Alert risky population due to some natural calamities (Early warning dissemination)
    - During Disaster
        - Mapping, Detection, and Damage and Loss Assessment
            - Mapping of disaster affected areas real time to carry out damage and loss assessment
            - Detection of human and animal body trapped in debris and in an inaccessible area
            - Provide access to internet services using Wifi hotspot
            - Spray disinfectant to expel locusts from agriculture fields
        - Surveillance and Live Video Streaming
            - Provide real time data to relief agencies for their quick assistance to the victims (Search and Rescue)
            - Provide access to the public through Social Media platforms, given the good internet bandwidth
            - Capturing movement of people and situation (including relief distribution) during emergency period
            - Identify the safe space for temporary shelter establishment
        - Public Awareness
            - Create public awareness to take necessary actions to reduce the mounting risk during the emergency
        - Delivery of Essentials
            - Delivery of consumable items, medicine, and personal protective equipment
        - Supply Chain Management
            - Provide alternate and safe routes to access the warehouse in disaster affected areas
    - Post-Disaster
        - Mapping of disaster affected areas to restore essential services providing institutions and points
        - Periodical monitoring of the development work during the recovery phase

- **Water Resources Department**
    - Estimation of crop yield for effective water release
    - Land use/Land cover (LULC) estimation for catchment area
    - Drone framework for reservoir maintenance
    - Drone framework for crop compensation

- Soil erosion, land slide (exposure) assessment in catchment
- Drone based framework for dam and canal management
- Drone policy for water management
- Tourism potential assessment
- Assessment of hydro-electric power potential

- **Public Works Department**
  - Precise measurements related to existing roads and bridges
  - Stockpile volumetric measurements
  - Inspection of inaccessible areas particularly under bridges and water bodies, bed data
  - Accurate and exhaustive data related to road levels and bridge levels
  - Horizontal curve details, along with measurements
  - Details of vertical grades and hilly areas boundaries
  - Ground features
  - Catchment area calculations
  - Traffic count and study

- **Home - Anti Terrorism Squad**
  - Law enforcement and border control surveillance
  - Thermal sensor drones for search and rescue operations
  - Geographic mapping of inaccessible terrain and locations
  - Unmanned cargo transport
  - Express shipping and delivery

- **Urban Development**
  - Aerial surveys and mapping
    - City planning
    - Mapping and GIS
    - Mapping urban areas and informal settlements (slums)
  - Infrastructure inspection
    - Building inspections
    - Bridge and road inspections
    - Green and blue infrastructure mapping and monitoring
  - Environmental monitoring
    - Air quality monitoring
    - Green space management
  - Traffic management
    - Traffic flow analysis
    - Emergency response

   - Disaster response and management
     - Post-disaster assessment
     - Search and rescue
   - Public safety
     - Surveillance and monitoring
     - Emergency communication

- **Transport**
  - Traffic monitoring and control with road safety system
  - Mobile ground command control station

- **Rural Development and Panchayat Raj**
  - Rural connectivity and road condition assessment
  - Asset mapping

### 1.2. Opportunities

- Indian government's vision is the Global Drone Hub by 2030 [2] [3].
- The Ministry of Civil Aviation (MoCA), Govt. of India has liberalized new Drone Rules, 2021 [4].
- The Indian government is providing attractive Drone Production Linked Incentive (PLI) scheme with 20% rate [5].
- The Ministry of Agriculture and Farmers Welfare, Govt. of India is providing full / partial funding support for purchase of drones and contingency expenditure towards Kisan Drone promotion for various agricultural and farmers organizations, and farmers [6].
- Drone market values in India (in USD) are as follows:
  - 0.9 Billion – by 2021 [7] [8]
  - 40.0 Billion – by 2030 (projected) [9] [10]
- Drones can boost India's GDP by upto 1.5% [11] [12].

### 1.3. Challenges

- Lacking strong drone R&D, and early stage funding
- Poor Infrastructure and drone manufacturing facility
- Lacking Skilled manpower, and User awareness
- Higher import dependency
- Heterogeneity in Maharashtra geographical conditions

### 1.4. Need, Urgency, and Forecast for the Drone Technology Proposed to be Developed

Productization of UAVs and their various technologies have a huge commercial opportunity. As of now, a significant quantity of drones and their components, including many design and critical hardware manufacturing, are mostly imported, which makes the vulnerable to technical, commercial and security risks. It is the need of the hour to develop completely indigenous drones and their allied technologies for Indian use cases. Design, development and manufacturing of drones and their allied technologies in India can help us to be become truly self-reliant in drone technologies. Local manufacturing with local technologies can certainly address this need along with increasing consumer confidence. The core objective of the proposed project is inherently aligned with the national initiatives like “Atmanirbhar Bharat” and, “Make in India”. In the project, various advanced drones and allied technologies such as multiple medium drones for aerial, terrestrial, water surface, underwater, AI enabled drones, will be developed.

Multiple technologies to be developed under this drone mission will be integrated and deployed in the field for real-life applications to reap the benefits of technology to common man and also for commercialization through possible Indian Industries to support the Make in India initiative by Govt. of India. It is proposed to involve industry in a bigger way by trying to increase its stake further. While the participating academic and research institutes, in coordination with the functionaries of various departments of the Maharashtra government, in this drone mission will remain as major resource centres, the industries will participate for mass-manufacturing and major executions. With active support, guidance and possible policy interventions from the state of Maharashtra, we can definitely increase local manufacturing manifold.

While academia research and develop the drone technology in combination with other emerging technologies to make it more robust, resilient and efficient, such that it approaches a higher level of autonomy in the future. It should be noted that this technology can open up new avenues for economics, faster and safer too. That is, the autonomous aerial vehicle technology industry can generate employment for skilled personnel in both urban and rural areas. Moreover, establishing a drone ecosystem will not only propel the technology readiness to the deployment status and provide support for creating SOPs, but also ensure that all the connected and peripheral systems and entities are market-ready, polished, scalable and deployable by multiple organizations thus help build capacity. Furthermore, UAV traffic management (UTM) service providers can leverage ecosystem to test and make their solutions more robust. Similarly, the regulators, like Ministry of Civil Aviation (MoCA), Directorate General of Civil Aviation (DGCA), can ensure that the regulatory compliance are established with proper safety and privacy guidelines for safe and compliant operations in the airspace.

Thus, our intention in this project is to create a unique architecture for drones which is easy to establish, evolve and scale as needed in both urban and rural areas. This will include establishment of UTM system, geo-fencing, drone corridors, and other critical infrastructures, like droneport to study their functioning and impact on the society and explore scope for improvement to enable the growth of the technology and market. The drones, in combination with other emerging technologies (such as artificial intelligence (AI), machine leaning/deep learning) and/or equipment (such as cameras, sensors and robot arms), can effectively use for a plethora of applications, like mobility, delivery, public safety, emergency services, inspection, surveillance, agriculture, disaster management, etc., which can be undertaken in a cheaper, faster and safer way. The proposed ecosystem will be capable of accommodating them all. Moreover, drone-port, drone corridors, and geo-fencing will be designed keeping in mind the requirements, applications and services of various drones. The essence of the proposed work is to develop drone technologies specific for Maharashtra / Indian scenarios that will facilitate rapid growth of the industry. The designs, technologies, and processes in this project will be systematically preserved so that replication along with scalability can be performed easily, viably and seamlessly. Furthermore, it fits into the India’s priorities to enable technological advancements which can lead to economic growth, improve standard of living and reinforce safety and security standards, and job creation.

There is an exponential growth in the demand of drones in India over the past 5 years, due to major thrust from the governments to use drones for a variety of purposes. Value of the drone industry and market in India was 0.9 billion USD in 2021 [7] [8] and will be 40.0 billion USD in 2030 (projected) [9] [10]. Drones can boost India's GDP by upto 1.5% [11] [12]. Even though the current ratio between military and commercial drone market in India is 70:30, this expected ratio will be 30:70 in the next 4-5 years. Hence, the commercial drone usage for societal, civil and industrial applications will be significantly high, as interestingly its demand will continue to grow large in the future. To meet this expected high demand, this proposed drone ecosystem will play a major role. It will provide end-to-end solutions for various applications that encompass developing, managing and running the drone, collecting data and analysing it, and offering the required service on a single place to the client. Also, it will help for the development of a next level of efficient and expanded drone systems which can accommodate a variety of mobility systems such as ground vehicles and systems, in addition to the drones. Hence, all strata of society - from the rich to the poor, the industries, businesses, governments, farmers, medical professions, defence entities and much more, stand to benefit immensely from developing and advancing this technology.

## 2. Drone Rules, Regulations, and Policies in India

While there are several classifications in use, ranging from military to specific personal UAVs, these UAV classifications help in differentiating existing systems, which can be used by regulatory bodies to develop rules that can fit all UAVs and which in turn can be imposed on the UAVs for safe flight. Maximum take-off weight (MTOW) classifies the aircraft based on their weight. This can be correlated with the expected kinetic energy imparted at impact, which in turn is considered to be the primary factor affecting safety of operations [13]. The Directorate General of Civil Aviation (DGCA) has defined its categorization based on MTOW including payload as

- Nano drone: Less than or equal to 250 grams
- Micro drone: Greater than 250 gram and less than or equal to 2 kilograms
- Small drone: Greater than 2 kilogram and less than or equal to 25 kilograms
- Medium drone: Greater than 25 kilogram and less than or equal to 150 kilograms
- Large drone: Greater than 150 kilograms.

The different classification of airspace is defined as [14]

- Class A airspace extends from 18,000 feet MSL to 60,000 feet mean sea level (MSL), or flight level 600 (FL 600).
- Class B airspace surrounds the busiest airports from the surface to 10,000 feet MSL.
- Class C airspace extends from the surface to 4,000 feet MSL. These airports are busy enough to have an air traffic control tower and be serviced by radar approach control.
- Class D airspace surrounds smaller airports that have control towers and extends from the surface to 2,500 feet MSL.
- Class E airspace is controlled, such as airspace that surrounds instrument approach paths or federal airways, in all other locations other than Class A, B, C or D airspace, not including the uncontrolled Class G airspace.
- Class G is uncontrolled airspace; and the future airspace management system for Unmanned Traffic Management (UTM) or U-space is targeted for this airspace.

UAV classification based on altitude to an extent can dictate collision avoidance requirements, and a simple classification is outlined below [13].

- Very low altitude (VLA/LOS): Operating in Class G airspace and less than 400–500 ft within visual contact
- Very low altitude (VLA/BLOS): Same as above but beyond the line of sight
- Medium altitude (MA): Operating in Class A through Class E airspace
- Very high altitude (VHA): Operating in Class E airspace above FL600.

Indian government has taken multiple steps to encourage safe and informed Remotely Piloted Aircraft (RPA) operations. Some of the key initiatives are as follows.

- DGCA has published its version of regulations governing RPA operations [15].
- Ministry of civil aviation has published drone ecosystem policy road map [16].
- Digital Sky platform was launched by DGCA [17] to obtain RPA operations permission online.
- Drone Rules 2021 was published by the Ministry of Civil Aviation (MoCA) [4].

- The MoCA is allowing to set up drone pilot training schools (Remote Pilot Training Organisations) for central and state governments, government-approved universities, and even private drone manufacturers.

As per Drone Rules 2021 [4], the following zones for drone operation are defined:

- "Green Zone" means the airspace of defined dimensions above the land areas or territorial waters of India, upto a vertical distance of 400 feet or 120 metre that has not been designated as a red zone or yellow zone in the airspace map for unmanned aircraft system operations and the airspace upto a vertical distance of 200 feet or 60 meters above the area located between a lateral distance of 8 kilometers and 12 kilometers from the perimeter of an operational airport.
- "Yellow Zone" means the airspace of defined dimensions above the land areas or territorial waters of India within which unmanned aircraft system operations are restricted and shall require permission from the concerned air traffic control authority. The airspace above 400 feet or 120 metre in the designated green zone and the airspace above 200 feets or 60 meters in the area located between the lateral distance of 8 kilometers and 12 kilometers from the perimeter of an operational airport, shall be designated as yellow zone.
- "Red Zone" means the airspace of defined dimensions, above the land areas or territorial waters of India, or any installation or notified port limits specified by the Central Government beyond the territorial waters of India, within which unmanned aircraft system operations shall be permitted only by the Central Government.

In addition to the existing policies, this proposed mission can potentially lead to new policies and regulations with respect to implementation of different activities, such as crop cutting experiment, crop insurance policy, revenue survey.

Few states have created their drone policies and also published these policies. Some of salient features of their policies are as follows.

- **Himachal Pradesh Drone Policy 2022** [18]
  - Key pillars of HP policy are:
    - Drone enabled governance
    - Drone flying training schools
    - Enabling policy infrastructure
    - Drone Mahotsav and Melas
  - To Promote future ready students with effective linkage with National Education policy (NEP) and National Skill Qualification (NSQF) in education institutes.
  - To promote and create industry-government partnerships for use of Drone in different areas of governance.
  - 50% of the consultant fee will be reimbursed (max. 1 lakh)
  - Lease rental for services 75% for first year (max 15 lakh) and 85% for manufacturers (max 20 lac)
  - Capital subsidy
    - Drone Enabled Technology and Services (DeTS): 25% (1 cr)
    - Drone System Design and Manufacturing (DSDM): 50% (2 cr)
  - Exemption from stamp duty and change in land use fee.
  - 100% reimbursement on State Goods and Services Tax (SGST)
  - Patent filing Domestic: reimburse 75% (or 5 lakh) International: 100% reimburse (or 10 lakh)

- **Telangana Drone Policy** [19]
  - Development of Testing Facility, Facilitation Cell and Co-working Space development for Drone Industry
  - Creation of Talent Pool by collaborating Atal innovation Mission, introduction of domain specific courses and fund Drone engineering research at universities
  - Incentive Schemes for the Drone industry
  - 100% reimbursement on State Goods and Services Tax (SGST)
  - 25% investment subsidy (max 30 million for top 25 companies) for Drone manufacture
  - 30% lease rental subsidy
  - 100% reimbursement on stamp duty and 100% exhibition stall rental
  - 25% capital invest for Service providers
  - 100% reimbursement on internet charges
  - R&D grant of up to 10 lakhs

- **Goa Drone Policy 2022** [20]
  - To promote Drone design, manufacturing, testing and maintenance facilities in the state
  - Establishment a sub-committee for drone experts under the Goa state advisory council to guide the Government
  - Establishment of testing and certification facilities with private partners
  - Support institution for setting up innovation labs
  - Allocations of land for setting Drone industry in the state
  - Incentives as per Goa Start-up Policy 2021 as per Goa IT Policy 2018
  - Coordinate with technical training institute and private enterprise
  - Network of state drone pilots and instructors
  - Reward startups in drone technology

- **Gujarat Drone Policy 2022** [21]
  - Government will act as a catalyst for promoting drone usage in various departments.
  - Promote setting up of Drone training Infrastructure.
  - Development of institutional capacity to train Drone pilots
  - Setup 50 'Drone ITIs' across state and target to train 20,000 youth.
  - Extension of drone services
  - Startup incentives
  - Public and private investment in R&D
  - Specifying flying zones
  - 25,000+ employment opportunities in the state.
  - Government will organize Drone Events and give awards and chances for pilot projects to winners.

## 3. Current Status of Drone Technology

### 3.1. Indian Scenario

The current status of the drone technology in Maharashtra/ India is as follows:

- Drones are scatteredly used without a proper technical support system in Maharashtra.
- Most of the drone operations are remotely piloted, not autonomously coordinated.
- No smart integrated drone ecosystem exits in India.

Also, as per our knowledge, no work in the performance evaluation of flying ad hoc networks (FANETs) and multi-drone systems, drones as user equipment and drones as flying base stations using a 5G testbed is ongoing in India.

With regard to different mission requirements and applications, today's UAVs vary significantly in their capabilities as a result of different mission requirements (from multi-copters, fixed-wing, hybrid/VTOL systems up to medium altitude long endurance (MALE) / high-altitude long endurance (HALE) systems), varying performance (including manoeuvrability and avoidance capability), and specific technical equipment (including sensor technology, degree of autonomy, transponders) [22]. Hence, this is a complex problem that requires to develop a diverse range of drones to cater to a larger market and at the same time makes the task of traffic management easier while guaranteeing safety and reliability.

There are organizations, who are working on various drone development, applications, training, and awareness. IIT Bombay has been working on various drone development, drone docking systems, and drone based applications, such as surveillance, delivery, monitoring, agriculture, nearshore bathymetry estimation, photogrammetry, swarm of drones, since 2006 [23] [24] [25] [26] [27] [28] [29] [30] [31] [32]. ideaForge Technology Ltd. incubated by IIT Bombay is a leading Indian drone manufacturer specializing in UAVs for defense, homeland security, and industrial applications, and listed on NSE/BSE. Their unique product is the "Switch" UAV, which is a rugged VTOL for high-altitude operations and surveillance [33]. Another drone company, named Drona Aviation Pvt. Ltd., incubated by IIT Bombay has been developing various nano drones [34]. The highlight of 2022 India Republic Day Beating the Retreat ceremony was the spectacular show put up by a thousand drones in Delhi. BotLab Dynamics, incubated at IIT Delhi Delhi, showed the highlight of 2022 India Republic Day Beating the Retreat ceremony, which was the spectacular show put up by a thousand drones in Delhi [35]. The success of the show resulted in them getting more event like the Djibouti Independence Day [36]. The Centre of Excellence (CoE) on Biologically Inspired Robots and Drones has also been formed at IIT Delhi to make robotic systems [37]. Robert Bosch Center for Cyber-Physical Systems at IISc, Bangalore is conducting research into autonomous navigation of drones. They are exploring to aid navigation by putting up required infrastructure, and yet accomplishing required precision [38]. They are also working on corridors for drones [39]. AI and Robotics Technology Park (ARTPARK), an Indian government-funded not-for-profit organization at IISc Bangalore, aims to develop an air ambulance for use in healthcare emergencies and casualty evacuation [40]. The Helicopter Lab at IIT Kanpur has been focusing on developing rotary winged vehicles, helicopters, and Vertical Takeoff and Landing (VTOL) capable aerial systems [41]. They are developing solar powered UAV [42]. C3iHub of IIT Kanpur is working on the cyber security issues in blockchain and critical infrastructure [43]. Embedded systems and firmware components of drones are vulnerable with respect to cyber-attacks. So, drone-specific cyber security research with a focus on embedded systems and firmware vulnerability analysis is very important requirement to develop hack-proof drone systems. However, this research is not reported widely. Rotocraft and Advanced Flight Technologies (RAFT) at IIT Madras has been exploring multiple avenues of aeromechanics which include experimental studies on rotor-based aircraft, numerical modeling of the aerodynamic environment around a rotor, studies on dynamic inflow modelling, dynamic stall, dynamic soaring, flapping wing flight to name a few [44]. The ePlane company incubated by IIT Madras is working on development of air-taxi [45]. Space tech start-up GalaxyEye Space wants to provide datasets that will help for drone applications [46]. TiHAN (Technology Innovation Hub on Autonomous Navigations) at IIT Hyderabad focuses on UAVs and Unmanned Ground Vehicles (UGVs) [47]. They are developing nano/micro category drones, bio-inspired drones and flapping wing micro aerial vehicles. Also, TiHAN is focusing on developing air taxis and air ambulances [47].

At least 10 consortia, including Reliance-backed Asteria Aerospace, Nandan Nilekani-backed ShopX, Spicejet, and Google-backed Dunzo, among others have been permitted by MoCA and DGCA, to carry out BVLOS drone projects in designated airspaces across the country [48]. India’s aviation regulator has approved the Agriculture Ministry’s request to operate drones at night and to use engine-powered drones rather than battery-operated ones in its fight against the spread of desert locusts in the western and central states [49]. Trinity F90+ drone from Quantum Systems, Germany, is India’s first fixed-wing VTOL drone in the small category to receive the DGCA certification for being an No Permission, No Takeoff (NPNT) compliant Drone/RPAS/UAV [50].

Dhaksha Unmanned Systems founded in 2019 working on gasoline powered UAVs with high endurance capacity and its one of the drone named AgriGator has received ‘Type Certificate’ from DGCA [51]. Aereo (formerly known as Aarav Unmanned Systems Pvt. Ltd.) developed the "Nayan" drone which is designed specifically for agricultural use, helping farmers monitor their crops and optimize farming practices [52]. General Aeronautics [53] and Garuda Aerospace Pvt. Ltd. [54] have developed spraying drones for agricultural use, and received ‘Type Certificate’ from DGCA. Quidich Innovation Labs is working on aerial analytics solutions for various industries and can provide services, like live aerial broadcasting using drones for sports events and entertainment industry [55]. Johnnette Technologies has been working on delivering advanced aerospace systems to Indian Armed Forces, and their selling product is the "JF-5" which is a heavy-lift drone capable of carrying payloads [56]. TechEagle Innovations has developed delivery drones which were used for delivery for India Post [57].

### 3.2. International Scenario

According to Concept of Operations (CONOPS) document of International Civil Aviation Organization (ICAO), with the availability of regulations, standards, and relevant supporting technology, the seamless integration of the unmanned traffic for drones with the conventional manned traffic is expected to begin in 2025. Till then the remotely piloted aircraft are expected to be accommodated in non-segregated airspace on case-to-case basis. Until 2031 a mature and complete set of technologies, standards, regulations, guidance and procedures will not be available to support transparent integration across the wide array of unmanned traffic for drones and the types of operation possible [58] [59].

As highlighted by Jiang et al. [60], UTM system can borrow fundamental ideas from ATM despite their obvious differences. Number of researchers have proposed potential concept of operation and system architecture for UTM [61]. Amazon describes its design, management and operations of the airspace for the safe and efficient integration of low-altitude small unmanned aircraft systems (UASs) [62] by classifying UAS into categories based on vehicle equipage and formulated criteria for airspace access based on the equipage [63]. Google UAS airspace system overview highlights that all UASs should be equipped with communication technology to perform cooperative flight along with Automatic Dependent Surveillance-Broadcast (ADS-B) to integrate UAS and manned aircraft traffic [64]. Foina et al. presented a cloud-based system for city-wide unmanned air traffic management, prototype sensor systems required by city police to keep the city safe, and an analysis of control systems for collision avoidance [65]. Barrado et al. presented a concept airspace segmentation based on various factors, ranging for density of drones in the airspace to the ground risks and public safety etc., and how it can be enforced to control drones [66]. The initial research outputs of the U-Flyte R&D gives an overview on how to develop an integrated approach to airspace modelling and traffic management platforms for operating large drone fleets over urban environments [67]. German Aerospace Center (DLR) proposes a concept to enable conflict-free routings of UAS together with other aircraft in high traffic scenarios, while meeting complex (urban) airspace requirements [22].

Multiple heterogeneous aerial vehicles (helicopters and airships) are combined together to develop a team under the project of COMETS (Real-Time Coordination and Control of Multiple Heterogeneous Unmanned Aerial Vehicles) to execute the different tasks namely fire detection, terrain mapping [68] [69]. A team of heterogeneous UAVs are integrated and synchronized together to perform the task of search and rescue operation [70] [71]. A team of four UGVs are designed to perform collaboratively with humans in a disaster response mission in an industrial environment under the EU FP7 TRADR project [72]. Similar research work has been addressed by a team of UGVs to design a multi-robot for patrolling and detecting environmental issues [73]. An autonomous surface vehicle has been developed to prepare an architecture of multi-domain map using the fused data from navigational sensors, GPS and IMU, 3D Lidar, and multibeam echo-sounder sonar [74].

Zipline originally started delivering blood and medical products in Rwanda in 2016, and they have used delivery drones for close proximity delivery [75]. Arace is a Hungary based company which manufactures VTOL mapping drones [76]. Wingtra is a Switzerland based company that manufactures flying wing mapping drone that can takeoff vertically and do transition for forward flight [77]. The Wingcopter is a VTOL Hybrid that can deliver packages [78].

## 4. Proposed Maharashtra Drone Mission

Drones are poised to revolutionize society and the economy, much like smartphones did in the past decade, and have great potential in various real-world applications, as mentioned earlier. The "***Maharashtra Drone Mission (MDM)***", to be launched by the Government of Maharashtra, aligns with the goal of fostering indigenous technology development and establishing Maharashtra as a Global Leader in drone technology. The MDM is a statewide drone program bringing together academic and research institutions, government, industries, and youth for development of Maharashtra through drone technology, with IIT Bombay serving as the Headquarter (Nodal) drone centre. This mission aims to develop a safe and reliable integrated ecosystem for drones with distributed autonomy, which can be used for both urban and rural areas. This drone ecosystem will be pivotal in advancing the technology and the industry, and most importantly smooth and efficient integration into our airspace and communities at large. An ecosystem is an environment with a collection of entities that are interconnected, interdependent and governed by some general rules, and a drone ecosystem is no different. As a matter of fact, it is an ecosystem that is evolving at breakneck speed and is constantly changing. To enable the same, IIT Bombay intends to establish a "***Centre of Excellence (CoE) in Drone and Anti-Drone Technology***", which will act as the Headquarter (Nodal) drone centre of MDM. Please note that, IIT Bombay is working on the official formation of this CoE with constitution of various decision-making committees. With this in mind, our main aim is to develop cutting edge and advanced technologies for solving some of the most critical and high-risk problems as well as high-impact projects by developing a drone ecosystem in Maharashtra. In turn, transformations significantly improve quality of life for all beings in a sustainable and eco-friendly way. Figure 2 shows some of the key elements of a drone ecosystem.

This MDM will provide a platform to expedite the translation of research into practical applications, carry out pilot projects in coordination with various government departments and deployment for users. It also emphasizes the need for infrastructure development, public education, policy, and standardization to ensure safety and reliability. By combining emerging technologies, like AI, ML, 5G communication, cyber security, drones can perform inspections and surveillance more efficiently and safely. The project includes the establishment of drone centres and drone port for safe integration into airspace. It aims to cater to diverse drone activities and promote interdisciplinary collaboration. The proposed mission involves R&D activities on drone ecosystem development, applications, and policy, such as drone platforms, traffic management, navigation, communication, and security. The essence of the proposed work is to develop drone technologies specific for scenarios of Maharashtra that will facilitate rapid growth of the industry. A large number of small scale and medium scale industries in the country engaged in the manufacturing of drones do not have in house R&D as in the case of public sector undertakings. They need support from R&D programmes, like MDM, for adopting new designs and modernizing their products. To achieve awareness and acceptance of drones as a key technology to solve various challenges, programmes, like MDM are necessary.

Skill development and entrepreneurship, support for Maharashtra drone policy and academic programs (such as scholarships, fellowships, internships), and outreach programs such as training, awareness, startup support (through seed grant), national and international interactions and conferences, technology promotion and marketing, workshops, hackathons, other events are part of the project. The initiative expects technology fallouts that can be used beyond the defined scope. Additionally, it highlights the economic potential of the autonomous aerial vehicle industry in generating employment and capacity building. The designs, technologies, and processes in this project will be systematically preserved, so the project aims to create a scalable and replicable architecture (which can be performed easily, viably and seamlessly), fostering research-industry collaboration and knowledge transfer. In summary, the MDM strives to develop a fully autonomous ecosystem for drones, encompassing infrastructure, applications, and interdisciplinary collaboration, while ensuring safety, privacy, economic growth, and job creation, and improving standard of living.

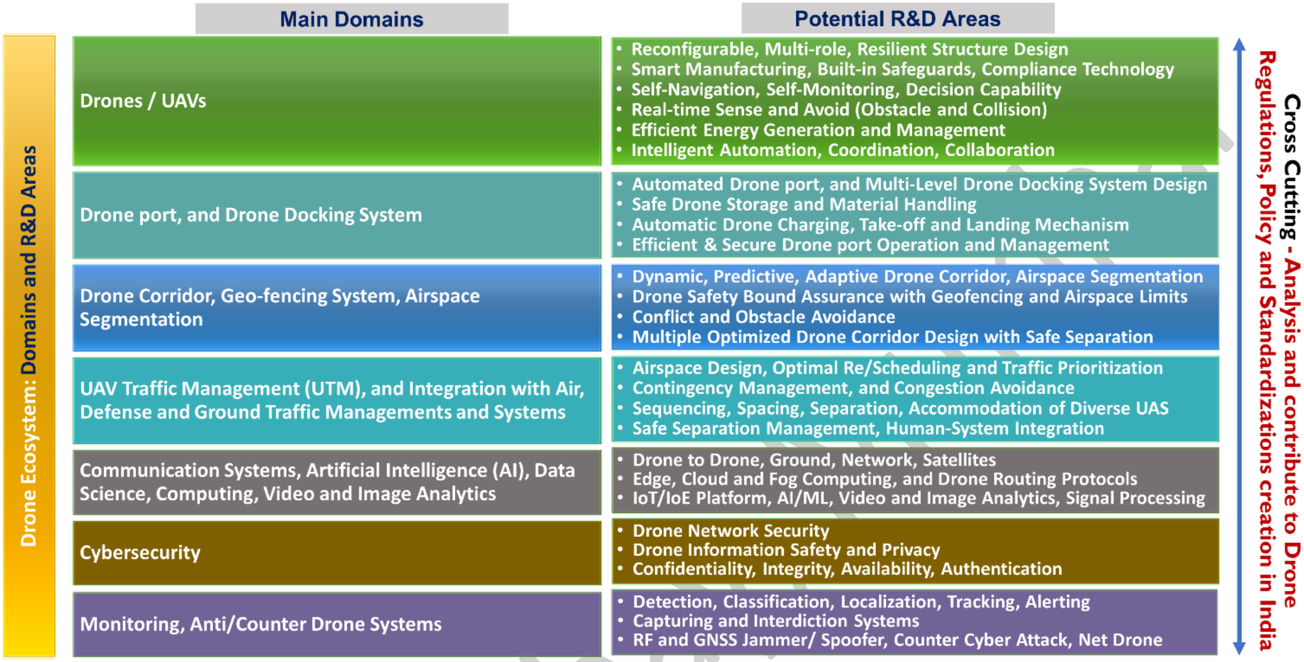


Figure 2: Key elements of the proposed drone ecosystem

This proposed work will focus on translational research, testing, demonstration, and deployment. To do the same, we will engage with the industries, entrepreneurs and other stakeholders not only for commercialization and deployment but also from the planning stage onwards at the beginning of the project. We would like to follow the process for achieving the scope of the project shown in Figure 3.

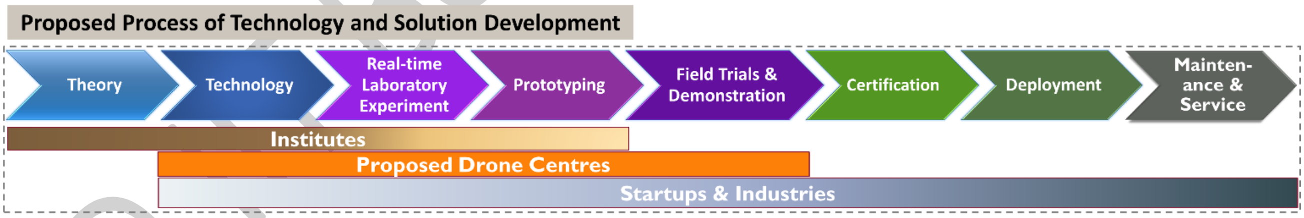


Figure 3: Proposed process for end-to-end solutions for drone-based applications

This process, given in Figure 3, will provide from research and development of drones to the end user, i.e., end-to-end solutions for drone based various developments and applications. The academic institutes usually focus on theoretical studies. The proposed Centres and MDM will primarily focus on technology development, real-time laboratory experiment, prototyping, and field trials and demonstration, while collaborating with industries and start-ups from the beginning of the project onwards. The industries and start-ups will mainly be responsible for commercialization, certification, deployment, maintenance, and service. The projects that will be taken up in this MDM programme will be translated to technology and production, by the industries. A smooth process of technology transfer will be ensured by participation of industries from the inception of the project onwards.

Please note that, any existing current technology available in open literature will be the base platform for the proposed drone technologies in this mission. Please refer to ***Appendix B*** for the R&D works done by IIT Bombay.

**5. Focus**

The main broad proposed focusses of the Maharashtra drone mission are as listed below:

- Establish Maharashtra as a World class Drone Hub
- Create safe and reliable integrated drone ecosystem for development of Maharashtra
- Develop one stop solution platform for drone applications
- Support for Maharashtra drone policy

**6. Objective**

Development, implementation and deployment of the drones and allied technologies, SOPs, policy, and support to the users with the help of industries and government agencies are as follows:

- **Drone System Design and Development**
  - Development of indigenous drones
  - Development of indigenous power generation and management systems
  - Development of indigenous autopilot system with multiple sensor suites and advance modes
  - Design of navigation systems for dynamic localization, intelligent path planning with obstacle and collision avoidance of UAV system
  - Development of detection and tracking systems for ensuring safe, reliable, and secure drone operations
- **Docking and Secure Communication Systems Development for Drones**
  - Development of multi-level drone docking systems, which can provide autonomous take-off, landing, recharging, and storage of multiple drones
  - Development of secure communication systems in a multi-drone system based on 5G and other related technologies
  - Development of cyber security system and testbed for drone ecosystem
- **Drone Operation and Management Development**
  - Development of UAV traffic management (UTM) system for mission plan and autonomous flight operation of UAV systems for mission execution of several drones for multiple purposes
  - Development of realistic adaptable and dynamic drone corridors featuring static, dynamic and adaptable geo-fence boundaries, applicable for actual flight scenarios for a variety of drones
  - Development of realistic, dynamic and adaptable airspace segmentation for actual flight scenarios for a variety of drones
  - Development and use of demand aggregator/tool by the users and execute a mission using a drone-in the-loop
- **Testing, Demonstration, Commercialization and Deployment of Drone Technologies**
  - System integration, and testing of new developments and designs in Hardware-In-Loop-Simulator (HILS)

- Field Trials, testing, and demonstration of various missions in controlled environment and real-world using real-time drone flying - live demo
- Commercialization and deployment of drone technologies

- **Application Specific Technology Development for Various Departments, such as**
  - Agriculture
  - Public Health
  - Disaster Management, Relief, and Rehabilitation
  - Water Resources Department
  - Public Works Department
  - Home
  - Urban Development
  - Transport
  - Rural Development and Panchayat Raj
  - Soil and Water Conservation
  - Revenue
  - Forest
- **Droneport, Equipment and Testing Facilities Establishment**
  - Mobile Command Control Station, Drone Localization Devices
  - Vehicular Communication (with 4G/5G) Testbeds, Cyber-Security Testbeds
  - Wind Tunnel, Wind Gust Generator / Shaper, Aerodynamics Facility
  - Radio Frequency Generator and Analyser with Anechoic Chamber, EMI/EMC Testing
  - Power Generation and Management, Propulsion Facility
  - Prototype Manufacturing, Workshops
  - Data Analysis Laboratory
  - Sensor and Device Testing Laboratory
  - Skill Development Facility
- **Skill Development and Entrepreneurship**
  - Training
  - Awareness
  - Startup Support through Seed Grant
- **Support for Drone Policy and Academic Programs, and Outreach Programs**
  - Support for Maharashtra Drone Policy
  - Support for Academic Programs: Scholarships, Fellowships, and Internships
  - National and International Interactions and Conferences
  - Technology Promotion and Marketing
  - Workshops, Hackathons, Other Events

The above listed facilities and laboratories will provide a synergy for developing, testing, and demonstrating technology for not only individual aspects of drone ecosystem but also for an integrated solution for application verticals.

We aim to develop these capabilities and to establish an automated drone port at IIT Bombay. The proposed droneport, shown in Figure 4, consists of runway airstrip, indoor drone testing facility with outdoor like environment, prototype manufacturing and assembling facility, charging/fueling station, hangar, ground control station, control tower (tracker/ transmitter-receiver), UTM facilitation. This droneport will have infrastructure needed to host and test various drone activities, to run UTM, and shall be capable of implementing a robust geo-fencing system along with monitoring the drones to optimize the path travelled without collision. Likewise, the droneport will have a hangar intended to safely store the drones when not in use and for maintenance. Adjacent to the hangar it will have an apron for prepping the drones before they take-off and also for readying the drone for storing. All of these facilities can be powered by solar power which includes the re-charging of the drones. The capability of this droneport can be further extended by including a runway which is capable of handling even fixed-wing drones. Additionally, this facility can be used to train drone trainers and pilots.

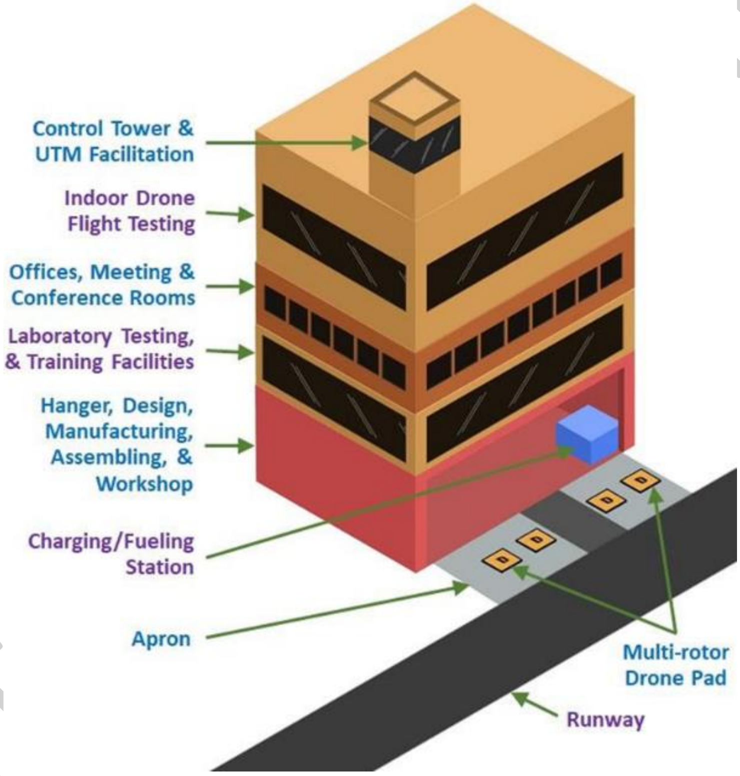


Figure 4: Proposed droneport concept at IIT Bombay

Also, indoor drone testing facility with motion capture system and outdoor like environment will be required to test and validate various designs, developments, approaches, and strategies before field testing in outdoor environment. In this indoor testing facility, outdoor like environment, like wind disturbance, will be created. This facility will help us to avoid possible untoward incidents and loss of vehicles, to speed up initiatives with less risk, to drive innovation, and to accelerate for achieving our several goals. Furthermore, a manufacturing unit will be instrumental in realizing our own prototype designs and developments, and also cater to any incubated start-ups or external organizations. This manufacturing unit can also incorporate an airworthiness testing facility.

Furthermore, IITB has the necessary permissions from Ministry of Civil Aviation (MoCA) and Airport Authority of India (AAI) for testing and trial of drones in the area shown in Figure 5, where the sites for the proposed runway airstrip and building are shown by yellow colour. These permissions are attached with this proposal as ***Appendix C***.

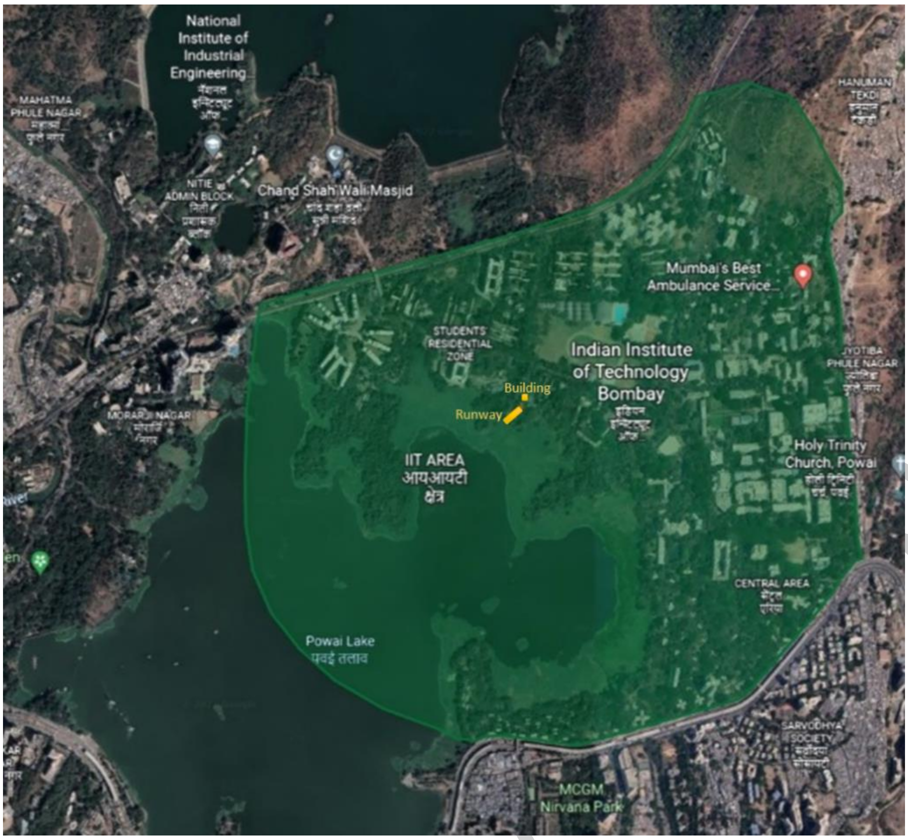


Figure 5: IITB's drone operation area, which has been permitted by Ministry of Civil Aviation and Airport Authority of India

Ensuring quality of a complex drone ecosystem, which is constantly evolving and changing, demands a multidisciplinary testing approach. It requires a well-planned testing strategy that is comprehensive. Individual component of the drone ecosystem including hardware and software, as well as the integrated solution need to be addressed. The following testing and validation will be performed as

- Functional
- Usability
- Reliability
- Communication
- Security
- Performance
- Compatibility
- Compliance
- Pilot
- Certification
- Upgradation

First, to demonstrate and perform field-trials of the proposed drone technologies, we are planning to create an ecosystem for drones in integrated and interconnected mobility systems within the campus of IIT Bombay. Later, this ecosystem can be replicated and scaled-up in several places in Maharashtra for various purposes. Note that, this ecosystem facility within IIT Bombay will be available for other users including possible virtual accesses. The modality of the uses and accesses will be worked out in due course.

Figure 6 proposes a drone ecosystem at IIT Bombay, where three 5G cellular towers will be setup around IIT Bombay's campus for rapid communication. Also, as parts of drone ecosystem, drone corridors shown in Figure 7, geo-fencing boundaries shown in Figure 8, airspace segmentation shown in Figure 9, multi-level drone docking facilities shown in Figure 10, and UTM shown in Figure 6 will be established. Three 5G cellular towers for rapid communication will be used to perform research on the scope of using triangulation method. The drones shall have automated tracking mechanism, which determines its position via satellite navigation or other sensors and periodically broadcasts it, enabling it to be tracked. Note that, this tracking mechanism requires no pilot's or external inputs, it is an automatic, continuous broadcast and thus the signal can be received by UTM and can be used along with the detection system to make the system safer and more robust. Besides, it can be received by other drones to provide situational awareness and allow self-separation.

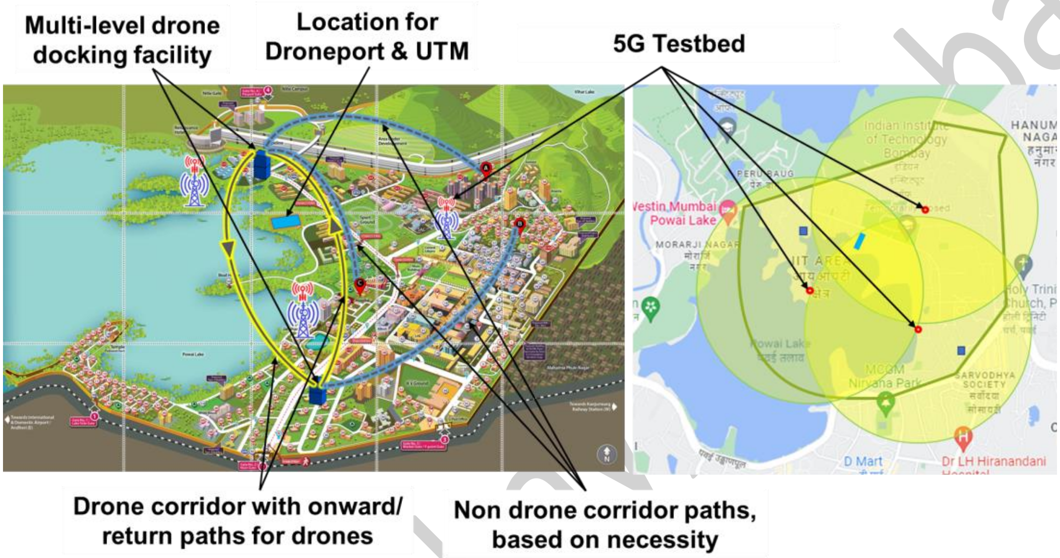


Figure 6: Proposed drone ecosystem at IIT Bombay

Drone corridors are nothing but flight lanes. Lanes facilitate safe and efficient 2-way movement of the drones between 2 points, while increasing the traffic flow, as shown in Figure 7. Drones shall not be allowed to travel in undesignated passages.

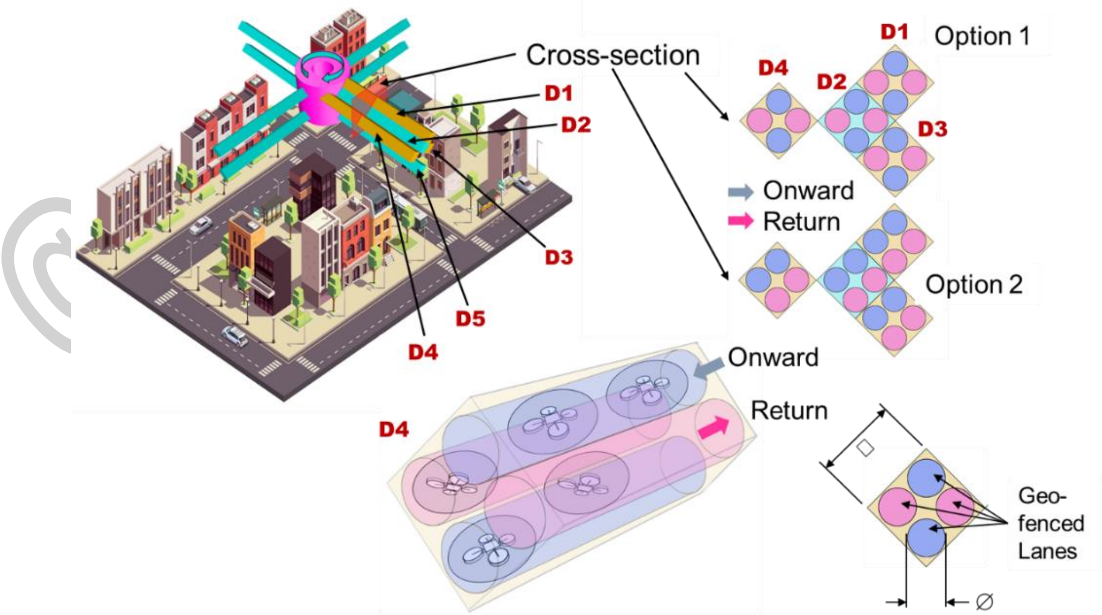


Figure 7: Drone corridors

Different kinds of airspace segments can be defined to prohibit or restrict access by the airspace users to this part of the airspace. To improve safety, geo-fences can be provided by sending the 3D coordinates defining its boundaries. Based on this 3-layered concept of geo-fence management, the geo-fencing boundaries of a drone ecosystem at IIT Bombay are proposed in Figure 8.

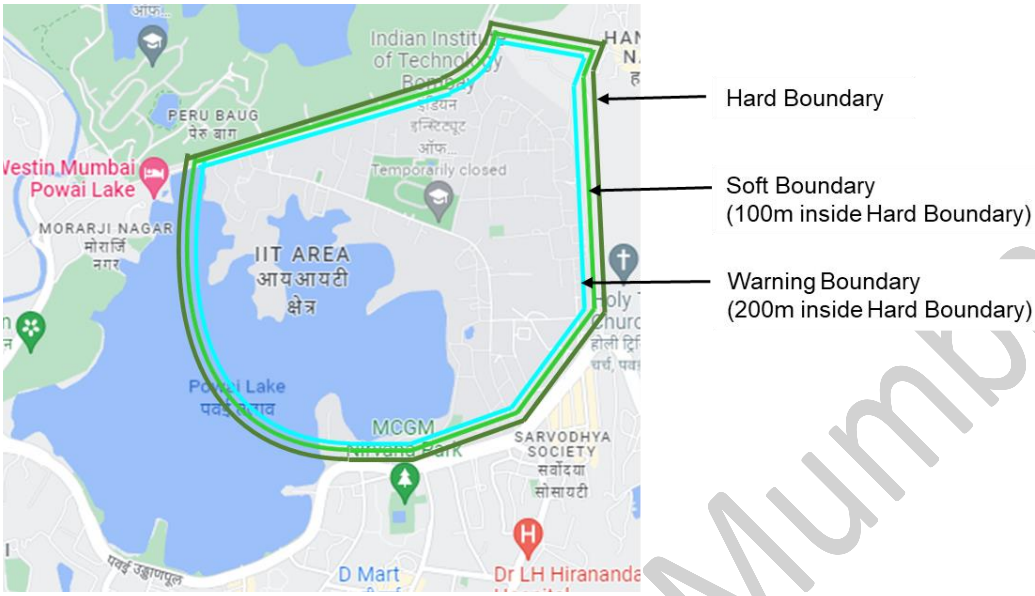


Figure 8: Proposed geo-fencing boundaries of a drone ecosystem at IIT Bombay

The airspace segments should be further divided into corridors for flights. Designated flight corridor for a class of drones can be considered. Corridor should facilitate quick and efficient take-off and landing. Corridors should have interconnectivities. UTM shall have capability to detect UAVs. Our concept intends to segment the airspace into a virtual multi-dimensional map, as shown in Figure 9.

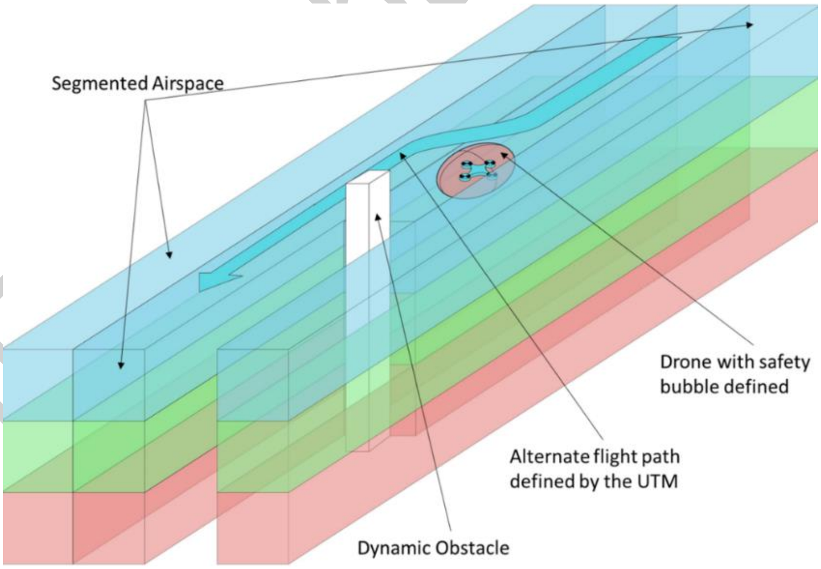


Figure 9: Dynamic airspace segmentation

A multi-level drone docking system, shown in Figure 10, is designed to accommodate landing and take-off of multiple UAVs. Each drone docking box/ station would provide a housing, take-off, and landing base, where the drone would land autonomously after a flight, and would get charged automatically between flights. It is a smart, weather-resistant, and temperature-controlled drone nesting. This system can have its own navigation system, allowing the drone to fly autonomously when required. This box/station can be permanently fixed or can be made mobile by fixing atop a ground vehicle; thus, our proposal is to make it as flexible as possible. This gives one an opportunity to quickly deploy the drone docking box/ station at remote locations without any other infrastructure and ensure the best-in-class experience.

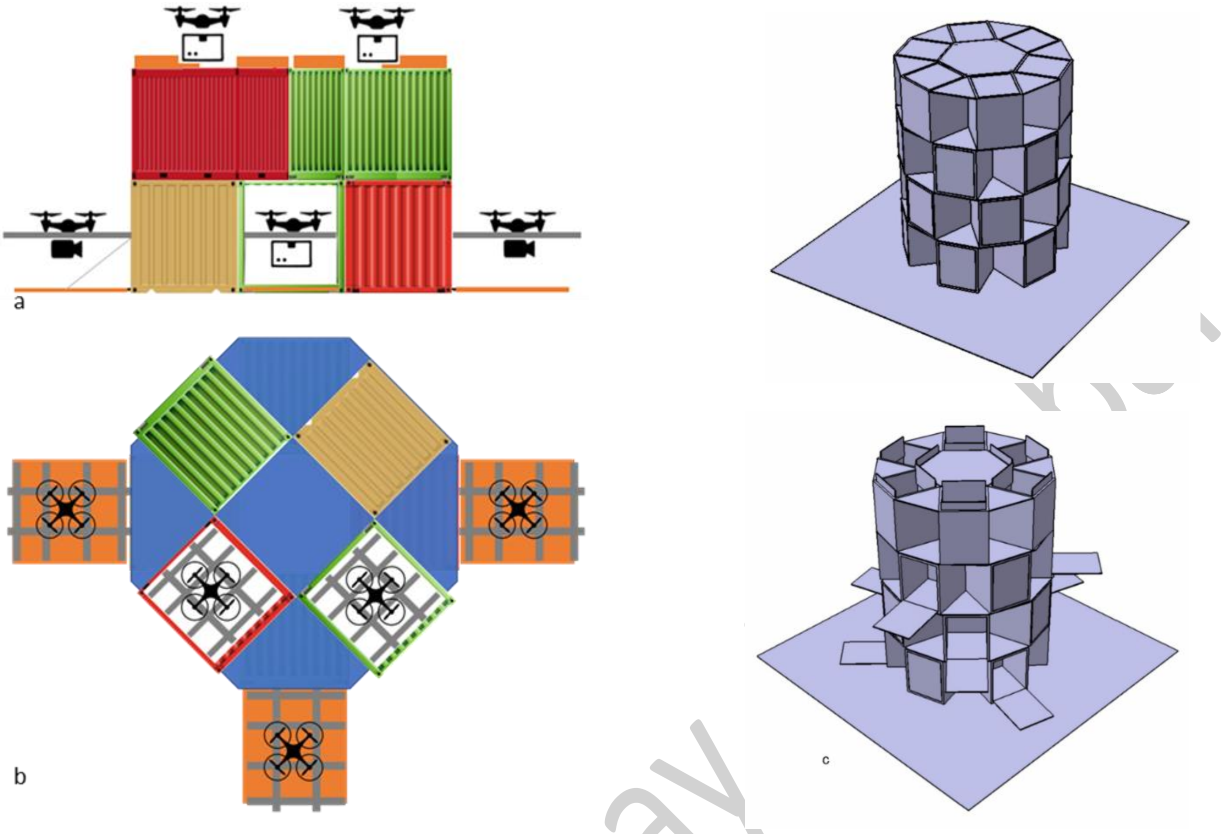


Figure 10: Multi-level Drone Docking System – a) Elevation, b) Top View, c) Configuration for Multi-level Drone Docking System

To make drones as an integral part of our local society, the proposed CoE at IIT Bombay will work with IIT Bombay's other entities, other academic institutes/universities, central government, state governments, security, defence and aerospace agencies, start-ups and industries, local authorities, local authorities. Some such potential entities are as shown in Figure 11.

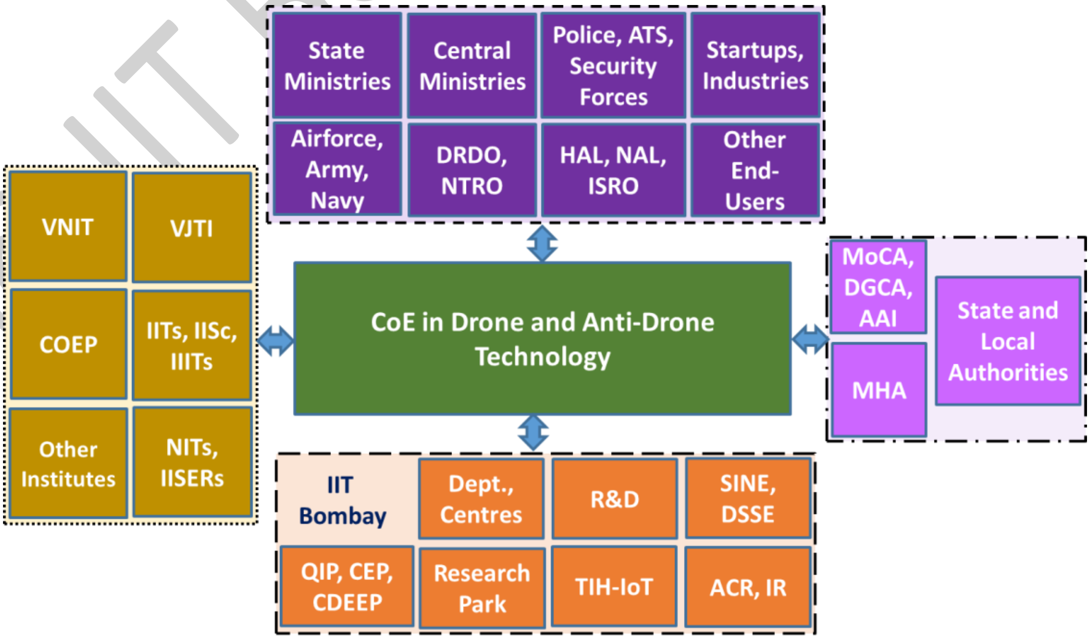


Figure 11: Proposed Interface with Potential Entities

## 7. Expected Deliverables

- Drone ecosystem, which can be used for both urban and rural areas, and counter drone technology for development of Maharashtra, and towards new paradigm technologies
- Application / use case specific solutions for various ministries / departments of Maharashtra
- Implementation and deployment of developed drone and allied technologies and products to the users
- SOPs, and Support for Maharashtra drone policy
- Integrated drone testing facility including drone port
- Control centre, Data resource and support centres, which can provide benchmark data for more usage and innovations
- Training, and awareness programs
- Employment generation
- Drone startups
- Drone backbone systems in academic and research institutes

## 8. Proposed Mission Structure

The proposed Maharashtra Drone Mission structure is shown in Figure 12.

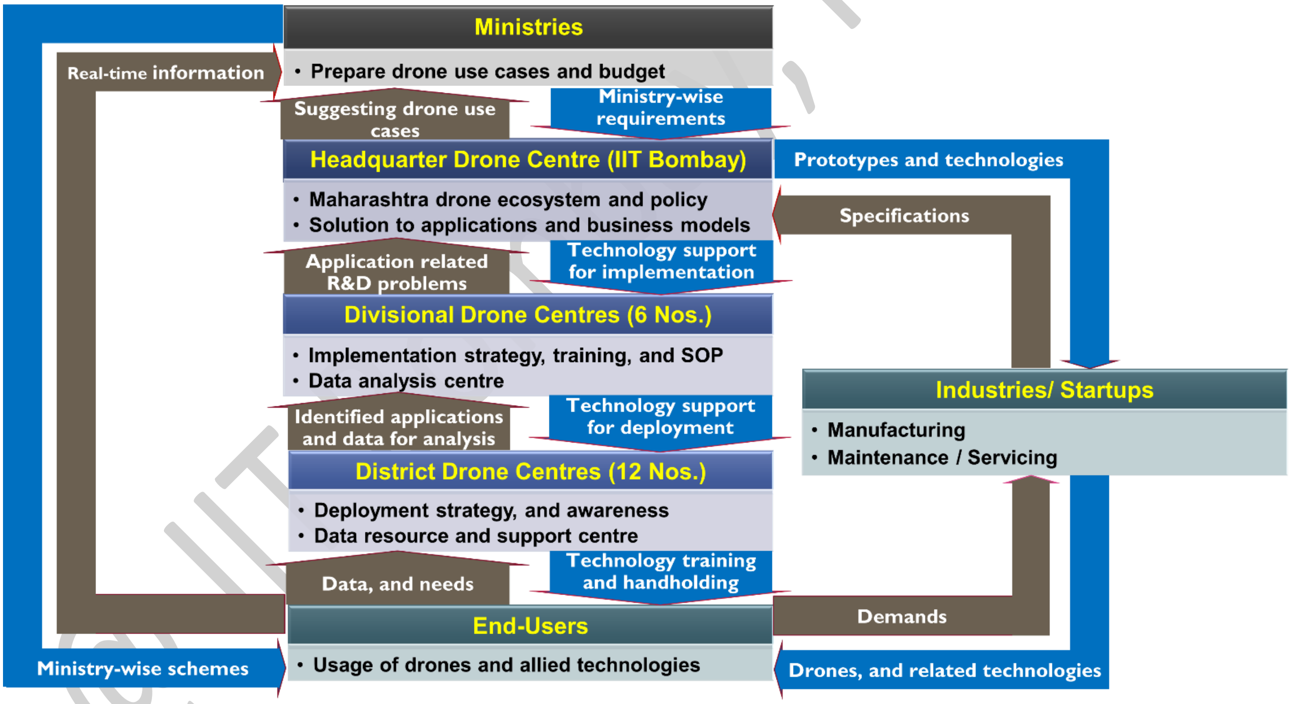


Figure 12: Proposed Maharashtra Drone Mission Structure

The headquarter drone centre will be established at IIT Bombay. Please refer to Section 12.2.1 for the list of investigators from IIT Bombay and their expertise. Also, more collaborators may get connected and be included as per the needs of the project in the future. Out of 6 divisional centres, 4 divisional centres have been identified at the following institutes: Visvesvaraya National Institute of Technology (VNIT), Nagpur; Veermata Jijabai Technological Institute (VJTI), Mumbai; College Of Engineering Pune (COEP) Technological University; and Shri Guru Gobind Singhji Institute of Engineering and Technology (SGGSIET), Nanded. Some of the capabilities of VNIT, VJTI and COEP are given in Section 12.2.2, whereas the same for SGGSIET, Nanded is yet to be identified by mutual interactions. Other divisional centres and the district centres will be identified later, and mentioned in the detailed project report (DPR).

## 8.1. Roles of Headquarter, Divisional and District Drone Centres, Expectations from the Government of Maharashtra and Their Roles

### 8.1.1. Roles of Headquarter Centre

- Lead and manage the drone mission, and establish the Headquarter Drone Centre at IIT Bombay
- Select the divisional and district centres, in consultation with the Nodal agency of Maharashtra government
- Create a safe and reliable integrated drone ecosystem and counter drone technology for development of Maharashtra, in collaboration with divisional and district centres and industries
- Needs assessment of application / use case specific problems of various ministries / departments of Maharashtra, and help the ministries / departments to prepare drone use cases and budget
- Provide the drone-based solution to these problems including business models, in collaboration with the divisional and district centres and industries
- Establish a state-of-the-art Integrated Drone Testing Facility at IIT Bombay
- Responsible for R&D work
- Technical support for SOP creation
- Support for Maharashtra drone policy
- Support for drone startups
- Coordination among participating organizations and Maharashtra government for conducting this drone mission
- Provide a unique environment for academic and research institutions, government, and industries to team together and focus on next-generation advances in drone technology

### 8.1.2. Roles of Divisional Centre

- Lead and manage a Divisional Centre
- Establish a data analysis and advanced training centre for skilled workforce development
- Coordinate and strengthen Drone District Centers across the region
- Serve as a drone training hub for district centres within the division
- Assist in deploying drone activities to districts needing more established centres in the division
- Develop Standard Operating Procedures (SoPs) for region-specific challenges and share best practices with other divisions through the Headquarter centre
- Aid the Drone Mission Headquarter centre in disseminating planned activities and initiatives
- Plan and execute implementation activities for the developed drone technologies and products within the division
- Technical support for R&D in coordination with the Headquarter centre and deployment for the district centres
- Support for preparing of application related R&D problem statements
- Identify specific regional issues requiring drone technology solutions

### 8.1.3. Roles of District Centre

- Lead and manage a District Centre
- Establish a data resource and support centre, which can provide benchmark data for usage and innovations
- Plan and execute the deployment activities for the developed drone technologies and products within the district(s)
- Serve as a drone awareness hub within the district(s)
- Organize and conduct trials, deployments, awareness campaigns, and training sessions to enhance drone skills and knowledge
- Offer essential technical, operational, and training support to end-users in the district(s)
- SOP implementation support
- Selection of drone applications within the district(s)
- Identify local challenges amenable to drone-based solutions and adapt SOPs accordingly
- Foster the development of skilled drone personnel within the district(s)
- Provide guidance and assistance to Government agencies and end-users in availing benefits from government schemes

### 8.1.4. Expectations from the Government of Maharashtra and Their Roles

- Problem statements for use cases / applications and requirements from the Government departments
- Drone procurements by the government agencies for usages and deployment, as per their requirements
- Create the Maharashtra drone policy, which is evolving and changing with time
- Support for testing, field trials, implementation, and deployment of the developed technologies and products.

## 8.2. Benefits for the Participating Institutes

The divisional and district centres, to be established as part of the MDM, will be the key centres for implementing and deployment arms of the mission activities. Further, they will also undertake R&D activities in consultation with the headquarter (IIT Bombay) towards providing solutions to the problems specific to their region(s). They will play a crucial role in the success of the mission. Some of the ways in which the partnering institutes will be benefited are given below:

- **Development of infrastructure:** The direct benefit for the partnering institutions will be the development in their infrastructure related to designing and assembling drones, servicing and applications.
- **Seamless transfer of technology:** The R&D outputs from the headquarter and divisional centres will be transferred to the district centres through proper training, that can lead to faster transfer of technology from lab to field.
- **Interdisciplinary R&D culture:** The partnering institutes will be entrusted with carrying out R&D activities to support their regions which will enhance the opportunity and aptitude towards R&D among the faculty and students at these institutes. These activities will be highly interdisciplinary requiring collaboration. This will foster a positive R&D ecosystem in the partnering institutions.

- **Human resources development:** Training of faculty members and others involved in the project at the partnering institutes will be provided. They can in turn train many students leading to the creation of skilled manpower in drone assembly, operation and service.
- **Curriculum development and modernization:** New and modern curriculum and courses relevant to the mission objectives will be developed. The complete curriculum will be shared with the partnering institutes who can include them as part of their degree program to offer minor and honours programs. In addition to curriculum development, online modules of some courses will be developed by IIT Bombay and other interested faculty members which can be used by these partnering institutes to fulfill their teaching commitments. The use of online learning materials towards course credit completion is a major recommendation of NEP 2020 and the partnering institutes can directly benefit from this.
- **Consultancy avenues:** The district and divisional centres can increase their revenue by offering drone-based services in their regions.
- **Fostering entrepreneurship and increasing placements:** The students of the partnering institutions will be fully equipped with the latest technologies related to different aspects of drones. They can be easily absorbed by several companies who provide drone and related data analytics services. In addition, the training will also enable the students to have their own startups through the development of suitable business models.

## 8.3. Team Structure for Mission Implementation

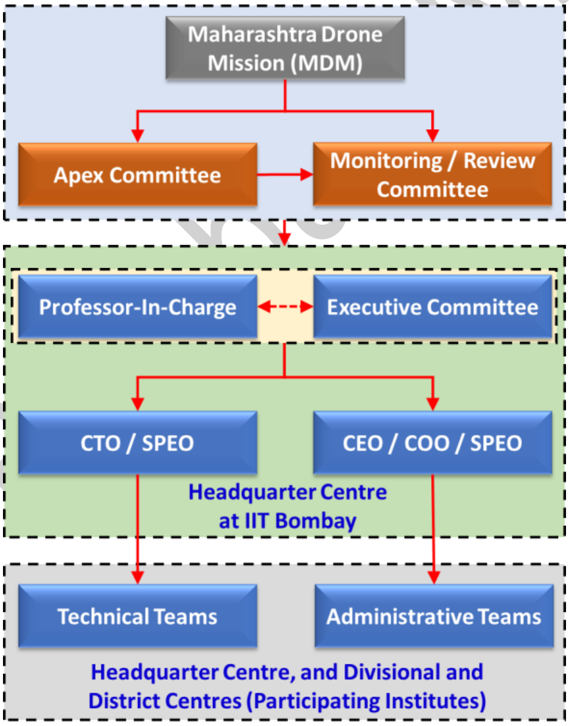


Figure 13: Team Structure for the Mission



This Maharashtra Drone Mission (MDM) will be implemented through the Headquarter drone centre at IIT Bombay. The team structure for this mission implementation shown in Figure 13 is as given below.

- This mission activities will be guided by an Apex Committee comprising of senior government officials / experts.
- A Monitor/ Review Committee will be constituted for reviewing the overall mission and its various projects. The members proposed for the Monitor/ Review Committee are as follows:

- ○ Senior officials from Government
- ○ Investigators from the Participating Academic and Research institutes
- ○ Experts / Officials from Industries / Startups
- ○ Experts from Renowned Academic and Research Organizations
- ○ Officials from User Agencies

- Continuous endeavor will be made to increase the number of startups / industries into this mission network.
- The Headquarter Centre will enter into MoAs with the Participating Institutes (Divisional and District Centres). The Centres will enter into MoAs with the industries.

The Headquarter Centre is to carry out the co-ordination activities, between the different organizations networked through this mission. In the Headquarter Centre, the Executive Committee consisting of the project investigator(s) of IIT Bombay, and a dedicated team under the Professor-in-Charge (PiC) consisting of Technical officers and Project Management Unit (PMU) officers, etc., will coordinate with the participating members, regularly monitor/ review the projects, conduct training/ awareness/ conferences/ workshops/ seminars, etc.

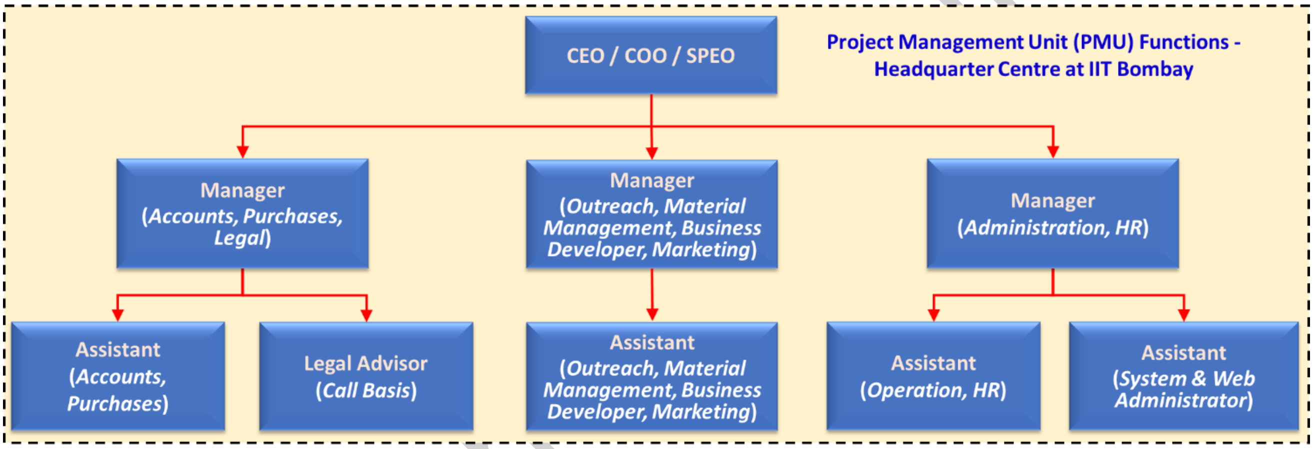


Figure 14: Administrative Teams

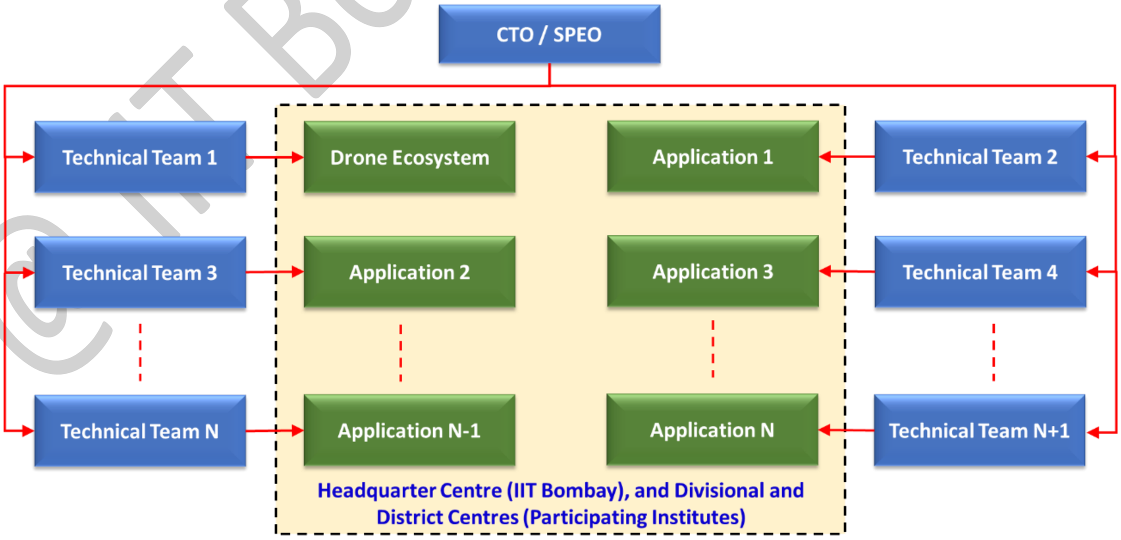


Figure 15: Technical Teams

The mission team structure including administrative and technical team structure is shown in Figure 13. The Headquarter Centre will be headed by the Professor-in-Charge appointed by IIT Bombay.

This centre has Administrative and Technical teams, headed by the Chief Executive Officer (CEO) / Chief Operating Officer (COO) / Senior Project Executive Officer (SPEO) and Chief Technology Officer (CTO) / SPEO, respectively. The Administrative team structure as shown in Figure 14 has further sub-teams for handling Administration and Human Resource (HR); Accounts, Purchases, and Legal; Outreach, Material Management, Business Developer, and Marketing. The structure for sub-teams has two layers, Manager and Assistant Staffs with corresponding responsibilities. The project is further divided into sub-projects as shown in Figure 15.

The concept of having technical teams and PMU staff hired under the centre is motivated to obtain following main benefits:

- Cost cutting on individual project
- Collaborative work without duplication
- Sustained quality technical staff

We believe that the sustainability of experienced human resources is a key for long-term sustainability of this mission and centres.

## 9. Implementation Plan

| Maharashtra Drone Mission: Action Plan | | Year 1 | | | | Year 2 | | | | Year 3 | | | | Year 4 | | | | Year 5 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Activities** | **Responsibility** | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 |
| Staff Hiring and MoUs | Headquarter Drone Centre (IITB) | ■ | ■ | | | | | | | | | | | | | | | | | | |
| | Divisional Drone Centres | | ■ | ■ | | ■ | ■ | | | | | | | | | | | | | | |
| | District Drone Centres | | | ■ | ■ | | ■ | ■ | | | | | | | | | | | | | |
| Submission of Inception Report, Initiation of Divisional and District Drone Centres | Submission of Inception Report | ■ | | | | | | | | | | | | | | | | | | | |
| | Initiation of 3 Divisional Drone Centres | | ■ | | | | | | | | | | | | | | | | | | |
| | Initiation of 6 District Drone Centres | | | ■ | | | | | | | | | | | | | | | | | |
| | Initiation of 3 Divisional Drone Centres | | | | | ■ | | | | | | | | | | | | | | | |
| | Initiation of 6 District Drone Centres | | | | | | ■ | | | | | | | | | | | | | | |
| Droneport Infrastructure, Equipment, Fabrication, Testing Facilities | Headquarter Drone Centre (IITB) | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | | | | | | | | | | |
| | Divisional Drone Centres | | | ■ | ■ | ■ | | | | | | | | | | | | | | | |
| | District Drone Centres | | | | ■ | ■ | ■ | | | | | | | | | | | | | | |
| Ecosystem for Drones and Counter Drones | Headquarter Drone Centre (IITB) | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| | Divisional Drone Centres | | | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| | District Drone Centres | | | | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| Application Specific Solutions | Headquarter Drone Centre (IITB) | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| | Divisional Drone Centres | | | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| | District Drone Centres | | | | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| Skill Development and Entrepreneurship | Headquarter Drone Centre (IITB): Startup Support | | | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| | Divisional Drone Centres: Training | | | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| | District Drone Centres: Awareness | | | | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| Support for Drone Policy and Academic Programs, and Outreach Programs | Support for Maharashtra Drone Policy and Academic Programs | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| | National and International Interactions and Conferences | | | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| | Technology Promotion and Marketing | | | | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| | Workshops, Hackathons, Other Events | | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| | Maharashtra Drone Mission Website | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |

Figure 16: Implementation Plan of the Mission

## 10. Self-sustainability

For self-sustainability of the proposed Centres, the revenue generation through various activities is required to cover the operating expenses and sustain themselves over the long term. Once the proposed drone ecosystem and counter drone technology are developed, this ecosystem can be used for several applications. Even though, few applications are proposed in this proposal, many other applications in various areas can be addressed later. Also, the state-of-art facilities and testbeds for testing and validation of the proposed drone ecosystem will be available for the industries and external users.

The project envisages the following main streams of revenue:

- **Government and User Agency Interactions**
  - Sponsored/ consultancy projects from the government ministries/ departments and user agencies
  - Consulting and advisory services to the government ministries/ departments and user agencies
- **Industry Interactions**
  - Sponsored projects from the industries and startups
  - Consulting and research services to the industries and startups
  - Technology transfers with the takers from the industries
  - Royalty earnings through licensing IPs, such as patents or software, to the industries and startups
  - Membership fee for subscription
- **Human Resource Development**
  - Niche training for industries, users, trainers, etc.
  - Skill building courses / workshops
  - Continuing education courses and programs to professionals
- **Facility and Laboratory Usage**
  - Usage by external users: Usage charge for facility and laboratory use by the industries and external users
  - Sponsored/ consultancy projects: Facility and laboratory utilization for the sponsored/ consultancy projects which will be charged additionally
  - Training/ Course / workshop: Facility and laboratory utilization for training/ Course / workshop which will be charged additionally
- **Return on startup investment:** We have projected investment in promising startups through seed grant which is required for drone technology development. Any success in the startup being able to raise future funds at higher valuation can provide revenue for the centres.
- **Fundraising**
  - Fundraising activities such as soliciting donations from individuals, corporations, and foundations

However, the above estimates are difficult to predict exactly due to emerging and disruptive drone technology, which can be used for multiple applications. The exact model of revenue generation will work out based on the prevailing situations during execution of the project.

## 11. Budget Estimates: Summary

The estimated budget details of all centres are given below. Please note that, the projected budgets for individual institute as well as its individual head may be re-appropriated dependent on the mission needs and situation, while keeping the total budget of this mission unchanged. In addition to the budget for testing and fabrication facilities, equipment given in Section 11.3, their further itemized budget will be provided in the detailed project report (DPR).

Please also note that, as per IIT Bombay's rules, formally the start date of any project is the date of first installment fund received by the bank at IIT Bombay.

## 11.1. Detailed Budget

### 11.1.1. Total Budget for All Centres (Headquarter, 6 Divisional and 12 District Centres)

| | | Budget (in Rupees, Lakhs) | | | | | |
|---|---|---|---|---|---|---|---|
| Sr. No. | Head | 1st yr. (12 months) | 2nd yr. (12 months) | 3rd yr. (12 months) | 4th yr. (12 months) | 5th yr. (12 months) | Total (5 years) |
| 1 | Manpower | 758.02 | 1095.33 | 1214.97 | 1316.85 | 1424.92 | 5810.09 |
| 2 | Consumable | 366.00 | 350.00 | 222.00 | 219.00 | 222.00 | 1379.00 |
| 3 | Contingencies | 243.00 | 274.00 | 231.00 | 248.00 | 260.00 | 1256.00 |
| 4 | Travel | 123.00 | 164.00 | 167.00 | 175.00 | 184.00 | 813.00 |
| 5 | Support for Academic Programs, and Outreach Programs: Scholarships, Fellowships and Internships for Academic Programs, National and International Interactions and Conferences, Training, Awareness, Ideathons, Other Events | 215.80 | 319.35 | 346.35 | 364.35 | 381.05 | 1626.91 |
| 6 | Startups / Innovators Support Services | 150.00 | 150.00 | 100.00 | 50.00 | 50.00 | 500.00 |
| 7 | Equipment, Testing and Fabrication Facilities | 3471.00 | 2442.50 | 944.00 | 37.50 | 0.00 | 6895.00 |
| 8 | Infrastructure for Headquarter Centre including Droneport/ Furnishing Place for Readying the Facilities | 1533.00 | 777.00 | 0.00 | 0.00 | 0.00 | 2310.00 |
| 9 | Institute Overheads [Expect on Travel] - (20% for Headquarter Centre at IIT Bombay and Divisional Centre at VNIT, 10% for Other Divisional and the District Centres) | 1208.04 | 844.83 | 489.94 | 356.89 | 373.72 | 3273.43 |
| 10 | **Grand Total (including Institute Overheads)** | 8067.86 | 6417.01 | 3715.27 | 2767.59 | 2895.70 | **23863.43** |

### 11.1.2. Budget for Headquarter, Divisional and District Centres

| | | Budget (in Rupees, Lakhs) | | | | | |
|---|---|---|---|---|---|---|---|
| Sr. No. | Head | 1st yr. (12 months) | 2nd yr. (12 months) | 3rd yr. (12 months) | 4th yr. (12 months) | 5th yr. (12 months) | Total (5 years) |
| 1 | **Headquarter Centre (1 No.)** | 5157.92 | 2970.04 | 1849.68 | 1347.49 | 1406.29 | **12731.43** |
| 2 | **Divisional Centres (6 Nos.)** | 842.10 | 1384.98 | 790.43 | 555.37 | 578.06 | **4150.94** |

| | | Budget (in Rupees, Lakhs) | | | | | |
|---|---|---|---|---|---|---|---|
| **Sr. No.** | **Head** | **1st yr. (12 months)** | **2nd yr. (12 months)** | **3rd yr. (12 months)** | **4th yr. (12 months)** | **5th yr. (12 months)** | **Total (5 years)** |
| 3 | **District Centres (12 Nos.)** | 859.80 | 1217.16 | 585.22 | 507.84 | 537.62 | **3707.64** |
| 4 | **Institute Overheads [Expect on Travel] - (20% for Headquarter Centre at IIT Bombay and Divisional Centre at VNIT, 10% for Other Divisional and the District Centres)** | 1208.04 | 844.83 | 489.94 | 356.89 | 373.72 | **3273.43** |
| 5 | **Grand Total (including Institute Overheads)** | **8067.86** | **6417.01** | **3715.27** | **2767.59** | **2895.70** | **23863.43** |

### 11.1.3. Headquarter (HQ) Drone Centre (IIT Bombay)

| | | Budget (in Rupees, Lakhs) | | | | | |
|---|---|---|---|---|---|---|---|
| **Sr. No.** | **Head** | **1st yr. (12 months)** | **2nd yr. (12 months)** | **3rd yr. (12 months)** | **4th yr. (12 months)** | **5th yr. (12 months)** | **Total (5 years)** |
| 1 | Manpower | 622.12 | 672.69 | 724.33 | 777.14 | 831.24 | 3627.51 |
| 2 | Consumable | 330.00 | 275.00 | 135.00 | 120.00 | 120.00 | 980.00 |
| 3 | Contingencies | 210.00 | 205.00 | 150.00 | 155.00 | 155.00 | 875.00 |
| 4 | Travel | 90.00 | 95.00 | 95.00 | 100.00 | 100.00 | 480.00 |
| 5 | Support for Academic Programs, and Outreach Programs: Scholarships, Fellowships and Internships for Academic Programs, National and International Interactions and Conferences, Training, Awareness, Ideathons, Other Events | 137.80 | 145.35 | 145.35 | 145.35 | 150.05 | 723.91 |
| 6 | Startups / Innovators Support Services | 150.00 | 150.00 | 100.00 | 50.00 | 50.00 | 500.00 |
| 7 | Equipment, Testing and Fabrication Facilities | 2295.00 | 860.00 | 500.00 | 0.00 | 0.00 | 3655.00 |
| 8 | Infrastructure for HQ Centre including Droneport/ Furnishing Place for Readying the Facilities | 1323.00 | 567.00 | 0.00 | 0.00 | 0.00 | 1890.00 |
| 9 | Institute Overheads (20%) - Except on Travel | 1013.58 | 575.01 | 350.94 | 249.50 | 261.26 | 2450.29 |
| 10 | **Grand Total (including Institute Overheads)** | 6171.50 | 3545.05 | 2200.62 | 1596.99 | 1667.55 | **15181.71** |

### 11.1.4. Division Drone Centre (Each)

#### 11.1.4.1. Division Centre at VNIT

| | | Budget (in Rupees, Lakhs) | | | | | |
|---|---|---|---|---|---|---|---|
| Sr. No. | Head | 1st yr. (9 months) | 2nd yr. (12 months) | 3rd yr. (12 months) | 4th yr. (12 months) | 5th yr. (12 months) | Total (4 years 9 months) |
| 1 | Manpower | 29.70 | 43.56 | 47.92 | 52.71 | 57.98 | 231.86 |
| 2 | Consumable | 6.00 | 7.00 | 8.00 | 9.00 | 9.00 | 39.00 |
| 3 | Contingencies | 5.00 | 6.00 | 7.00 | 8.00 | 9.00 | 35.00 |
| 4 | Travel | 5.00 | 6.00 | 6.00 | 7.00 | 7.00 | 31.00 |
| 5 | Support for Academic Programs, and Outreach Programs: Scholarships, Fellowships and Internships for Academic Programs, National and International Interactions and Conferences, Training, Awareness, Ideathons, Other Events | 10.00 | 12.00 | 15.00 | 16.00 | 17.00 | 70.00 |
| 6 | Equipment, Testing and Fabrication Facilities | 200.00 | 50.00 | 50.00 | 0.00 | 0 | 300.00 |
| 7 | Furnishing Place / Infrastructure for Readying the Facilities | 30.00 | 0.00 | 0.00 | 0.00 | 0.00 | 30.00 |
| 8 | Institute Overheads (20%) - Except on Travel | 55.14 | 33.01 | 17.28 | 17.14 | 18.60 | 141.17 |
| 9 | **Grand Total (including Institute Overheads)** | 335.84 | 204.07 | 109.70 | 109.85 | 118.57 | **878.03** |



#### 11.1.4.2. Each of Divisional Centres at VJTI and COEP

| | | Budget (in Rupees, Lakhs) | | | | | |
|---|---|---|---|---|---|---|---|
| Sr. No. | Head | 1st yr. (9 months) | 2nd yr. (12 months) | 3rd yr. (12 months) | 4th yr. (12 months) | 5th yr. (12 months) | Total (4 years 9 months) |
| 1 | Manpower | 29.70 | 43.56 | 47.92 | 52.71 | 57.98 | 231.86 |
| 2 | Consumable | 6.00 | 7.00 | 8.00 | 9.00 | 9.00 | 39.00 |
| 3 | Contingencies | 5.00 | 6.00 | 7.00 | 8.00 | 9.00 | 35.00 |
| 4 | Travel | 5.00 | 6.00 | 6.00 | 7.00 | 7.00 | 31.00 |
| 5 | Support for Academic Programs, and Outreach Programs: Scholarships, Fellowships and Internships for Academic Programs, National and International | 10.00 | 12.00 | 15.00 | 16.00 | 17.00 | 70.00 |

| | | Budget (in Rupees, Lakhs) | | | | | |
|---|---|---|---|---|---|---|---|
| **Sr. No.** | **Head** | **1st yr. (9 months)** | **2nd yr. (12 months)** | **3rd yr. (12 months)** | **4th yr. (12 months)** | **5th yr. (12 months)** | **Total (4 years 9 months)** |
| | Interactions and Conferences, Training, Awareness, Ideathons, Other Events | | | | | | |
| 6 | Equipment, Testing and Fabrication Facilities | 200.00 | 50.00 | 50.00 | 0.00 | 0 | 300.00 |
| 7 | Furnishing Place / Infrastructure for Readying the Facilities | 30.00 | 0.00 | 0.00 | 0.00 | 0.00 | 30.00 |
| 8 | Institute Overheads (10%) - Except on Travel | 27.57 | 16.51 | 8.64 | 8.57 | 9.30 | 70.59 |
| 9 | **Grand Total (including Institute Overheads)** | 308.27 | 187.57 | 101.06 | 101.28 | 109.28 | **807.45** |

**11.1.4.3. Each of the Remaining 3 Divisional Centres at State Government Institutes including SGGSIET, Nanded**

| | | Budget (in Rupees, Lakhs) | | | | |
|---|---|---|---|---|---|---|
| **Sr. No.** | **Head** | **2nd yr. (12 months)** | **3rd yr. (12 months)** | **4th yr. (12 months)** | **5th yr. (12 months)** | **Total (4 years)** |
| 1 | Manpower | 39.60 | 43.56 | 47.92 | 52.71 | 183.78 |
| 2 | Consumable | 6.00 | 7.00 | 8.00 | 9.00 | 30.00 |
| 3 | Contingencies | 5.00 | 6.00 | 7.00 | 8.00 | 26.00 |
| 4 | Travel | 5.00 | 6.00 | 6.00 | 7.00 | 24.00 |
| 5 | Support for Academic Programs, and Outreach Programs: Scholarships, Fellowships and Internships for Academic Programs, National and International Interactions and Conferences, Training, Awareness, Ideathons, Other Events | 10.00 | 12.00 | 15.00 | 16.00 | 53.00 |
| 6 | Equipment, Testing and Fabrication Facilities | 200.00 | 50.00 | 50.00 | 0.00 | 300.00 |
| 7 | Furnishing Place / Infrastructure for Readying the Facilities | 30.00 | 0.00 | 0.00 | 0.00 | 30.00 |
| 8 | Institute Overheads (10%) - Except on Travel | 28.56 | 16.51 | 8.64 | 8.57 | 62.28 |
| 9 | **Grand Total (including Institute Overheads)** | 319.16 | 187.57 | 101.06 | 101.28 | **709.06** |

### 11.1.5. District Drone Centre (Each)

#### 11.1.5.1. Each of First 6 District Centres at State Government Institutes

| | | Budget (in Rupees, Lakhs) | | | | | |
|---|---|---|---|---|---|---|---|
| **Sr. No.** | **Head** | **1st yr. (6 months)** | **2nd yr. (12 months)** | **3rd yr. (12 months)** | **4th yr. (12 months)** | **5th yr. (12 months)** | **Total (4 years 6 months)** |
| 1 | Manpower | 7.80 | 17.16 | 18.88 | 20.76 | 22.84 | 87.44 |
| 2 | Consumable | 3.00 | 3.00 | 4.00 | 4.00 | 4.00 | 18.00 |
| 3 | Contingencies | 3.00 | 3.00 | 4.00 | 4.00 | 5.00 | 19.00 |
| 4 | Travel | 3.00 | 3.00 | 3.00 | 3.00 | 4.00 | 16.00 |
| 5 | Support for Academic Programs, and Outreach Programs: Scholarships, Fellowships and Internships for Academic Programs, National and International Interactions and Conferences, Training, Awareness, Ideathons, Other Events | 8.00 | 10.00 | 10.00 | 11.00 | 11.00 | 50.00 |
| 6 | Equipment, Testing and Fabrication Facilities | 98.50 | 19.50 | 2.00 | 0.00 | 0.00 | 120.00 |
| 7 | Furnishing Place / Infrastructure for Readying the Facilities | 20.00 | 0.00 | 0.00 | 0.00 | 0.00 | 20.00 |
| 8 | Institute Overheads (10%) - Except on Travel | 14.03 | 5.27 | 3.89 | 3.98 | 4.28 | 31.44 |
| 9 | **Grand Total (including Institute Overheads)** | 157.33 | 60.93 | 45.76 | 46.74 | 51.12 | **361.88** |

#### 11.1.5.2. Each of the Remaining 6 District Centres at State Government Institutes

| | | Budget (in Rupees, Lakhs) | | | | |
|---|---|---|---|---|---|---|
| **Sr. No.** | **Head** | **2nd yr. (9 months)** | **3rd yr. (12 months)** | **4th yr. (12 months)** | **5th yr. (12 months)** | **Total (3 years 9 months)** |
| 1 | Manpower | 11.70 | 17.16 | 18.88 | 20.76 | 62.65 |
| 2 | Consumable | 3.00 | 3.00 | 4.00 | 4.00 | 14.00 |
| 3 | Contingencies | 3.00 | 3.00 | 4.00 | 4.00 | 14.00 |
| 4 | Travel | 3.00 | 3.00 | 3.00 | 3.00 | 12.00 |
| 5 | Support for Academic Programs, and Outreach Programs: Scholarships, Fellowships and Internships for Academic Programs, National and International | 8.00 | 10.00 | 10.00 | 11.00 | 39.00 |

| | | Budget (in Rupees, Lakhs) | | | | |
|---|---|---|---|---|---|---|
| **Sr. No.** | **Head** | **2nd yr. (9 months)** | **3rd yr. (12 months)** | **4th yr. (12 months)** | **5th yr. (12 months)** | **Total (3 years 9 months)** |
| | Interactions and Conferences, Training, Awareness, Ideathons, Other Events | | | | | |
| 6 | Equipment, Testing and Fabrication Facilities | 98.50 | 19.50 | 2.00 | 0.00 | 120.00 |
| 7 | Furnishing Place / Infrastructure for Readying the Facilities | 20.00 | 0.00 | 0.00 | 0.00 | 20.00 |
| 8 | Institute Overheads (10%) - Except on Travel | 14.42 | 5.27 | 3.89 | 3.98 | 27.55 |
| 9 | **Grand Total (including Institute Overheads)** | 161.62 | 60.93 | 45.76 | 46.74 | **315.05** |

## 11.2. Budget for Manpower (Technical + Admin)

### 11.2.1. Headquarter Centre (IIT Bombay) as per IRCC's norms

| | | Budget (in Rupees, Lakhs) | | | | | |
|---|---|---|---|---|---|---|---|
| **Designation (No. of persons)** | **Monthly Emoluments (in Rupees, Lakh) per person** | **1st yr. (12 months)** | **2nd yr. (12 months)** | **3rd yr. (12 months)** | **4th yr. (12 months)** | **5th yr. (12 months)** | **Total (5 years)** |
| i) Senior Project Executive Officer (SPEO)-CEO/COO (1 person) | 2.5 including OCA/HRA (10% Increment Yearly) | 30.00 | 33.00 | 36.30 | 39.94 | 43.93 | 183.17 |
| ii) Senior Project Executive Officer (SPEO)– CTO (1 person) | 2.5 including OCA/HRA (10% Increment Yearly) | 30.00 | 33.00 | 36.30 | 39.94 | 43.93 | 183.17 |
| iii) Senior Project Research Scientist/ Senior Project Manager (8 persons) | 0.948 (0.072 Increment Yearly) + 0.10 (OCA/HRA) | 100.61 | 107.52 | 114.43 | 121.34 | 128.26 | 572.16 |
| iv) Project Research Scientist/ Project Manager/ Sr. Project Engineer (14 persons) | 0.72 (0.06 Increment Yearly) + 0.075 (OCA/HRA) | 133.56 | 143.64 | 153.72 | 163.80 | 173.88 | 768.60 |
| v) Project Research Associate / Project Research Engineer / Project Engineer/ | 0.528 (0.048 Increment Yearly) + 0.0625 (OCA/HRA) | 184.39 | 199.37 | 214.34 | 229.32 | 244.30 | 1071.72 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Assistant Project Manager (26 persons) | | | | | | | |
| vi) Project Research Assistant / Sr. Project Technical Assistant/ Sr. Project Assistant (17 persons) | 0.396 (0.036 Increment Yearly) + 0.05 (OCA/HRA) | 90.98 | 98.33 | 105.67 | 113.02 | 120.36 | 528.36 |
| vii) Pilot cum Technician (2 persons) | 0.45 including OCA/HRA (10% Increment Yearly) | 10.80 | 11.88 | 13.08 | 14.40 | 15.84 | 66.00 |
| viii) Expert / Consultant (2 person) | 1.5 including OCA/HRA (10% Increment Yearly) | 36.00 | 39.60 | 43.56 | 47.93 | 52.73 | 219.82 |
| ix) Project/ Administrative Assistant / Project Technical Assistant (2 person) | 0.216 (0.024 Increment Yearly) + 0.03125 (OCA/HRA) | 5.94 | 6.80 | 7.66 | 8.53 | 9.39 | 38.32 |

As per IRCC norms of IITB, the following are the details of qualifications and experience for recruiting various positions in the project:

| Position / Designation | Qualifications and Experience | Role |
|---|---|---|
| CEO / COO / Senior Project Executive Officer (SPEO) | • PhD with minimum 8 years relevant experience OR<br>• MBA/MTech or equivalent degree with minimum 12 years relevant experience OR<br>• Applicant should have sufficient experience in managing large activities/ centres/ projects at higher/ middle level managerial/ scientific/ academic positions | Leadership and vision, resource allocation, stakeholder management, risk management, overall performance monitoring |
| CTO / Senior Project Executive Officer (SPEO) | • PhD with minimum 8 years relevant experience OR<br>• MBA/MTech or equivalent degree with minimum 12 years relevant experience OR<br>• Applicant should have sufficient experience in managing large activities/ centres/ projects at higher/ middle level managerial/ scientific/ academic positions | Technical leadership, innovation, technology strategy, technical talent development, project quality assurance |
| Senior Project Research Scientist/ | • PhD with minimum 4 years relevant experience OR | Each Senior Project Research Scientist/ Senior Project Manager will lead one technology |

| Position / Designation | Qualifications and Experience | Role |
|---|---|---|
| Senior Project Manager | • MTech/ME/Mdes/MBA or equivalent degree with minimum 8 years relevant experience OR<br>• BTech/BE/MA/MSc/MCA or equivalent degree with minimum 10 years relevant experience | /application vertical as a Team Leader of that technology / application vertical. |
| Project Research Scientist/<br>Project Manager/<br>Sr. Project Engineer | • PhD OR<br>• MTech/ME/Mdes or equivalent degree with minimum 4 years relevant experience OR<br>• BTech/BE/MA/MSc/MCA/MBA or equivalent degree with minimum 6 years relevant experience | Each Project Research Scientist/ Project Manager/ Sr. Project Engineer will be the key technical person after the Team Lead to provide support to one application / technical vertical of the project and a Team Leader as a Sr. Technical Officer. |
| Project Research Associate/<br>Project Research Engineer/<br>Project Engineer/<br>Assistant Project Manager | • MTech/ME/Mdes or equivalent degree OR<br>• BTech/BE/MA/MSc/MCA/MBA or equivalent degree with minimum 2 years relevant experience | Each Project Research Associate/ Project Research Engineer/ Project Engineer/ Assistant Project Manager will provide support to one application / technical vertical of the project as well as a Team Leader and a Sr. Technical Officer as a Technical Officer. |
| Project Research Assistant/<br>Sr. Project Technical Assistant | • BTech/BE/MA/MSc/MCA/MBA or equivalent degree OR<br>• BA/BSc or equivalent degree with 2 years relevant experience | Each Project Research Assistant/ Sr. Project Technical Assistant will provide support to one application / technical vertical of the project as a Jr. Technical Officer. |
| Project Technical Assistant | • 3-year Diploma in Engineering in the appropriate discipline OR<br>• ITI in the appropriate trade OR<br>• Bachelor's degree in the appropriate discipline OR<br>• Persons with proven skill experience of at least 5 years | The responsibilities of this person will be to do a broad variety of mechanics tasks such as machining and fabrication, milling, metal working, grinding, welding, maintenance of equipment. |
| Pilot cum Technician | • BTech/BE/MA/MSc/MCA/MBA or equivalent degree<br>• BA/BSc/BCom/BBA or equivalent degree with 2 years' relevant experience<br>• DGCA certified Drone pilot | Pilot cum Technician will be responsible for flying and testing drones, and support for manufacturing and assembling drones and drone docking systems. |
| Expert / Consultant | • Qualifications and experience to be decided and mentioned in the DPR | Advisory role, needs assessment, technology evaluation, implementation, integration and deployment planning, support for complex or high-risk practical problem solving, risk assessment, |

| Position / Designation | Qualifications and Experience | Role |
|---|---|---|
| | | regulatory and standard compliance, troubleshooting, support for strategic planning, cost analysis |
| Project Manager | • PhD OR<br>• MTech/ME/Mdes or equivalent degree with minimum 4 years relevant experience OR<br>• BTech/BE/MA/MSc/MCA/MBA or equivalent degree with minimum 6 years relevant experience | Each Project Manager will lead one sub-team of Administrative team as a Manager of that sub-team. |
| Sr. Project Assistant | • MA/MCom/MCA/MBA or equivalent degree OR<br>• BA/BSc/BCom/BBA or equivalent degree with 2 years relevant experience<br>• Desirable: Knowledge of Computer Applications, Secretarial experience | Each Sr. Project Assistant will provide support to one sub-team of Administrative team of the project and a Manager as an Assistant Manager. |
| Project/ Administrative Assistant | • BA/BSc/BCom/BBA or equivalent degree<br>• Desirable: Knowledge of Computer Applications, Secretarial experience | The responsibilities of this person will be to do a broad variety of administrative tasks including: managing active calendar of appointments; expense reports; arranging detailed travel plans, itineraries, and agendas; compiling documents for travel-related meetings; etc. |

**11.2.2. Divisional Centre (Each)**

| Position / Designation (No. of persons) | Monthly Emoluments (In Rupees, Lakh) per person |
|---|---|
| i) Project Scientist/ Project Manager (2 persons) | 0.75 including OCA/HRA (10% Increment Yearly) |
| ii) Senior Project Engineer/ Assistant Project Manager (2 persons) | 0.50 including OCA/HRA (10% Increment Yearly) |
| iii) Project Engineer/ Senior Project Assistant (2 persons) | 0.40 including OCA/HRA (10% Increment Yearly) |

**11.2.3. District Centre (Each)**

| Position / Designation (No. of persons) | Monthly Emoluments (In Rupees, Lakh) per person |
|---|---|
| i) Senior Project Engineer/ Assistant Project Manager (1 person) | 0.50 including OCA/HRA (10% Increment Yearly) |
| ii) Project Engineer/ Senior Project Assistant (2 persons) | 0.40 including OCA/HRA (10% Increment Yearly) |

## 11.3. Budget for Testing and Fabrication Facilities, Equipment

### 11.3.1. Headquarter Centre

| Sr. No. | Name of equipment/ facility/ testbed/ component | Quantity | Total Estimated Cost (in Lakhs, Rs.) |
|---|---|---|---|
| 1 | Drones and their components (onboard computation, EO/IR payloads, etc.): New Innovation – 10, Swarm – 8, Spraying – 3, Imaging – 3, Delivery – 3, Structural Monitoring – 3, Road Traffic – 3, Water Resources Management – 3, Urban Mapping – 3, Other Applications – 4, Training – 4 | 47 | 885.00 |
| 2 | Multi-Level Drone Docking Station and Mobile Ground Station Components | As reqd. | 360.00 |
| 3 | Cameras, Gimbles, Sensors, and Associate systems | As reqd. | 626.00 |
| 4 | Command control station, Vbox, Instrumented Vehicle, Agisoft Metashape, Driver physiological monitoring devices | As reqd. | 72.00 |
| 5 | 5G Testbed (Vehicular communication) | 3 | 330.00 |
| 6 | Wind tunnel and wind guest generation components | As reqd. | 420.00 |
| 7 | Radio Frequency Generator and Analyzer with Anechoic Chamber Facility | 1 | 400.00 |
| 8 | Power generators and supplies, multi material and Industrial composite color 3D printers, cutting and moulding machines, vacuum bag, CNC milling machine and tools (soft materials-aluminium), laser cutting, storage and transportation of drones, temperature-controlled UV sanitized box components, automatic PCB prototype machine, net facility for drone testing (steel pipes and nylon net), hardware spares, other mechanical and electrical equipment, etc. | As reqd. | 148.00 |
| 9 | Servers (for AI/ML computation), workstations, UPSs, display systems, laptops, printers, scanners, TVs, projectors, teleconferences, software, simulation and tool suites, HILS system integration, electronic design automation tools, autopilot, single board computer, microcontroller, testbed for memory forensics, write blocker and chipoff facility, vector network and spectrum analyzers, data acquisition systems, other computational and electronics equipment, etc. | As reqd. | 246.00 |
| 10 | Communication systems, routers, switches, cables, IoT devices, access points, base stations, gateways, GPU, RTK/RTX GPS, precise positioning GPS, video and data telemetries, control tower/trackers/transmitter-receiver, air module for swarm, ultrasonic anemometer, LIDAR/mmwave radar, antenna, UAV flight management unit, IMUs, accelerometers, magnetometers, gyroscopes, etc. | As reqd. | 168.00 |

### 11.3.2. Divisional Centre (Each)

| Sr. No. | Name of equipment/ facility/ testbed/ component | Quantity | Total Estimated Cost (in Lakhs, Rs.) |
|---|---|---|---|
| 1 | Drones and their components (onboard computation, EO/IR payloads, etc.): Spraying - 2, Imaging – 2, Delivery – 2, Training and R&D – 4 | 10 | 73.00 |
| 2 | Drone Docking System and Ground Station Interface Components | As reqd. | 14.00 |
| 3 | Cameras, Gimbles, Sensors, and Associate systems | As reqd. | 38.50 |
| 4 | Power generators and supplies, 3D printers, cutting and moulding machines, vacuum bag, CNC milling machine and tools, thrust stand for thrust measurement, carbon fibre composite fabrication facility, storage and transportation of drones, automatic PCB prototype machine, hardware spares, other mechanical and electrical equipment, etc. | As reqd. | 62.00 |
| 5 | Servers (for AI/ML computation), workstations, UPSs, display systems, laptops, printers, scanners, TVs, projectors, teleconferences, software, simulation and tool suites, digital oscilloscopes and probes, autopilot, single board computer, microcontroller, testbed for memory forensics, write blocker and chipoff facility, vector network analyzer, other computational and electronics equipment, etc. | As reqd. | 80.00 |
| 6 | Communication systems, routers, switches, IoT devices, access points, base stations, gateways, GPU, RTK/RTX GPS, precise positioning GPS, video and data telemetries, trackers/transmitter-receiver, LIDAR/mmwave radar, antenna, UAV flight management unit, IMUs, accelerometers, magnetometers, gyroscopes, multimeters, etc. | As reqd. | 32.50 |

### 11.3.3. District Centre (Each)

| Sr. No. | Name of equipment/ facility/ testbed/ component | Quantity | Total Estimated Cost (in Lakhs, Rs.) |
|---|---|---|---|
| 1 | Drones and their components (onboard computation, EO/IR payloads, etc.): Spraying - 1, Imaging – 1, Delivery – 1, Training and Awareness– 2 | 5 | 30.00 |
| 2 | Drone Docking System and Ground Station Interface Components | As reqd. | 7.00 |
| 3 | Cameras, Gimbles, Sensors, and Associate systems | As reqd. | 30.00 |
| 4 | Power generators and supplies, 3D printers, cutting and moulding machines, vacuum bag, CNC milling machine and tools, thrust stand for thrust measurement, carbon fibre composite fabrication facility, storage and transportation of drones, hardware spares, other mechanical and electrical equipment, etc. | As reqd. | 21.00 |

| Sr. No. | Name of equipment/ facility/ testbed/ component | Quantity | Total Estimated Cost (in Lakhs, Rs.) |
|---|---|---|---|
| 5 | Servers, workstations, UPSs, display systems, laptops, printers, scanners, TVs, projectors, teleconferences, software, simulation and tool suites, digital oscilloscopes and probes, autopilot, single board computer, microcontroller, vector network analyzer, other computational and electronics equipment, etc. | As reqd. | 22.00 |
| 6 | Communication systems, routers, switches, IoT devices, access points, base stations, gateways, GPU, RTK/RTX GPS, video and data telemetries, trackers/transmitter-receiver, LIDAR, antenna, UAV flight management unit, IMUs, accelerometers, magnetometers, gyroscopes, multimeters, etc. | As reqd. | 10.00 |

### 11.4. Infrastructure for Droneport at IIT Bombay

| Name of facility/ testbed/setup | Area (sq. ft.) | Estimates cost (in Rupees, Lakhs) |
|---|---|---|
| Infrastructure for Droneport including Building, Multi-level Drone Docking Systems (construction, furbishing, readying the facilities, etc.) | 27000 | 1890 |

### 11.5. Justifications for Consumables, Contingencies, and Travel

| Head | Justification |
|---|---|
| Consumables | Batteries, chargers, cables, connectors, soldering station, magnifier and accessories, motors, ESC, propellers, airframes, maintenance, software upgrades, printer cartridge, fuel, laboratory and office expenses and stationaries, books, pointers, white boards, field consumables towards data collection (small thermometers, water baths for thermal sensor calibration, pipes and other minor items), AMC, wires, mechanical handling tools/machines/components, small fixtures, fabrication material, carbon fibre sheets, metal blocks, etc. |
| Contingencies | Fabrication of drones, multi-level drone docking systems, mobile ground command and control stations. Each technology development, including new / innovative drones development, effort needs multiple drones for testing versions and demonstration of the technology as well as accounting for component failures and damages.<br>Fabrication of temperature-controlled UV box. For transport of items sensitive to temperature such as medicines, vaccines, tissues/organs. To be developed for use with drones.<br>Patent fees, unforeseen expenses, registration fees of trainings, workshops, conferences, facility and equipment utility charges, logistics, consultancy, honorarium, purchasing some equipment, infrastructure facility to conduct different activities like small and quick fabrications or experiments, overlength and colour publication charges, inviting some experts in the related research areas, etc. |
| Travel | Field testing, collecting ground-truthing points and validation, conveyance, attending meetings, trainings, workshops, seminars, conferences, etc. |

## 12. Additional Information

### 12.1. Exit Mechanism at the End of the Project Period

After completion of the project, the Headquarter centre and other participating centres will plan with the Government of Maharashtra to continue the drone activities further. The facilities and equipment to be setup under this proposed mission will also be used later after completion of the mission for future drone related activities.

### 12.2. Investigators / Contact Details of IIT Bombay, VNIT, VJTI, COEP, and Their Capabilities

#### 12.2.1. Details of the Investigators of IIT Bombay and Their Expertise

The details of the investigators of IIT Bombay and their expertise are as follows.

Table 2: Details of the Investigators of IIT Bombay and Their Expertise

| Investigator | Areas of Expertise |
|---|---|
| **Arnab Maity (PI)**<br>Associate Professor<br>Department of Aerospace Engineering, IIT Bombay, Powai, Mumbai 400076<br>Telephone: 022 2576 7136 (Office)<br>Email: arnab@aero.iitb.ac.in , arnab.maity@iitb.ac.in | • Guidance, navigation and control of aerospace vehicles<br>• UAV traffic management, geofencing, airspace separation, drone corridor<br>• Drone ecosystem, drone port and docking system<br>• Control and estimation of decentralized distributed and cyber physical systems<br>• Fault tolerant control and estimation<br>• Aerospace engine modeling and control |
| **Tom V. Mathew (Co-PI)**<br>Professor<br>Department of Civil Engineering, IIT Bombay, Powai, Mumbai 400076<br>Telephone: 022 2576 7349 (Office)<br>Email: tvm@civil.iitb.ac.in | • Traffic flow modelling and simulation<br>• Traffic signal design<br>• Driver simulation and warning system |
| **J. Adinarayana (Co-PI)**<br>Professor<br>Centre of Studies in Resources Engineering (CSRE), IIT Bombay, Powai, Mumbai 400076<br>Telephone: 022 2576 7689 (Office)<br>Email: adi@iitb.ac.in | • Precision Agriculture using multi-mode disruptive technologies/ platforms [UAVs; Remote sensing; GIS; Geographical Information, Communication and Dissemination Technologies (Geo-ICDTs); Sensor Networks; Internet of Agriculture Things (IoAgTs); Crowd-sourcing; UAVs; Plant Phenomics]<br>• Agro/Rural-Informatics in decision making |
| **A. M. Pradeep (Co-PI)**<br>Professor<br>Department of Aerospace Engineering, IIT Bombay, Powai, Mumbai 400076 | • Propeller sizing and design<br>• Advanced propulsion systems for UAVs |

| Investigator | Areas of Expertise |
|---|---|
| Telephone: 022 2576 7104 (Office)<br>Email: ampradeep@aero.iitb.ac.in | |
| **Dhwanil Shukla (Co-PI)**<br>Assistant Professor<br>Department of Aerospace Engineering, IIT Bombay, Powai, Mumbai 400076<br>Telephone: 022 2576 7119 (Office)<br>Email: dhwanil@aero.iitb.ac.in | • UAV Aerodynamics<br>• Rotary Wing Aerodynamics<br>• Experimental methods in Aerodynamics |
| **Eswar Rajasekaran (Co-PI)**<br>Assistant Professor<br>Department of Civil Engineering, IIT Bombay, Powai, Mumbai 400076<br>Telephone: 022 2576 7325 (Office)<br>Email: eswar.r@civil.iitb.ac.in | • UAV Remote Sensing<br>• Thermal Remote Sensing<br>• Modelling Evapotranspiration From RS<br>• RS Applications In Hydrology<br>• Drought Monitoring |
| **Pennan Chinnasamy (Co-PI)**<br>Associate Professor<br>Centre for Technology Alternatives for Rural Areas (CTARA), IIT Bombay, Powai, Mumbai 400076<br>Telephone: 022 2576 7297 (Office)<br>Email: p.chinnasamy@iitb.ac.in | • UAV remote sensing on water resource management<br>• Surface water and groundwater modeling<br>• Water accounting and budgeting,<br>• Remote sensing and climate change impact on water resources |
| **Parmeshwar D. Udmale (Co-PI)**<br>Assistant Professor<br>Centre for Technology Alternatives for Rural Areas (CTARA), IIT Bombay, Powai, Mumbai 400076<br>Telephone: 022 2576 7288 (Office)<br>Email: udmale@iitb.ac.in | • Drone Applications in Agriculture and Disaster Management<br>• Agriculture Water Management<br>• Hydrometeorological Extremes and Hazards in the Changing Climate<br>• Disaster Risk Assessment, and Management at the local level through a Transdisciplinary Approach<br>• Droughts, Food Security and Multi-dimensional Poverty in Rural Areas |
| **Prasanna Chaporkar (Co-PI)**<br>Professor<br>Department of Electrical Engineering, IIT Bombay, Powai, Mumbai 400076 | • Wireless Communication<br>• Communication system design and analysis<br>• Artificial intelligence and machine learning<br>• Stochastic control<br>• Probability theory and statistical analysis |

| Investigator | Areas of Expertise |
| --- | --- |
| Telephone: 022 2576 7449 (Office)<br>Email: chaporkar@ee.iitb.ac.in | |
| **Ganesh Ramakrishnan (Co-PI)**<br>Professor<br>Department of Computer Science and Engineering, IIT Bombay, Powai, Mumbai 400076<br>Telephone: 022 2576 7728 (Office)<br>Email: ganesh@cse.iitb.ac.in | • Human assisted AI/ML and its application for video surveillance analytics<br>• AI/ML in resource constrained environments and Data Efficient Machine Learning<br>• Learning with symbolic encoding of domain knowledge in ML and NLP<br>• Constrained Decoding and Post-editing for Machine translation<br>• OCR and ASR |
| **Arnab Jana (Co-PI)**<br>Associate Professor<br>Centre for Urban Science and Engineering, IIT Bombay, Powai, Mumbai 400076<br>Telephone: 022 2576 9331 (Office)<br>Email: arnab.jana@iitb.ac.in | • Sustainable urban infrastructure planning<br>• Urban informatics<br>• Behaviour and choice modelling<br>• Building Sciences |
| **Jayadipta Ghosh (Co-PI)**<br>Associate Professor<br>Department of Civil Engineering, IIT Bombay, Powai, Mumbai 400076<br>Telephone: 022 2576 7337 (Office)<br>Email: jghosh@iitb.ac.in | • Structural Reliability and Risk Assessment<br>• Earthquake Engineering<br>• Ageing and Corrosion Deterioration Problems<br>• Seismic Fragility Analysis<br>• Bridge Engineering<br>• Machine Learning |
| **Rajbabu Velmurugan (Co-PI)**<br>Professor<br>Department of Electrical Engineering, IIT Bombay, Powai, Mumbai 400076<br>Telephone: 022 2576 7444 (Office)<br>Email: rajbabu@ee.iitb.ac.in | • Image and video processing for target tracking, abnormal activity detection, and analysis using ML techniques<br>• Audio localization using microphone arrays<br>• Edge ML algorithms for image and audio applications<br>• System design and development for DSP algorithms |
| **Anirban Guha (Co-PI)**<br>Professor<br>Department of Mechanical Engineering, IIT Bombay, Powai, Mumbai 400076<br>Telephone: 022 2576 7590 (Office)<br>Email: anirbanguha@iitb.ac.in | • Kinematics and robotics<br>Modeling of human locomotion : Devices for assisting human motion; Design of mechanisms : Safety devices : Remotely operated vehicles; Design of machines for the textile industry; Tensegrity mechanisms<br>• Application of artificial intelligence and machine learning in industrial problems: Structural health monitoring; Modeling of industrial processes; Image analysis |

| Investigator | Areas of Expertise |
|---|---|
| | • Simulation and design optimization of impact resistant structures: Manufacturing strength bearing members of composites (3D weaving); Explosion resistant structures and modelling of ballistic impact |
| **Gaurav S. Kasbekar (Co-PI)**<br>Associate Professor<br>Department of Electrical Engineering, IIT Bombay, Powai, Mumbai 400076<br>Telephone: 022 2576 9407 (Office)<br>Email: gskasbekar@ee.iitb.ac.in | • Modeling, design and analysis of wireless networks<br>• Communication networking and network security<br>• Game theoretic and economic aspects of spectrum allocation<br>• Cognitive radio networks<br>• Lifetime and coverage problems in wireless sensor networks<br>• Medium access control and node cardinality estimation problems in Cognitive Radio Networks and Machine-to-Machine networks<br>• Interference management in wireless cellular networks<br>• Resource allocation in millimeter Wave networks<br>• Applications of wireless sensor networks to agriculture<br>• Group key management and authentication problems in the Internet of Things<br>• Intrusion detection in wired and wireless networks<br>• Drone communications and security |
| **Raaj Ramsankaran (Co-PI)**<br>Professor<br>Department of Civil Engineering, IIT Bombay, Powai, Mumbai 400076<br>Telephone: 022 2576 7348 (Office)<br>Email: ramsankaran@civil.iitb.ac.in | • UAV applications in Cryosphere studies<br>• UAV based topographic surveying and coastal surveying<br>• UAV for Building Information Modelling (BIM) |
| **Chandra Sekher Yerramalli (Co-PI)**<br>Professor<br>Department of Aerospace Engineering, IIT Bombay, Powai, Mumbai 400076<br>Telephone: 022 2576 7125 (Office)<br>Email: chandra@aero.iitb.ac.in | • UAV structure and design<br>• Advanced composite materials<br>• Failure and damage modelling<br>• Ceramic composites |
| **Arpita Sinha (Co-PI)**<br>Professor<br>Systems and Control Engineering, IIT Bombay, Powai, Mumbai 400076 | • Motion planning of autonomous vehicles<br>• Multi-robot coordination<br>• Swarm robotics |

| Investigator | Areas of Expertise |
|---|---|
| Telephone: 022 2576 7899 (Office)<br>Email: arpita.sinha@iitb.ac.in | |
| **Shashi Ranjan Kumar (Co-PI)**<br>Associate Professor<br>Department of Aerospace Engineering, IIT Bombay, Powai, Mumbai 400076<br>Telephone: 022 2576 7108 (Office)<br>Email: srk@aero.iitb.ac.in | • Guidance and Control of Unmanned Autonomous Vehicles<br>• Cooperative Control, Collision and Obstacle Avoidance, and Path Planning of UAVs<br>• Trajectory Tracking and Following Control<br>• Cooperative Pursuit and Evasion<br>• Consensus and Formation Control of Multi-Agent Systems |
| **Krishnendu Haldar (Co-PI)**<br>Assistant Professor<br>Department of Aerospace Engineering, IIT Bombay, Powai, Mumbai 400076<br>Telephone: 022 2576 7114 (Office)<br>Email: krishnendu@aero.iitb.ac.in | • Modeling flexible structures<br>• Smart materials modeling and simulations<br>• Mechanics of solids and multi-physics coupling |
| **Nagendra R Velaga (Co-PI)**<br>Professor<br>Department of Civil Engineering, IIT Bombay, Powai, Mumbai 400076<br>Telephone: 022 2576 7341 (Office)<br>Email: n.r.velaga@iitb.ac.in | • Intelligent Transportation Systems<br>• Driver safety<br>• GIS and GNSS applications in transport<br>• Transportation accessibility and mobility<br>• Integrated and flexible transport systems<br>• Sustainable transportation and development |

Also, more collaborators may get connected and be included as per the needs of the project in the future.

### 12.2.2. Contact Details and Capabilities of VNIT, VJTI, and COEP

The contact details and some of capabilities of VNIT, VJTI, and COEP are as follows.

Table 3: Contact details and some of capabilities of VNIT, VJTI, and COEP

| Contact Details | Some of Capabilities of the Institute |
|---|---|
| **Pramod M. Padole (Contact Person)**<br>Director and Professor<br>VNIT, Nagpur 440010<br>Telephone: 0712 280 1363 / 0712 222 3969 (Office)<br>Email: director@vnit.ac.in | • Embedded system<br>• Microprocessing<br>• Motor, Battery management system<br>• Image and signal processing<br>• Robotics<br>• GIS, Remote sensing<br>• Drone applications – Traffic monitoring, structural health monitoring |

| Contact Details | Some of Capabilities of the Institute |
|---|---|
| **Faruk Kazi (Investigator)**<br>Professor<br>Department of Electrical Engineering, VJTI, Mumbai – 400019, Maharashtra<br>Telephone: 022 24198180 (Office)<br>Email: fskazi@el.vjti.ac.in | • Cyber security of drone ecosystem<br>• Drone communication<br>• IoT and AI applications to drones and anti-drones<br>• Drone manufacturing<br>• Environmental use cases<br>• Structural health monitoring |
| **Sudhir D. Agashe (Contact Person)**<br>Vice Chancellor and Professor<br>COEP Technological University, Pune 411005<br>Telephone: 020 25507001 (Office)<br>Email: vc@coeptech.ac.in | • Drone manufacturing<br>• Sensor design<br>• Navigation<br>• Embedded system,<br>• Signal and image processing,<br>• Drone based surveillance and asset mapping |

### 12.3. Existing Major Equipment, Facilities and Labs

Some of the following major equipment, facilities and labs available at IIT Bombay will be used as per requirements in this proposed mission:

| Existing Major Equipment / Lab |
|---|
| 3-axis angular motion simulator |
| Hardware-in-loop simulation (HILS), Software-in-loop simulation (SILS) |
| Flight simulator |
| Gas turbine engine |
| Autonomous Robots & Multi-robot Systems Lab |
| OPAL-RT & Protocol Emulator |
| Miniature Aerial Vehicle (MAV) Lab |
| Propulsion and Engine Lab |
| Aerospace Structure Lab |
| Aerodynamics & CFD Lab |
| Transportation Systems Engg. Labs |
| Agro-Informatics Lab |
| Rural Data Research and Analysis (RuDRA) Lab |
| Sustainable Water, Agriculture, and Rural Development (SWARD) Lab |

We have accounted the existing facilities and the upcoming facilities to be setup under RGSTC's drone project, while preparing the budget. The list of the proposed facilities and equipment in this mission does not include the existing and upcoming ones.

### 12.4. Drone Project funded by RGSTC

Rajiv Gandhi Science and Technology Commission (RGSTC), Govt. of Maharashtra has sanctioned a project on "Development of Smart Drone Ecosystem and Demonstration of Societal Applications towards Larger Drone Deployment Strategy of Maharashtra" for the funding support of Rs. 33.73 Cr. (approx.) to IIT Bombay, Mumbai, VJTI, Mumbai, and SVERI's College of Engineering, Pandharpur for the duration of 2022-27. This RGSTC funded project focuses on developing drones and allied technologies with the aim of serving mainly three societal applications (agriculture, disaster management after natural disasters, and delivery) in the rural areas of Maharashtra. The project includes development of fully autonomous secure drones and supporting ecosystem as relevant for these applications, as well as setting up of some of the drone design, testing and training facilities necessary to meet the objectives. Considering the funding support required for establishing a World-class state of art centre in Drone and Anti-Drone Technology, this RGSTC's project has provided us an initial funding support to work on drone technology.

The development of following drone and allied technologies, which is not in the scope of the RGSTC project, is unique to the proposed MDM:

- Drone ecosystem
  - Multi-level drone docking system
  - Various innovative drones, such as multiple medium drones for aerial, terrestrial, water surface, underwater, AI enabled drones
  - UAV traffic management
  - Dynamic and adaptable airspace segmentation
  - Indigenous autopilot system with multiple sensor suites and advance modes
  - Monitoring system including detection and tracking systems
  - Secure communication systems in a multi-drone system based on 5G and other related technologies
  - Cyber security system and testbed for drone ecosystem: Threat modelling of drone ecosystem, cyber security and vulnerability analysis of communication backbone, hardware trojan analysis in embedded systems used in drone, side channel attacks
  - Counter drone technology
  - Realistic adaptable and dynamic drone corridors featuring static, dynamic and adaptable geo-fence boundaries for Urban areas
- Agriculture application
  - Involvement of more partners and experiments over different crops in the MDM: In the RGSTC project, we are focussing only on three cash crops (grapes, Sugarcane and Pomegranate) available at two sites (Nashik and Pune). Whereas, in the MDM, multiple partners will be involved to develop and test algorithms over multiple crops at different climatic regions in Maharashtra which will make these algorithms more robust.
  - In the MDM, we will provide the required solutions for identification of diseases and pests, as well as irrigation supply and irrigation scheduling, which were not considered in the RGSTC funded project.
  - Testing of new technologies is limited in the RGSTC funded project. In the MDM, we are planning to use hyperspectral sensor for plant biotic and abiotic stress monitoring. Further, the proposal to use UAV based passive microwave radiometer for irrigation monitoring will be a first of a kind of study in India, as per our knowledge. UAV with Lidar too will be tested and used for the first time for operational crop monitoring purposes.

    - The major user requirement in the MDM is spraying. The algorithms developed in the RGSTC project and MDM will be modified suitably for optimizing and improving the precision of drug delivery to crops.
    - There is a potential to use ground-based robots (along with drones) to carry out precision delivery of drugs in required quantity to the crops after analysing the UAV obtained images through the developed algorithm.
    - There will be some commonalities between RGSTC and MDM in terms of algorithms (say for crop type mapping, phenology mapping and water stress detection). The outputs from RGSTC will be essential for MDM's models as it involves advanced technologies as well as multiple crops.
- Disaster management application
    - Mapping of land use land cover, multiple hazards, exposure, and damages using drones in selected pilot cases
    - Mapping the extent of drought and impacts on crops for an area of interest
    - Mapping the extent of forest fires and impacts for an area of interest
    - Feasibility and accuracy of drone applications in mapping extent, intensity of hazards, and crop damages as an alternative to crop cutting experiment (in agriculture and disaster management context) tested through multiple experiments
    - A standard set of guidelines for using drones for mapping the extent of multiple hazards and damages, feeding into hazard-specific disaster management steps to be adopted by the state
- Delivery application
    - Delivery and mobility system for urban areas
    - Delivery and mobility system for rural areas, augmented with the new technologies to be developed in the MDM such as multi-level drone docking system, multi-drone communication system based on 5G and other related technologies, UAV traffic management, dynamic and adaptable airspace segmentation, indigenous autopilot system with multiple sensor suites and advance modes, detection and tracking systems
- Various applications for other ministries / departments such as (where multiple use cases shared by these departments are given in Section 1.1)
    - Home Department
    - Water Resources Department (WRD)
    - Public Works Department (PWD)
    - Urban Development
    - Transport Department
    - Rural Development and Panchayat Raj Department

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## *Appendix A*

## Proposed Drone based Solutions for Various Use Cases / Applications

### *Application 1*

## Delivery and Mobility System using Drones

### 1. Introduction and Background

The concept of delivery using drones revolutionizes how goods and services are delivered. These unmanned aerial vehicles combine cutting-edge aerospace technology to offer a new, efficient, and sustainable solution for timely deliveries.

Traditional methods of transportation and last-mile delivery face limitations, like infrastructure constraints, traffic congestion, time consuming. In contrast, delivery using drones can provide a versatile, eco-friendly alternative. These autonomous aerial vehicles can navigate urban areas and remote locations swiftly, promising to transform the way we connect people and services. The significance of the drone delivery system becomes even more pronounced in healthcare, where the timeliness of deliveries of life saving medicine takes precedence.

This proposal outlines a plan to develop drone delivery system for various applications in healthcare, logistics, security while ensuring safety, reliability, and regulatory compliance.

### 2. State-of-Art Available Technology

Governments around the world are working to define which solutions and procedures for drones offer the best way forward. In the recent years, many organizations across globe have focused their research on creating - a legal framework conditions for a future UAV traffic management (UTM), possible Concept of Operations (CONOPS) for the use of UAVs, and even technical and operational requirements for the architecture of future UTM system, drone corridors, drone docking system. Single European Sky Air Traffic Management Research’s (SESAR’s) recent study on the growth in the number of drones predicts a European fleet of over 7 million by 2050. Of these, over 400,000 drones will be for commercial applications [1]. Most likely, businesses such as parcel services and online retailers will be the major players establishing their own drone fleets. Given the typical volumes of such businesses, it is likely that this will pose huge demands on the airspace in terms of capacity and conflict resolution. The aforementioned UTM concepts – National Aeronautics and Space Administration (NASA) UTM [2] and UTM provide infrastructure and some concepts for operating the airspace free of conflicts.

The project “Skyways”, which is led by the National University of Singapore (NUS) in cooperation with Airbus Helicopters, is aimed at deploying UAV to deliver parcels across Singapore. The concept foresees the implementation of specific aerial corridors in which small UAV would be able to fly within a predefined aerial network [3]. First flights within a pilot UTM airspace have been demonstrated in Switzerland by their national Air Navigation Service Provider (ANSP), Skyguide [4]. IIT Bombay has been working on various drone development, drone docking systems, and drone based applications, such as delivery, swarm of drones, since 2006 [5] [6] [7] [8] [9] [10] [11]. AI and Robotics Technology Park (ARTPARK), an Indian government-funded not-for-profit organization at IISc Bangalore, aims to develop an air ambulance for use in healthcare emergencies and casualty evacuation [12]. IIT Kanpur, has recently launched a technology innovation hub to find cyber security solutions for anti-drone technologies, intrusion detection system, and block-chain. The ePlane company incubated by IIT Madras is working on development of air-taxi [13]. TiHAN (Technology Innovation Hub on Autonomous Navigations) at IIT Hyderabad is focusing on developing air taxis and air ambulances [14]. Johnnette Technologies has been working on delivering advanced aerospace systems to Indian Armed Forces, and their selling product is the "JF-5" which is a heavy-lift drone capable of carrying payloads [15]. TechEagle Innovations has developed delivery drones which were used for delivery for India Post [16]. Zipline originally started delivering blood and medical products in Rwanda in 2016, and they have used delivery drones for close proximity delivery [17].

Delivery drones have evolved in the recent years, driven by advancements in various key technologies as listed below:

- *Propulsion Systems*: Modern delivery drones are equipped with propulsion systems, such as electric motors and battery technologies. These systems provide the necessary thrust for vertical takeoff and landing (VTOL) capabilities, allowing drones to operate in confined spaces and navigate challenging terrains [18].
- *Autonomy and Navigation*: The integration of sensors, GPS, and computer vision systems enables delivery drones to operate autonomously. These systems allow for precise navigation, obstacle detection, and collision avoidance during flights, ensuring safe and reliable delivery operations [19].
- *Payload Capacity*: Ongoing research and development efforts have improved the payload capacity of delivery drones. State-of-the-art models can carry a variety of payloads, from small packages to medical supplies, making them versatile for a wide range of applications [20].
- *Communication and Connectivity*: Delivery drones rely on robust communication systems to transmit data and receive commands in real-time. Low-latency communication protocols, such as 5G, ensure seamless remote piloting and monitoring, enhancing operational efficiency [21].
- *Energy Efficiency*: Energy-efficient designs, including aerodynamic optimizations and lightweight materials, are developed to extend the range and endurance of delivery drones [22].
- *Regulatory Compliance*: Advanced identification and tracking systems, along with geo-fencing technology, are being integrated to ensure safe and compliant operations within airspace [23].
- *User-Friendly Interfaces*: User-friendly interfaces and mobile apps have been developed to simplify the interaction between operators and delivery drones. These interfaces facilitate mission planning, monitoring, and data analysis [24].

In conclusion, the state-of-art in delivery drone technology is constantly evolving with improvements along all aspects described above to make delivery drones more capable, reliable, and safe.

## 3. Potential Use Cases / Applications

The use cases of interest as expressed by the Maharashtra government departments are as listed below:

- ***Medical Supplies Delivery to Remote Locations*:** Delivery drones can transport critical medical supplies, including medications and equipment, to remote or inaccessible areas, ensuring that patients in underserved regions receive timely and life-saving healthcare resources.
- ***Vaccine Distribution to Remote Areas*:** Utilizing delivery drones to distribute vaccines to remote and hard-to-reach locations enables efficient vaccination campaigns, particularly in rural or isolated communities, contributing to the global effort to control and eradicate diseases.
- ***Emergency Delivery of Anti-Snake Venom and Anti-Rabies Shots*:** Delivery drones can provide rapid response in emergencies, delivering crucial anti-snake venom and anti-rabies shots to bite victims, helping to mitigate the life-threatening effects of these venomous encounters.
- ***Express Shipping and Delivery Services*:** Businesses can offer swift and efficient express shipping and delivery services using delivery drones, ensuring customers receive their packages, documents, or goods promptly, reducing delivery times compared to traditional ground transportation.
- ***Emergency Reconnaissance*:** The drones with video camera, 2-way audio communication, and loudspeaker can be used for emergency reconnaissance.

These use cases will be targeted in the project on a priority basis.

The likely end users include:

- Public Health Department
- Home Department
- Disaster Management, Relief, and Rehabilitation Department
- Urban Development
- Rural Development and Panchayat Raj
- Agriculture Department
- Transport Department
- Service Providers

**4. Proposed Activities and Plan**

There is an increasing need for delivery of essential, medicine, healthcare, and good services, as well as human transportation in both urban and rural areas particularly unconnected area. Coupled with the emergent need for minimization of human-contact, our proposed safe-Drone Delivery and Mobility solution aims to bridge the gap between creating a deployment-base and minimizing human-contact. This proposed solution will also provide temperature-controlled and fast deliveries. Moreover, this service will ensure all packages that pass through the network are scanned past the security. The proposed solution in this project is aimed at a primary response to the impacts on emergency situation, remote, and unconnected area. In addition, the drones are usually driven by the battery power which is totally pollution free, i.e., they do not emit any form of greenhouse gases. Therefore, they do not have any negative effect towards the climate change.

The proposed technology in this project will involve knowledge from various scientific and engineering domains to develop and implement the key technologies. The proposed drone mobility and delivery system will address the challenge of effective fast, reliable, temperature- controlled, security scanned, contactless, sanitized delivery to the last-mile of the supply chain. It will improve both urban and rural mobility for delivery service, and cope up with emergency and pandemic situations. The proposed activities and technological development shall be a pioneer in achieving a mix of central and distributed drone technologies thus serve and integrate with merchants of various scales in the best way possible.

The broad activities of the proposed complete drone delivery system will be undertaken as follows.

- Delivery drone development for the stated use cases
- Multi-level drone docking system development
- Temperature-controlled UV sanitizer box development for healthcare related use cases
- Development of peripheral equipment to enable safe delivery
- Development of hack-proof communication system with effective cyber security technology to ensure secure delivery
- Flight operation using the proposed UAV traffic management (UTM) and drone corridors with virtual geo-fence boundaries, airspace segmentation and dynamic adaptation
- Obstacle and collision avoidance autopilot design for safe flight of drone
- User facing demand aggregator/tool development
- Field trails, testing, and live demonstration using real-time drone flying.

Also, the drones with video camera, 2-way audio communication, and loudspeaker will be developed for emergency reconnaissance.

This proposed drone delivery and mobility technology can be used to impact all strata of the society, hence it beautifully fits into the Maharashtra state’s priorities to enable technological advancements which can lead to economic growth, employment generation, improving standard of living and reinforce safety and security standards.

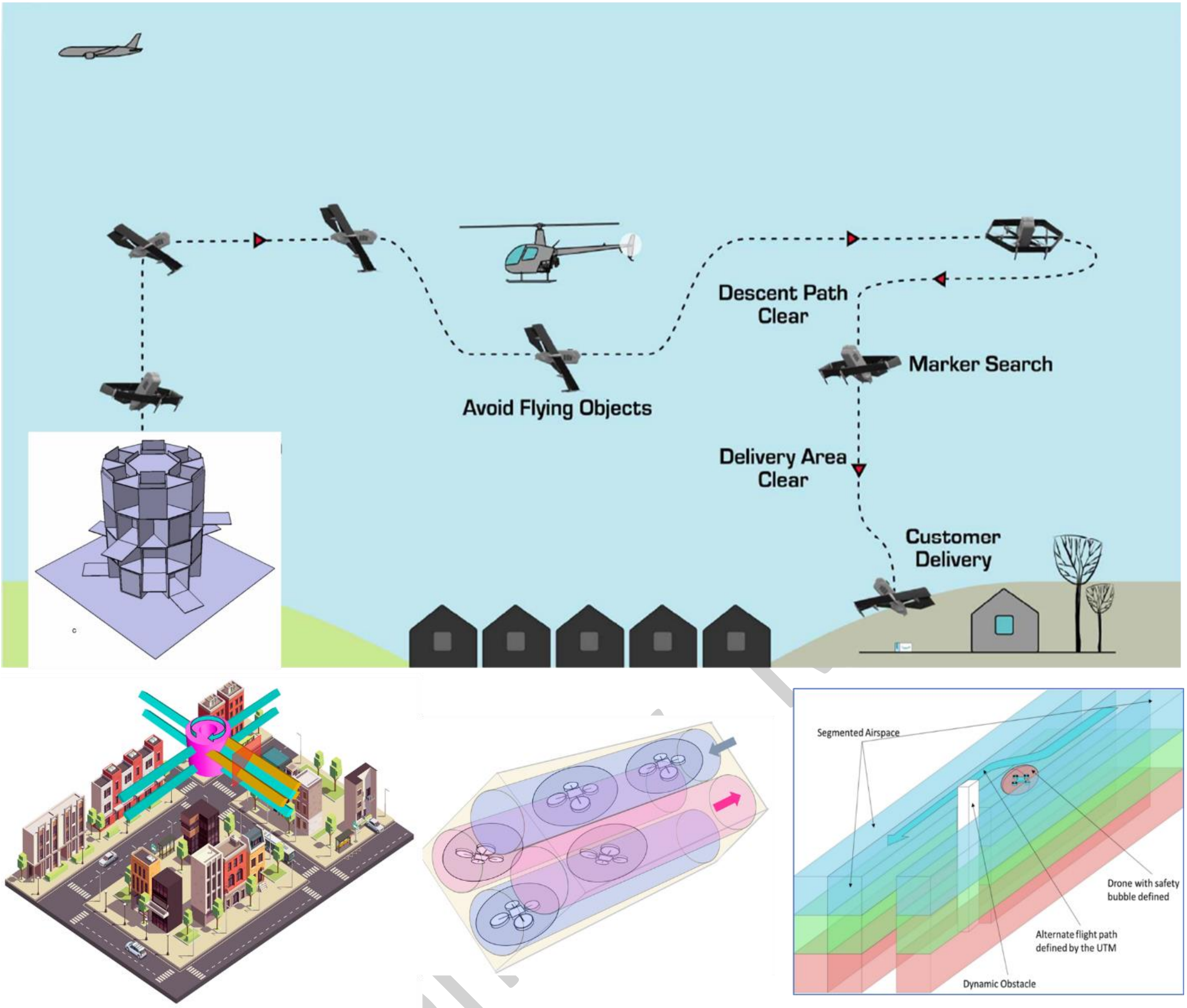


Figure 1: Drone delivery and mobility system

**Execution of Drone Delivery:**

To execute a drone delivery system, the following steps are envisaged:

1. The customer places a request for a delivery at their location through the Demand Aggregator. In the Demand aggregator, they also select the emergency-safe Drone delivery option.
2. Demand aggregator passes on the request to the Store, and the Store confirms the order along with estimated preparation time.
3. Post confirmation by the Store, the pickup time, the weight and dimensions of the package, the information of the pickup and delivery locations will be sent to the nearby homes of Drones.
4. One of the nearer homes (possibly nearest home) validates the request as well as confirms the availability of a suitable Drone and the order delivery to the customer by the Demand Aggregator.
5. The Drone home prepares the Drone (flight planning, platform selection, permissions) and notifies estimated time of arrival for pickup to the store.
6. The Package, in a temperature controlled and UV sanitized box, will be picked up by a person from the Store, who keeps it at the pickup location after mandatory sanitization and security scan.

7. The drone will fly to the pick-up location from the home location using the communication devices such as GPS, cellular network/data, Wi-Fi, camera, etc.
8. The Drone's real time updates will be shared with the Demand Aggregator which will further be displayed to the customer.
9. The drone can be integrated with unmanned traffic management (UTM), drone corridor, and virtual geo-fence boundaries.
10. It will pick-up the packet based on the digital code provided by the store and travel to the desired delivery location provided by the customer using real-time navigation, guidance and control systems based on available communication devices and camera while ensuring safety and reliability.
11. The drone will deliver the packet at the desired location, which can be identified by either a desired marker or scanning that location.
12. The Demand Aggregator is notified about the successful delivery to the customer.
13. It will travel to another location for the next pick-up, if its available power is sufficient, or return to its nearest home location.

### 5. Expected Delivery / Outcomes

The expected deliverables from this project are as follows.

- Specialized delivery drones and drones for emergency reconnaissance designed for the stated use cases
- Automated multi-level drone docking system in-tune with the drone and the use cases
- A realistic adaptable and dynamic drone passage platform with virtual geographic boundary applicable for actual flight scenarios for a variety of drones in both urban and rural setups
- Development of mission plan and flight operation several drones using UTM, and dynamic localization, intelligent path planning, and robust autopilot of UAV system
- Secure drone-to-drone/ ground station communication systems augmenting the standard communication of UAV system, and ability to use a demand aggregator/tool by drone-in the-loop
- Controlled flight tests followed by demonstrations and field trials of the entire drone delivery systems.

### 6. Yearly Milestones

- **Year 1:**
  - Autonomous point to point drone-based delivery of payload of medicines up to 1 kg up to a distance of 10 km using a multirotor drone over rural area
  - Temperature controlled box for sensitive payloads
- **Year 2:**
  - Point to point delivery using multirotor drones with autonomous docking stations to minimize human intervention
  - Drone for emergency reconnaissance
  - Demand aggregator tool for users to command autonomous drone deliveries
- **Year 3:**
  - VTOL Hybrid drone based autonomous deliveries with up to 2 kg payload capacity and 50 km range

- Point to point delivery using multirotor drones implementing realistic adaptable and dynamic drone passage platform with virtual geographic boundary applicable for actual flight scenarios

- **Year 4:**
    - Multiple autonomously coordinated delivery drone flights using UTM, and dynamic localization, intelligent path planning, and robust autopilot.
    - Multi-level autonomous drone docking station to serve the delivery drones
- **Year 5:**
    - Field trial and demonstration of the complete drone delivery and mobility system.

## 7. PERT/BAR Chart with Timeline

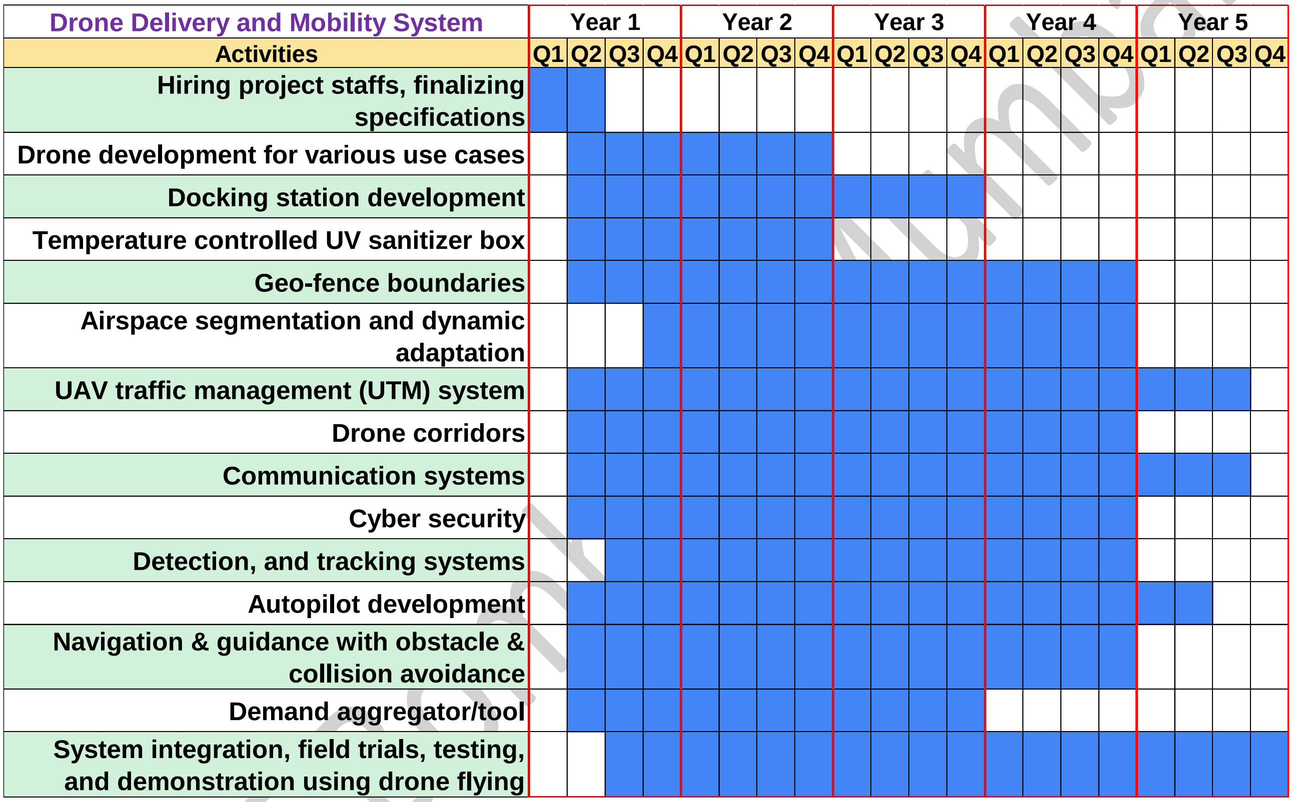


Figure 2: Timeline of a broad overview of the proposed drone mobility and delivery system

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## *Application 2*

# Human-Like Intelligent System using Drones

### 1. Introduction and Background

The current lot of unmanned platforms have the capabilities to scan the immediate environment for predefined parameters and take actions as per some predetermined algorithm. We plan to go beyond that and develop human-like capabilities in UAVs to enhance the effectiveness of each platform. This capability being developed will be platform agnostic and can be used to enhance effectiveness overall of UAVs. Some illustrations of the capabilities that we plan to develop for UAVs with their designated flying zone (or perimeter) by UAVs through AI and video analytics based intelligent surveillance of every corner of the area through the feed received from cameras, are:

- Identify difference between a boy holding a toy gun and a man holding an actual gun
- Identity difference between a terrorist holding someone as a hostage and two terrorists working together
- Identify if someone is acting suspiciously and take a call to investigate further
- Identify if someone is dead or alive and needs immediate medical help
- Track someone in a clandestine manner or spy on some terrorist secretly using a swarm framework of UAVs
- Identify that the system energy of a UAV is about to get depleted and scan a hitherto unknown area for supply and plug into a supply and charge itself automatically
- Understand if the available plug points are compatible with the connectors that are available for charging
- Understand if lifting a payload can be done individually or needs co-ordination; if it requires coordination between different UAV, identify the most efficient way to accomplish the same
- Understand if the UAV system is under attack and take evasive actions to conserve itself.

Apart from the aforementioned intelligence features, human-like intelligence using drones is also envisioned to lead to some important technologies aimed at improving the performance and safety of the platform, necessary to make the overall drone system employable in various applications, as follows:

- Perimeter monitoring using Video analytics on UAVs
- Real time object identification in resource constrained UAV settings
- Swarm UAV Technology

### 2. State-of-Art Available Technology

In today's world, platforms have evolved to an extent where we are able to deploy the systems in a variety of situations. Since the systems are incorporated with a variety of sensors, they have in effect become an extension/replacement of human personnel. However, their cognition and understanding capabilities are highly underdeveloped. And as a result, the effectiveness of the current platforms is limited to situations where there is a high level of predictability; for example, it is effective in information gathering, spraying insecticides in a predetermined pattern. However, when the environment is highly dynamic in nature, they turn into remote platforms and the user takes over and applies his cognition capabilities to that environment for that platform. Since a human is capable of taking in limited inputs, each platform in a dynamic environment will necessarily need a remote human operator. We plan to develop a revolutionary sensor processing/fusion capability along with the necessary cognition to understand all these inputs and take quick actions. Not only this, this environmental information will be shared with other platforms so that they also now are aware and will calibrate their response accordingly.

Let us understand this further by taking an example of crowd control. In current situations, the UAVs are used for remote surveillance of crowds and information gathered via these platforms is sent to personnel on the ground to effectively control a crowd. The platforms do not have the capabilities to understand if a crowd is currently peaceful or have they become violent. If they are violent then which sections are leading/encouraging this. If the platform is too close and is being attacked, it currently does not understand and defend itself. Suppose, the platforms had these capabilities, the effectiveness of the surveillance would increase multi fold. These platforms can sense unrest and quickly zoom in on the culprits causing commotion, they can immediately intimate ground personnel to take appropriate actions to stop this from spreading. They can also understand when they are being attacked and they can take evasive manoeuvres or fly up high from their reach and use zoom cameras to still keep track of the people causing commotion.

As per our knowledge, currently the proposed human-like intelligence using drones does not exist in India.

### 3. Potential Use Cases / Applications

The potential use cases include:

- *Surveillance for Law Enforcement and Border Control*: Human-like intelligent drones play a pivotal role in law enforcement and border control operations. They provide persistent and adaptive surveillance, enhancing situational awareness, and supporting security and enforcement agencies in safeguarding borders and public safety.
- *Emergency Situation Monitoring*: These advanced drones are invaluable for monitoring emergency situations, including the movement of people. They offer real-time insights, and enabling coordinated responses during emergency situations.
- *Search and Rescue in Complex Environments*: These drones are equipped to detect and locate humans and animals trapped in inaccessible areas during search and rescue missions. Their capabilities aid in identifying and reaching those in distress more effectively, potentially saving lives.
- *Inaccessible Terrain Mapping*: Human-like intelligent drones are instrumental in mapping and exploring otherwise inaccessible or challenging terrains and locations. They contribute to geographic mapping with precision, helping plan infrastructure development, environmental monitoring, and scientific research.

The likely end users include:

- Home Department
- Disaster Management, Relief, and Rehabilitation Department
- Public Works Department
- Public Health Department
- Urban Development

### 4. Proposed Activities and Plan

The project proposes to develop the capabilities of human-like intelligence (recognition, cognition, reasoning and decision making, etc.) using UAVs to exponentially enhance the capabilities of the current platforms. Through such an intervention, a drone is proposed to be equipped with the following capabilities:

- Intelligence
    - Computing and control for precision response and securing perimeters

- Computer vision and machine learning for managing high volumes with high fidelity
- Artificial Intelligence that integrates human-based domain expertise with statistical analysis of historical information to provide meaningful insights

- Integration and collaboration
  - Self-navigation, self-monitoring, and decision capability
  - Coordination and real-time feedback
  - Identification, sense, and avoid (collision and obstacle)
  - Optimized swarming capability
- Appropriate assessment of the flying zone by UAVs through AI-based video analytics solutions - intelligent surveillance of every corner of the area through the feed received from cameras will be performed. For these and other similar requirements, we will address AI/ML needs within the UAVs, through integrated data curation and compute efficient machine learning algorithms within the resource constrained environments of UAVs. For assessing larger areas within minimal time, AI enabled swarm framework of UAVs will also be developed.
- From an application point of view, innovative algorithms will be piloted and then deployed to govern periphery of a campus that is being monitored through coordinated learning of human intrusion and loitering detection models across multiple UAVs using approaches such as federated learning and meta learning. Additionally, semi-automated detection of abnormal human or vehicle activity or loitering within the periphery of the campus or within a predefined region of interest will be facilitated using UAVs.

## 5. Expected Delivery / Outcomes

The proposed human-like intelligence system using UAVs is expected to deliver:

- *Perimeter monitoring using Video analytics on UAVs*: Indigenous algorithms and software that will complement while also have the capability to be integrated with existing software and hardware setups. Further enhanced with AI & statistical analysis of historical information to provide meaningful insights to enhance safety & security processes.
- *Real time object identification in resource constrained UAV settings*: Indigenous algorithms and software for identification of obstacles and making judgement on whether they are lying in the flight path.
- *AI enabled Swarm UAV Technology*: Overcoming vulnerability of individual UAVs and evolving AI algorithms and software for swarm of UAVs. This will necessitate creating new stereo-vision algorithms for localization, obstacle detection and maneuvering around obstacles, and methods to split and merge swarms.

## 6. Yearly Milestones

- **Year 1:**
  - Computing and control for precision response and securing perimeters
  - Demonstration of basic terrain mapping application.
- **Year 2:**
  - Computer vision and ML for managing high volumes with high fidelity
  - Artificial Intelligence integrating human-based domain expertise
- **Year 3:**
  - Self-navigation, self-monitoring, and decision capability

- Coordination and real-time feedback
- AI enabled swarm framework for UAVs and its validation

- **Year 4:**
  - Identification, sense, and avoid (collision and obstacle)
  - Real time object identification in resource constrained settings
- **Year 5:**
  - Human Intrusion and loitering detection system
  - Validation and demonstration
  - Field trials for surveillance for law enforcement application.

## 7. PERT/BAR Chart with Timeline

| Human-like Intelligent System using Drones | Year 1 | | | | Year 2 | | | | Year 3 | | | | Year 4 | | | | Year 5 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Activities | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 |
| High precision UAV-based AI and ML models development for detecting human intrusion & loitering | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | | | | | | | | | | | | |
| UAV-based Human Recognition development for access control to track pathways of authorized personnel | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | | |
| UAV-based vehicle access control based on color, number etc to trigger alerts | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | | | | | | | | |
| UAV-based integrated AI systems to ingest multi-modal sensory inputs | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | | | | |
| UAVs-based AI algorithms to avoid potential collisions based on speed estimation for moving objects etc. | | | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | | | | |
| Integrated data curation and compute efficient AI/ML within UAVs' resource constrained environment | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| Design of algorithm for swarm of UAVs | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | | | | | | | | |
| Advanced flocking algorithms | | | | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | | | | |
| Incorporation of multiple sensors from multiple UAVs for object detection across various terrains | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | | | | |
| Assessing and addessing Communication aspects | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| Ability to maintain separation between UAVs to avoid collision and neighbor prediction | | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | | | | |
| Navigation & guidance with obstacle & collision avoidance | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | | | | |
| Field trials, testing, and demonstration using drone flying | | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |

Figure 1: Timeline of human-like intelligent system using drones

*Application 3*

# Drone based Structural Reliability Updating, Risk, and Resilience Measurement

## 1. Introduction and Background

Present reliability assessment of civil structure and infrastructure systems utilizes empirical models that may not be indicative of the true state of the structure in the field. This can be overcome using the data-driven approach provided by the drones. The measurement data from the drones can be utilized to predict, or even update, the fragility estimates of structural systems given the hazard occurrence.

## 2. State-of-Art Available Technology

Present state of the art relies on empirical models on multiple NDT tests that is labour intensive and costly. After the images captured by the drone can be mapped to a large pool of damage photographs, using pattern recognition the damage state of a structure can be easily recognized, and subsequently the reliability can be computed [1].

## 3. Potential Use Cases / Applications

The potential use cases include:

- To determine the present structural condition and reliability assessment of building and bridge infrastructure systems in conjunction with traditional non-destructive testing (NDT) sensing technology.
- For post-disaster reconnaissance after a hazard event to promptly estimate the remaining service life and safe load resisting capacity of the structure.

The likely end users include:

- Urban Development
- Disaster Management, Relief, and Rehabilitation Department
- Public Works Department
- Home Department

## 4. Proposed Activities and Plan

Typically, fragility functions denote conditional probabilistic statements that predict the likelihood of meeting or exceeding a damage state threshold given the hazard intensity or in-situ structural loads. Unlike traditional fragility curves that are only conditioned on the hazard, this study aims to develop and subsequently utilize multidimensional fragility models to gain maximum benefit from the data collected by the drone squadrons. The functional form of such fragility models is shown in the equation below:

$$Fragility_{DS} = P[Demand > Capacity_{DS} \mid HI, \mathbf{x}]$$

where, for a given damage state DS the likelihood of structural demand exceeding the capacity is conditioned on the intensity of hazard, as well as vector that comprise of parameters that inform structural, geometric, and material characteristics [2]. Some of these parameters can directly be inferred from the measurements by the drone squadron for better approximations of fragility using the parameterized models presented above. For post-disaster scenarios, where large structural damage datasets may be assimilated by the drones, updated fragility estimates may be estimated using techniques such as Bayesian updating for better preparedness for the next hazard event [3].

This is particularly relevant for natural hazards, such as earthquakes wherein the main shock is often followed by a series of damaging aftershocks [4].

A representative depiction is shown in Figure 1. The figure demonstrates the development of parameterized fragility functions for a given infrastructure type (bridges) under different hazard scenarios using statistical learning techniques followed by: a) data-driven fragility quantification for the intact structure, as well as b) fragility updating for subsequent prediction of damage likelihood in future events. The data available from the drones may also be utilized for computing bridge downtime as well the number of lanes that can be kept open to traffic for post-disaster recovery efforts and vehicle movement. For buildings, such data can be utilized “tagging” in a post-disaster scenario as per the ATC-20 guidelines, wherein a building is tagged “Green” (unrestricted access), “Yellow” (restricted access), or “Red” (no access) according to the severity of the observed damage. The updated fragility estimates may next be utilized to derive: a) structural vulnerability to compute expected economic losses for structural repair by the asset owner or insurer, b) annual risk estimates after convolving with regional hazard curves, and c) resilience quantification to estimate the target time to full functional recovery.

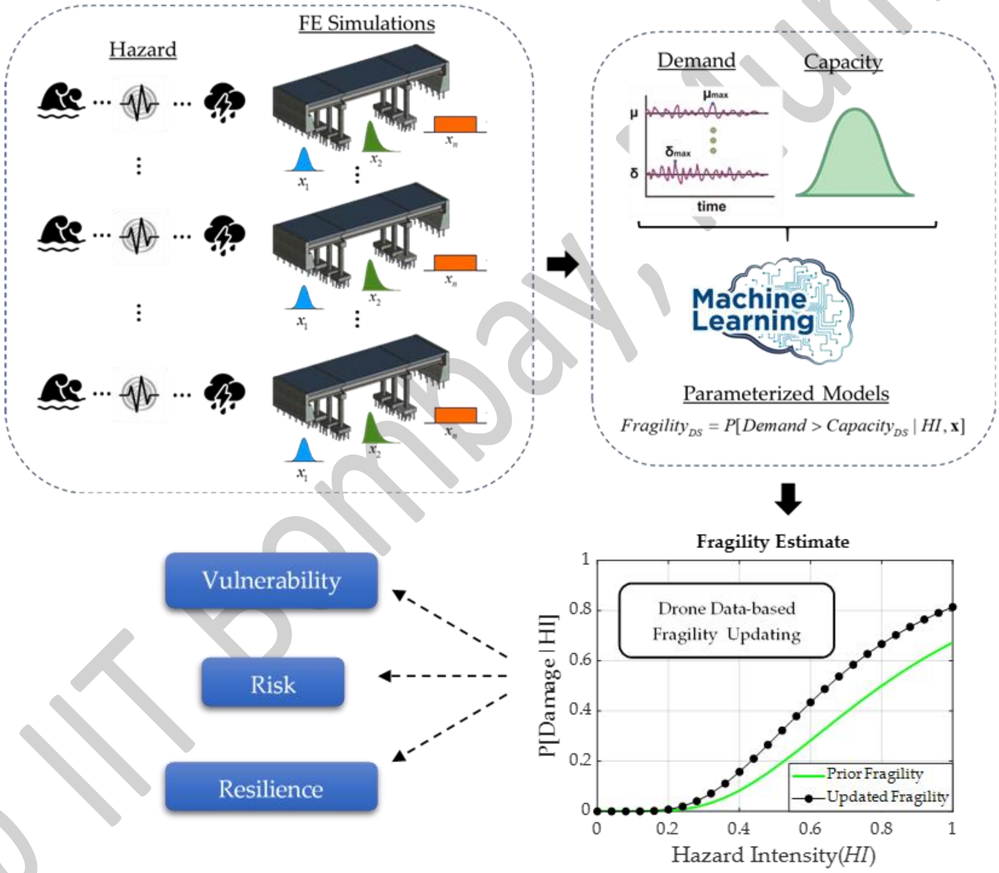


Figure 1: Representative depiction the development of parameterized fragility functions for a given infrastructure



## 5. Expected Delivery / Outcomes

- A framework for in-situ estimation for reliability assessment of structure and infrastructure systems using the data available from drone-based measurements.
- Development of high-fidelity numerical models that are capable of incorporating the measurement data from the drones.

- Lastly, this study will also develop a framework for post-disaster reconnaissance using drones, wherein the computer models will promptly update using the drone data and help estimate remaining load bearing capacity or life-expectancy

## 6. Yearly Milestones

- **Year 1:**
  - Database preparation for damage identification using image recognition
  - Demonstration of basic terrain mapping application
- **Year 2:**
  - Formulation of reliability analysis for buildings
  - Formulation of reliability analysis for bridge structures
  - Development of numerical models for structure and infrastructure systems
- **Year 3:**
  - Model validation and response assessment under different loading conditions
  - Drone deployment and data collection
- **Year 4:**
  - Reliability estimation using the collected field data after processing
  - Research dissemination
- **Year 5:**
  - Reliability estimation using the collected field data after processing

## 7. PERT/BAR Chart with Timeline

| Reliabiliy Estimation of Structure and Infrastructure Systems using Drones | Year 1 | | | | Year 2 | | | | Year 3 | | | | Year 4 | | | | Year 5 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Activities** | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 |
| **Database preparation for damage identification using image recognition** | ■ | ■ | ■ | ■ | | | | | | | | | | | | | | | | |
| **Formulation of reliability analysis for buildings** | | ■ | ■ | ■ | ■ | ■ | ■ | | | | | | | | | | | | | |
| **Formulation of reliability analysis for bridge structures** | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | | | | | | | |
| **Development of numberical models for structure and infrastructure systems** | | | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | | | | | |
| **Model validation and response assessment under different loading conditions** | | | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | | | | | |
| **Drone deployment and data collection** | | | | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | | | | | |
| **Reliability estimation using the collected field data after processing** | | | | | | | | | | | | | | | ■ | ■ | ■ | ■ | ■ | ■ |

Figure 2: Timeline of drone based structural reliability updating, risk, and resilience measurement

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*Application 4*

# Road Traffic Monitoring and Control with Road Safety System using Drones

## 1. Introduction and Background

With a growing population (human and vehicular) in urban areas, rapid urbanization and urban sprawl, the traditional methods employed for road traffic management become inadequate in monitoring traffic, inefficient in catering to the demand, and providing optimal solutions for effective road traffic movement. The existing road traffic monitoring and control system is incapable of responding to the dynamic flow of road traffic in an urban environment [1]. Another major issue with the current system is the response time in the event of a road traffic incident. Hence a growing need for dynamic road traffic monitoring and management system is urgent and pivotal [2]. To achieve this, the applicability of Unmanned Aerial Vehicles (UAV) like drones could be explored towards this project to monitor the road traffic conditions on multiple routes from a birds-eye perspective [3]. The proposed methodology defines a system of drones that automatically detects road accidents and the details regarding the accidents will be immediately reported to the concerned authorities. The proposed project will also help in developing a new methodology for evaluating road traffic flow conditions in urban areas using UAV videos

## 2. State-of-Art Available Technology

For next-generation smart cities, small UAVs (also known as drones) are vital to incorporate in airspace for advancing the transportation systems in three major domains of transportation, namely, road safety, traffic monitoring and management. Advances in computer vision algorithms to extract key features from UAV acquired videos and images can be successfully used in traffic flow analysis methods, risk assessment and assistance [4]. Hence, a drone-based system that offers a comprehensive solution to multiple traffic engineering problems needs to be developed. Barriers for wide-scale deployments, such as airspace use regulations, technological constraints (battery life, flight range etc.) need to be addressed separately.

## 3. Potential Use Cases / Applications

The potential use cases include:

- Traffic monitoring and control with road safety system
- Traffic count and study
- Traffic flow analysis - Traffic management
- Emergency response - Traffic management

The likely end users include:

- Transport Department
- Public Works Department
- Urban Development Department
- Traffic police
- Municipal corporations
- Disaster management

## 4. Proposed Activities and Plan

The establishment of a communication network with UAVs shall subsequently ensure high-resolution video data transmission between the UAVs and the central data collection station. By integrating the road maps and geographical information, the data from the central server shall be transmitted to a road traffic monitoring centre, for traffic management. Initially, the video feed from the drone data will be converted to frames and used for training the computer vision algorithm for object and road traffic infrastructure identification. The trained algorithm will later be used to identify and classify different objects on the road (two-wheelers, cars, heavy vehicles, stationary objects etc.). The number of vehicles with their class moving along various road links, junctions and inside the network shall be identified and vehicular trajectory information will be extracted for the moving objects. The trajectory data will be used to extract microscopic and macroscopic road traffic parameters such as speed, distance maintained with leading and adjacent vehicles, time spent moving and time spent stopped in a position, accelerations, lane changes, turning movements, etc. The observed and derived road traffic parameters shall be used for further analysis towards achieving the proposed objectives. The extracted information can be used to track vehicle movement in an intersection and monitor and control the road traffic in an area by identifying the congested routes, to identify suitable rerouting strategies. In hazardous driving identification, the vehicle's movement will be assessed continuously and upon repetitive or prolonged exhibition of aggressive driving resulting in a safety hazard to other road users, the information can be conveyed to road traffic authorities and enforcement agents for further action. Also, using surrogate safety aspects for a vehicle, road traffic stream or location will be analysed and the infrastructure with a high number of potential conflicts can be highlighted as a hot spot.

The objectives of this proposal include:

- To extract and validate road traffic parameters from the video data acquired from the drone system using object detection algorithms
- To develop a road traffic congestion monitoring system for urban road networks to aid municipal and road traffic enforcement agencies
- To identify vehicles exhibiting hazardous driving behaviour for the enforcement agencies for efficient and safe road traffic movement
- To identify accident hotspots on road traffic infrastructures to aid in proactive road traffic safety management

## 5. Expected Delivery / Outcomes

- Drone network with satellite/birds-eye view traffic monitoring and data acquisition.
- A transferable tool/system for active application and usage to support traffic enforcement and local governing agencies.
- Monitoring and recording high-fidelity traffic data for daily trend assessment of traffic movement, future analysis & research purposes.
- Proactive safety assessment and accident hot-spot identification on the road network.

## 6. Yearly Milestones

- **Year 1:**
  - Drone system deployment and preliminary video data acquisition and extraction.
- **Year 2:**
  - Automated extraction of the traffic parameters (count) from the video data and proof of concept of congestion monitoring.

- **Year 3:**
    - Automated extraction of the traffic parameters (speed/density) from the video data and congestion monitoring system.
    - Proof of concept of hazardous vehicles and accident hot spots.
- **Year 4:**
    - Development of system to Identify hazardous vehicles and accident hot spots.
- **Year 5:**
    - System deployment, testing, and training.

## 7. PERT/BAR Chart with Timeline

| Road Traffic Monitoring and Control with Road Safety System using Drones | Year 1 | | | | Year 2 | | | | Year 3 | | | | Year 4 | | | | Year 5 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Activities** | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 |
| **Drone network development** | ■ | ■ | ■ | ■ | | | | | | | | | | | | | | | | |
| **Video data acquisition** | | ■ | ■ | ■ | ■ | ■ | ■ | | | | | | | | | | | | | |
| **Extract and validate road traffic parameters from drone video data** | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | | | | | | | | |
| **Road traffic congestion monitoring system** | | | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | | | | | | |
| **Identify vehciles exhibiting hazardous driving behavious** | | | | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | | | | |
| **Indentify accident hotspots on road traffic infrastryctures** | | | | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | | | | |
| **Deployment, training, testing, documentation, etc.** | | | | | | | | | | | | | | | ■ | ■ | ■ | ■ | ■ | ■ |

Figure 1: Timeline of road traffic monitoring and control with road safety system using drones

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## *Application 5*

# UAV for Agriculture

## 1. Introduction and Background

Agriculture industry is the backbone of the state as it provides food security and contributes to about 12% the state's Gross Domestic Product (Economic Survey of Maharashtra 2021-22) [1]. Advanced technologies are being introduced in the sector to increase the production, reduce the damages to both the crop and the environment and to make agriculture more sustainable. Satellite remote sensing (RS) is a major technology that can aid in agricultural monitoring. However, considering the limitations with the satellite platform (such as the trade-off between spatial, spectral, and temporal resolutions, cloud cover etc.) it is not possible to image the agricultural lands at a farm level on a continuous and on-demand basis. Unmanned Aerial Vehicles (UAV, commonly drones) are smaller and agile platforms that can provide finer spatial coverage of agricultural farms with on-demand data collection capability. In addition to data collection, UAVs are also used for spraying fertilizer and pesticides over croplands. UAVs are considered as a path braking platform for data collection over croplands towards precision agriculture, and irrigation activities. Though UAVs offer value added capabilities in data collection, the technology is still at its early stages with comparatively lesser observation capabilities (described below) that require the development of customized drones with suitable sensors, compatible algorithms and standard protocols of operation.

## 2. State-of-Art Available Technology

### 2.1. Status of UAV remote sensing for agricultural mapping and monitoring

The first major difference between satellite and UAV is the limited choices in the sensors that are available. With satellites, it is possible to collect data with different type of sensors covering a large portion of the electromagnetic spectrum such as (i) Panchromatic, multispectral (cover visible, Near Infrared and shortwave infrared), hyperspectral imagers, thermal infrared sensors, active microwave synthetic aperture radar (SAR), passive microwave radiometers, lidar sensors and fluorescence sensors observing solar induced chlorophyll fluorescence (SIF). These multitude of sensors onboard satellites, provide a variety of data that are complementary to each other which enables efficient crop monitoring on a regional scale. UAVs offer ability to monitor crops at plot scale that can aid in precision agriculture activities, however with a limited suite of sensors such as (i) RGB visible images, (ii) multispectral (visible and NIR), (iii) hyperspectral (visible and NIR), (iv) Thermal infrared, (v) passive microwave radiometers and (vi) lidar sensors. Of these, only RGB and multispectral imaging technology are nearing a maturity level that can be operationally utilised for agriculture. Other sensors are still at experimental stages without standard algorithms and protocols. In addition to the limited choice of sensors, the sensors used in UAVs themselves are not sophisticated when compared with the ones in the satellites. For example, the thermal sensor in UAVs are non-calibrated, uncooled sensors with varying radiometric performance between flights. Almost all the sensors have certain changes when compared with satellite remote sensing and hence, the data collection and processing must be carried out with additional field measurements and sensor calibrations to better utilize the data from UAV platform. UAV remote sensing offers a great potential to map agricultural fields and its conditions, however, the technology is in its early stages with a need for R&D and standardization.

### 2.2. Status of UAV remote sensing for spraying fertilizers and pesticides

UAVs are now widely used for spraying fertilizers and pesticides. It is being seen as a value addition to farmers as they normally face labour shortages and get affected by the harmful chemicals being sprayed. However, this technology too is at its early stages. Right now, spraying happens in a haphazard manner. Current UAVs do not offer the necessary stability and control towards spraying due to extraneous factors. There are high chances of over- or under-delivery of the fertilizers and due to wind, these chemicals can be carried to neighbouring fields. In addition, UAVs can be used for near-precision delivery if the crop nutrition requirement or the severity of pest infestation are known in advance. Towards this, UAV remote sensing-based models and algorithms need to be developed for reliably identifying the group of crops that need supplements.

Based on literature survey, apart from spraying drones, UAV remote sensing is used at present to address issues such as:

- Crop acreage estimation
- Identification of diseases/pests
- Survey of extent and damage to crops post disasters.

As mentioned before, these surveys are caried out through image analysis of RGB and multispectral images, primarily normalized difference vegetation index (NDVI) and red-edge index. Though these technologies have sufficiently matured, still there is no standardization of procedure for operational uses. Different agencies adopt different data collection and processing procedure which hinders direct comparison of the results. Further, there is a time lag between the onset of stress event in crops and the appearance of visual clues in RGB images and change in NDVI values in multispectral data. This time lag will act as speed breaker to the application of crop protection strategies as the crop might have already undergone serious and irreversible damage leading to decrease in the yield. This is one of the reasons to use multi-sensor data for agricultural monitoring when using satellite remote sensing.

## 3. Potential Use Cases / Applications

In the Maharashtra Drone Mission, the main user requirement from the agriculture department is development and efficient usage of spraying drones. In addition to development and testing of drones and accessories for spraying, we would like to develop remote sensing-based models towards precision spraying. That is, how UAV remote sensing image analysis can aid in identifying crops that require specific inputs of fertilizers and pesticides. In addition, the UAV remote sensing can be used for:

- Crop type and acreage mapping
- Crop phenology mapping
- Mapping crop water stress, irrigation supply and irrigation scheduling
- Identification of diseases and pests
- Crop yield forecasting and above ground biomass estimation

The likely end users include:

- Agriculture Department
- Water Resources Department
- Rural Development and Panchayat Raj
- Disaster Management, Relief, and Rehabilitation Department
- Farmer organizations and farmers themselves.

## 4. Proposed Activities and Plan

### 4.1. UAV remote sensing

The MDM proposes to develop and test algorithms towards a multi-sensor, UAV based agri-monitoring protocol that can be implemented in a seamless manner. We aim to thoroughly analyse the potential and limitations of available UAV-based remote sensing sensors and further to standardize operating procedures that can guide the end users across the state to perform UAV based data collection and analysis in a similar manner.

The key components of each module and the proposed technology to be tested are listed below.

#### 4.1.1. Crop type and acreage mapping, phenological stage mapping

- Potential sensors – RGB visible, multispectral images (primarily NDVI) and lidar.
- Ancillary data to be collected – Collection and development of database containing labelled images for different crops and phenological stages.
- Data analysis strategy – Machine learning and deep learning-based image classification.

#### 4.1.2. Mapping crop water stress, irrigation supply and irrigation scheduling

- Potential sensors – Multispectral, thermal infrared and passive infrared radiometer, lidar.
- Ancillary data to be collected – Meteorological data, crop allometric measurements, root zone soil moisture and crop evapotranspiration.
- Data analysis strategy – Assimilating UAV data within a field scale hydrological model to simulate crop water use and requirements in a continuous manner.

#### 4.1.3. Identification of abiotic stresses, diseases and pests

- Potential sensors – Hyperspectral sensor.
- Ancillary data – Spectroscopic measurements of crops under different phenological stages, stress and disease conditions using a field spectroradiometer.
- Data analysis strategy – Spectral matching and machine learning.

#### 4.1.4. Crop yield forecasting and above ground biomass estimation

This module will include the output from the previous three modules (crop type and acreage estimations, crop water stress and diseases and pests).

- Potential sensors – Multispectral, thermal infrared and passive infrared radiometer, lidar
- Ancillary data – Field scale crop yield information, crop allometric measurements
- Data analysis strategy – Semi-empirical models after accounting for various crop stresses.

In addition to these, after any natural calamities leading to crop damages, a quick survey can be carried out using the developed algorithms to estimate the nature, extent and severity of crop damages. This can aid in providing relief measures and claim insurance. Agri-insurance companies too can use these algorithms to plan insurance premiums and provide settle insurance claims.

### 4.2. UAV spraying

The algorithms developed will be utilized for identifying the stress in crops (either due to nutrients and infestation) and suitable drug chemical delivery as recommended by agri-experts will be attempted with drones. Initially, we will be using the UAVs available in the market to test near-precise delivery and in the second phase of the project, suitable UAVs will be developed with improved stability and control towards precision drug delivery.

## 5. Expected Delivery / Outcomes

- Crop type and acreage mapping, phenological stage mapping
- Mapping crop water stress
- Identification of abiotic stresses, diseases and pests

- Yield forecasting algorithm for identifying plants needing spraying
- Irrigation modelling and scheduling

## 6. Yearly Milestones

- **Year 1:**
  - Procurement of instruments and manpower recruitment
  - Development of algorithms for crop type and acreage mapping, phenological stage mapping.
- **Year 2:**
  - Development of spectral library using hyperspectral sensor for multiple crops.
  - Development of models for identification of abiotic stresses (nutrient stresses), diseases, and pests
- **Year 3:**
  - Passive microwave-based crop water stress detection models
- **Year 4:**
  - Yield forecasting Algorithm for identifying plants needing spraying
- **Year 5:**
  - Irrigation modelling and scheduling.

## 7. PERT/BAR Chart with Timeline

| UAV for Agricultural Applications | Year 1 | | | | Year 2 | | | | Year 3 | | | | Year 4 | | | | Year 5 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Activities** | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 |
| **Manpower recruitment and procurement** | ■ | ■ | | | | | | | | | | | | | | | | | | |
| **Deployment of sensors in field** | ■ | ■ | ■ | ■ | | | | | | | | | | | | | | | | |
| **Crop type and phenology mapping** | | | ■ | ■ | ■ | ■ | ■ | ■ | | | | | | | | | | | | |
| **Spectral library development from field** | | | ■ | ■ | ■ | ■ | ■ | ■ | | | | | | | | | | | | |
| **Crop disease and pests mapping** | | | | | | | ■ | ■ | ■ | ■ | ■ | ■ | | | | | | | | |
| **Crop nutrient stress mapping** | | | | | | | ■ | ■ | ■ | ■ | ■ | ■ | | | | | | | | |
| **Crop water use mapping** | | | | | | | | | | | ■ | ■ | ■ | ■ | | | | | | |
| **Drone based spraying** | | | | | | | | | | | ■ | ■ | ■ | ■ | | | | | | |
| **Spatial disaggregation algorithms** | | | | | | | | | | | | | ■ | ■ | | | | | | |
| **Irrigation mapping and scheduling model** | | | | | | | | | | | | | ■ | ■ | ■ | ■ | ■ | ■ | | |
| **Crop yield forecasting and biomass** | | | | | | | | | | | | | | | | | | ■ | ■ | ■ |
| **Reports/manuscripts** | | | | | | | | | | | | | | | | | | | | ■ |

Figure 1:Timeline of UAV for agriculture applications

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## *Application 6*

# Drone Applications for Disaster Management – Mapping Hydro-Meteorological & Climatological Hazards and Impacts

## 1. Introduction and Background

Disaster is a serious disruption in the normal functioning of society due to exposure to natural hazards such as earthquakes, tsunamis, storms, heavy rainfall, floods, landslides, droughts, extreme temperatures, and forest fires. Such natural hazards turn into disasters and can lead to various social, economic, and environmental impacts like loss of human life and injuries, loss of livestock, and damage to infrastructure, and the environment. The extent and intensity of impacts could amplify if such hazards happen in an area simultaneously (multi-hazards) or after one event is accelerated by another (cascading hazards). Although the risk of such natural hazard-related disasters cannot be completely eliminated, effective disaster management can minimize the loss and damages. According to IPCC, define disaster management as *"Processes for designing, implementing, and evaluating strategies, policies, and measures to improve the understanding of disaster risk, foster disaster risk reduction, and transfer, and promote continuous improvement in disaster preparedness, response, and recovery practices, with the explicit purpose of increasing human security, well-being, quality of life, and sustainable development"* [1]. The integration of Remote Sensing, GIS, drone technology, and machine learning has significantly enhanced the collection of spatially and temporally precise data, enabling evidence-based decision-making in disaster management with exceptional accuracy. The following section describes in brief about present state of the art of potential drone applications in disaster management (mainly with respect to, floods, drought, landslides, and forest fires).

## 2. State-of-Art Available Technology

Drone applications in disaster management could support activities from preparing for disasters to emergency response during the disaster and post-disaster management phases, such as damage assessment and relief distribution. For example, the high accuracy of the drone image-based digital elevation model (DEM) could be used to identify the low-lying areas feeding into a hydrological model to simulate a scenario-based flood inundation map in an area of interest. Similarly, land use and land cover can be mapped accurately to superpose flood inundation maps to identify residential areas with high exposure and potential damage from a flood hazard. During a disaster, drones can be used for real-time mapping of the area inundated to design evacuation and justify prioritization of evacuation activities. After the catastrophe recedes, drone images can be used to assess the damage to residential areas, infrastructure, and environment and decide better strategies to build back.

Similarly, drone applications can be instrumental in efficiently managing other disasters, such as landslides, droughts, forest fires, etc., minimizing the losses and damages. In India, applications of drone technology in the disaster management field in existing literature have evolved in recent years. To list a few, various studies have used RGB, multispectral, hyperspectral, and thermal imagery to assess the extent and damage of different hazards. Vishnu et al. [2] explored the use of drones for mapping flood extent and evaluating the damage in the context of the devastating floods that occurred in Kerala, India, in 2018; Prabhakar et al. [3] used multispectral image data to estimate hailstorm damage to major crops; Chandel et al. [4] used thermal-RGB imagery to identify water stress in crops; Gupta and Shukla [5] have used drones to map landslides and assess their impact in the hilly region of India. The drone-based image data has been proven instrumental in mapping and analyzing the different types of hazards and effects. The specific cases of drone applications with respect to existing technology, mainly for assessment of exposure and damage from various hydro-climatological and meteorological hazards, are listed below:

### 2.1. Heavy Rains and Floods

A drone equipped with high-resolution sensors can capture detailed imagery of the area exposed to unseasonal rainfall, floods, and droughts. Such images (Figure 1 and Figure 2) can be used to assess the damages in urban and residential areas, damages to infrastructure, agriculture, and sensitive ecosystems using pre- and post-disaster data. In flood-affected areas, the drone can be utilized to map, for example, [6], houses and bridges washed away or destroyed by floods mostly in flood-prone areas. Drones equipped with thermal cameras can be used to locate humans and livestock for evacuation purposes during a flood disaster.

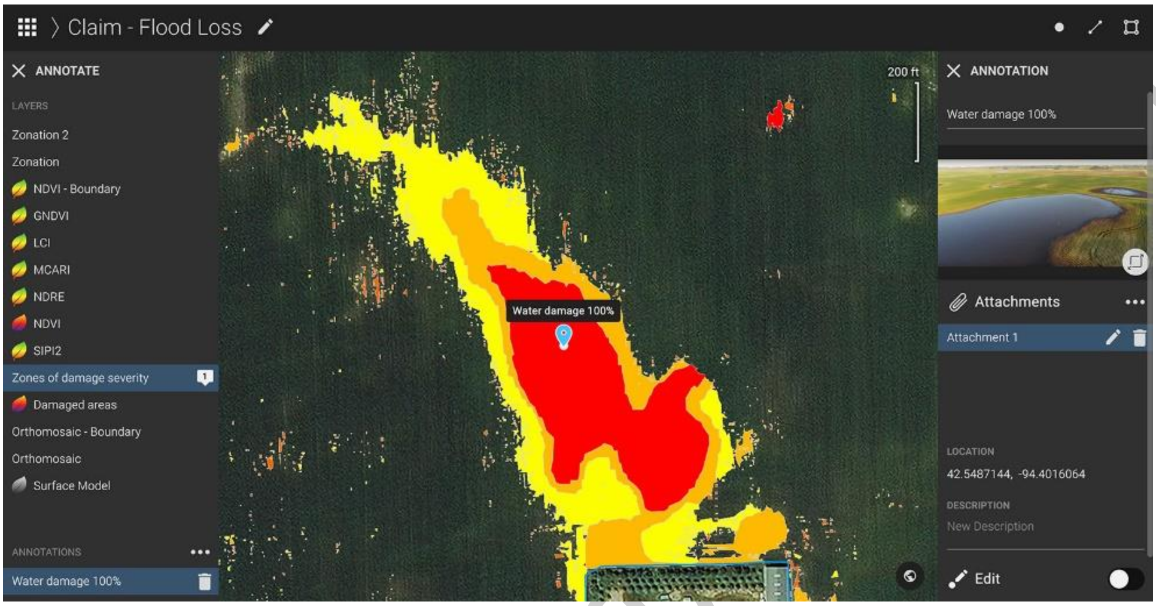


Figure 1: Drone Use cases for mapping damages from floods and droughts [7]

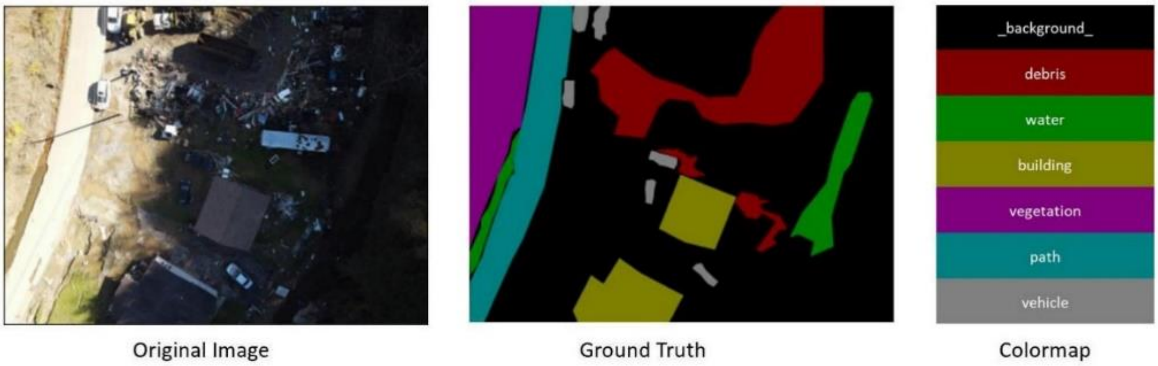


Figure 2: Original Image and Ground Truthing of Flood Damage [8]

### 2.2. Droughts

Presently, experimental plots for Crop Cutting Experiments (CCEs) are selected using stratified multistage random sampling, limited to a fixed number of farm plot areas (about 25 to 100 sq. m). However, drone imaging (Figure 3) can monitor crop acreage and estimate crop damage caused by different hazards over a more extensive/continuous area using a range of sensors. It is to be noted that the drone application will partially replace the ground-truthing CCEs and could reduce the number of experiments saving associated time and expenses. The use of drones for yield estimation as an alternative to CCE, mainly for the following purposes is proposed:

- Crop acreage monitoring

- Broad crop damage/condition assessment and paisewari estimation from hazards such as climate extremes (or pest attacks)
- Crop yield estimation to be used for crop production estimates for a particular season (based on acreage and condition assessment).

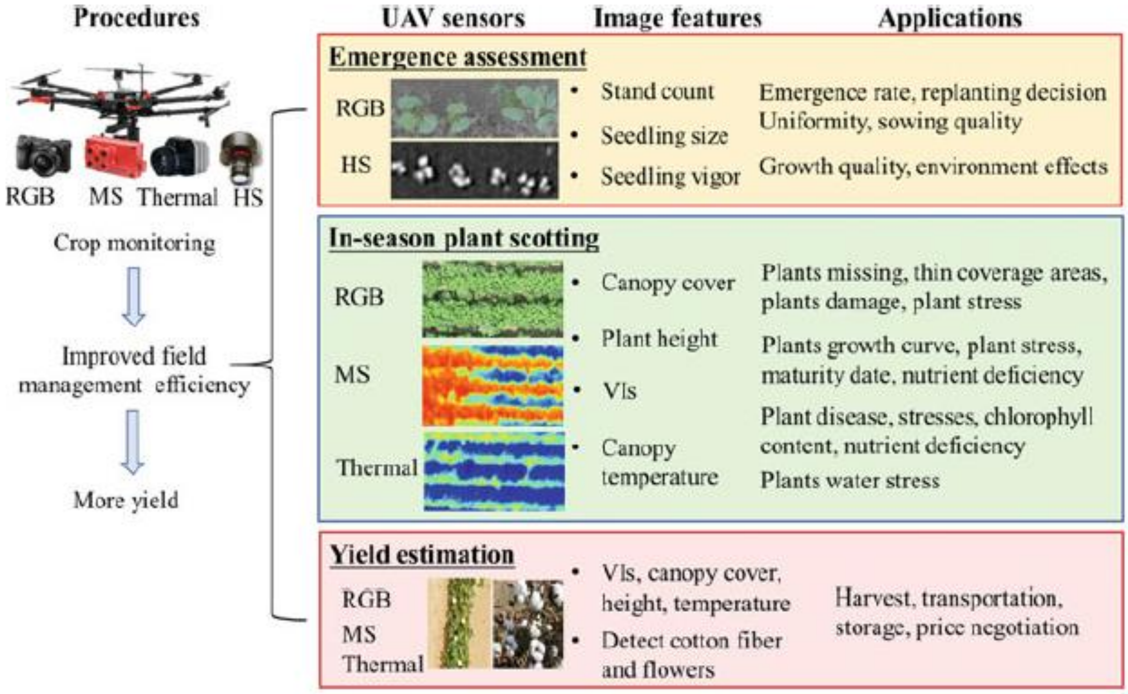


Figure 3: UAV systems for cotton monitoring from emergence, development to harvest. RGB: red–green–blue; MS: multispectral; HS: hyperspectral; VIs: vegetation indices [9]

## 2.3. Landslides

Integrated use of satellite data drone images and ground surveys can help to understand the spatial and temporal evolution of potential landslides (Figure 4) [10]. Drone-based images can be also helpful for monitoring the potential areas susceptible to landslides and the potential entities exposed in case of an adverse event, strengthening preparedness [11]. It can be efficiently used to assess the rapid damage caused by landslide disasters as in [5].

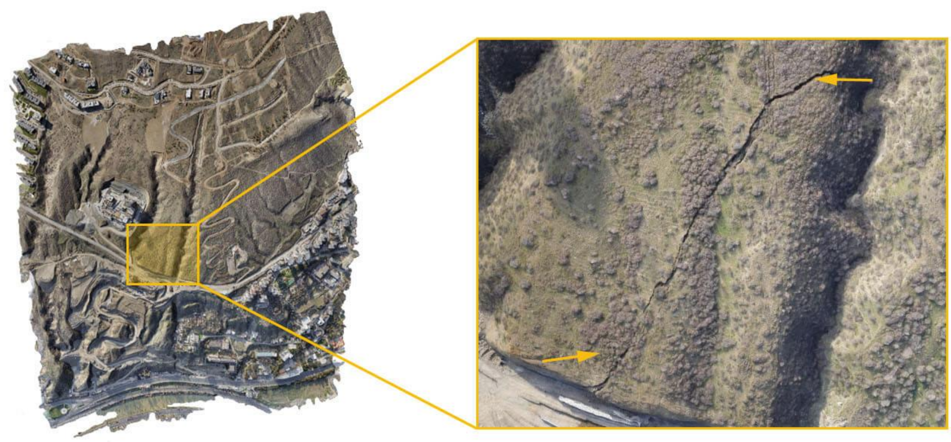

Figure 4: Aerial Imagery of Landslide [10]

### 2.4. Forest Fires

Forest fires or wildfires are often difficult to monitor over larger and remote areas and can pose significant damage in the form of economic loss to the ecosystem, and human and wildlife deaths [12]. Drones or a swarm of drones are not only helpful in mapping land, land cover, and vegetation conditions as wildfire hotspots, but also in mapping buffer zones, detecting and monitoring the extent of wildfires (Figure 5), and real-time support of forest fire fighting [12, 13, 14].

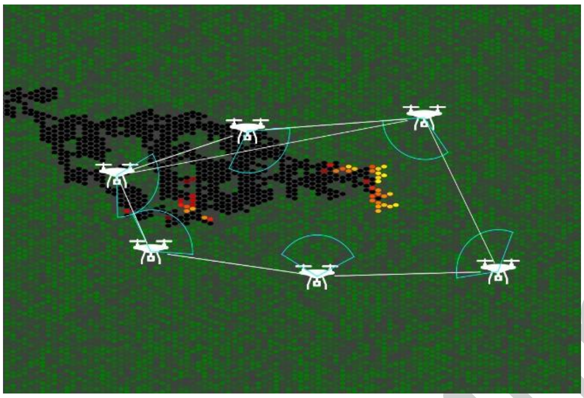

Figure 5: Using drone swarms to monitor and combat future wildfires [13]

## 3. Potential Use Cases / Applications

Table 1 provides a summary of remote sensing and GIS (mainly drone applications) for disaster management phases against selected Hydro-Meteorological Hazards, (1) Prevention, (2) Preparedness and Early Warning, (3) Response and Relief, (4) Recovery, Rehabilitation, and Reconstruction.

Table 1: Potential uses of drones for strengthening phases of the Hydro-Meteorological Hazards related Disaster Management

| **Disaster Management Phases** | **(1) Heavy Rainfall** | **(2) Floods** | **(3) Droughts** | **(4) Landslides** | **(5) Forest Fires** |
|---|---|---|---|---|---|
| **What is at stake?** | *Lives, Urban Areas, Agriculture* | *Lives, Urban Areas, Infrastructure, Agriculture* | *Lives, Agriculture, Environment* | *Lives, Infrastructure* | *Lives, Agriculture, Habitat* |
| **(A) Prevention** | - | *(A.2.1) Mapping flood-prone areas*<br>*(A.2.2) Planning and Surveillance of embankments*<br>*(A.2.3) Regulation on property development in hazard-prone areas* | *(A.3.1) Planning and monitoring watershed management activities* | *(A.4.1) Mapping landslide-prone areas*<br>*(A.4.2) Planning and Surveillance of nets and artificial walls*<br>*(A.4.3) Regulation on property development in hazard-prone areas* | *(A.5.1) Planning fireproofing activities* |

| | | | | | |
|---|---|---|---|---|---|
| **(B) Preparedness** | ***(B.1.1) Land Use Land Cover (Exposure) mapping as part of Risk Assessment*** | ***(B.2.1) Hazard mapping (DEM as input to model)***<br>***(B.2.2) Land Use Land Cover (Exposure) Mapping as part of Risk Assessment***<br>*(B.2.3) Setting up an Early Warning System* | ***(B.3.1) Land Use Land Cover (Exposure) Mapping as part of Risk Assessment*** | ***(B.4.1) Hazard mapping (DEM as input to model)***<br>***(B.4.2) Land Use Land Cover (Exposure) Mapping as part of Risk Assessment*** | ***(B.5.1) Land Use Land Cover (Exposure) Mapping as part of Risk Assessment***<br>***(B.5.2) Hazard mapping (Vegetation Condition Indices)***<br>***(B.5.3) Buffer Zone Mapping*** |
| **(C) During Disaster** | *(C.2.1) Near-real-time exposure monitoring*<br>*(C.2.2) Locating human and livestock lives affected*<br>*(C.2.3) Emergency evacuation planning* | *(C.2.1) Real-time flood and exposure monitoring*<br>*(C.2.2) Locating human and livestock lives trapped*<br>*(C.2.3) Emergency evacuation planning* | *(C.3.1) Monitoring drought conditions (Soil moisture and water levels)* | *(C.4.1) Real-time landslide and exposure monitoring*<br>*(C.4.2) Locating human and livestock lives trapped*<br>*(C.4.3) Emergency evacuation planning* | *(C.5.1) Real-time Forest fire and exposure monitoring*<br>*(C.5.2) Locating human and livestock lives trapped*<br>*(C.5.3) Emergency evacuation planning* |
| **(D) Response** | ***(D.1.1) Damage assessment***<br>*(D.1.2) Designing and prioritizing response/ relief* | ***(D.2.1) Mapping flood-inundated areas***<br>***(D.2.2) Damage assessment***<br>*(D.5.3) Designing and prioritizing response/relief* | ***(D.3.1) Mapping drought-affected areas (pilot case basis)***<br>***(D.3.2) Damage assessment***<br>*(D.3.3) Drought Declaration, designing and prioritizing response/relief (crop-specific compensations)* | *(D.4.1) Mapping landslide extent*<br>*(D.4.2) Damage assessment*<br>*(D.4.3) Designing and prioritizing response/relief* | ***(D.5.1) Mapping fire extent***<br>***(D. 5.2) Damage assessment***<br>*(D.5.3) Designing and prioritizing response/relief* |
| **(E) Recovery** | - | *(E.2.1) Designing and prioritizing relief, recovery, and rehabilitation* | *(E.3.1) Designing and planning drought-proofing measures (ponds, reservoirs)* | *(E.4.1) Designing and prioritizing relief, recovery, and rehabilitation* | *(E.5.1) Reforestation planning*<br>*(E.5.2) Rehabilitation of affected humans, livestock, and wildlife* |

Note: The activities in **<u>Bold and Underlined text</u>** will be focused on as part of the proposed research and expected deliverables/outcomes.

**Study Area:** Pilot cases from Maharashtra

The likely end users include:

- Disaster Management, Relief, and Rehabilitation Department
- Rural Development and Panchayat Raj
- Water Resources Department
- Agriculture Department
- Forest Department
- Revenue Department
- Urban Development
- Public Works Department
- Public Health Department
- National Disaster Response Force
- National Disaster Management Authority
- Municipal Corporations
- Insurance Agencies

## 4. Proposed Activities and Plan

Although there are a number of applications of drones in Hydro-Meteorological Hazards and Disaster Management as mentioned in Table 1, the present proposal focuses on drone use for mapping and specifically *formulating a methodology for the assessment of the extent of hazards and impacts during and post-disaster phases*.

## 5. Expected Delivery / Outcomes

- Finer scale mapping of land use land cover, multiple hazards, exposure, and damages using drones in selected pilot cases
- Feasibility and accuracy of drone applications in mapping extent, intensity of hazards, and crop damages as an alternative to Crop Cutting Experiment (in agriculture and disaster management context) tested through multiple experiments
- A standard set of guidelines for using drones for mapping the extent of multiple hazards and damages, feeding into hazard-specific disaster management steps to be adopted by the state.

## 6. Yearly Milestones

- **Year 1:** Mapping land use land cover using drones in an area of interest
- **Year 2:** Mapping the extent of drought and impacts on crops using drones in an area of interest
- **Year 3:** Mapping the extent of forest fires and impacts using drones in an area of interest
- **Year 4:** Mapping the extent of socioeconomic and environmental exposure to major multiple hazards in an area of interest

- **Year 5:** Module-based training programs designed for milestones of Year 1, 2, 3, and 4.

## 7. PERT/BAR Chart with Timeline

| Drone Applications in Disaster Management | Year 1 | | | | Year 2 | | | | Year 3 | | | | Year 4 | | | | Year 5 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Activities** | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 |
| **Framework development for drone applications in disaster management** | ■ | ■ | | | ■ | | | | ■ | | | | ■ | | | | | | | |
| **Mapping land use land cover using drones: Data collection and preparation, and data analysis, report** | ■ | ■ | ■ | ■ | | | | | | | | | | | | | | | | |
| **Droughts - extent and damage: Data collection and preparation, data analysis - drought mapping and damage assessment, report** | | | | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | | | | | | | | |
| **Forest fires - extent and damage: Data collection and preparation, data analysis - drought mapping and damage assessment, report** | | | | | | | | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | | | | |
| **Mapping socio-economic and environmental exposure to major multiple hazards in an area of interest** | | | | | | | | | | | | | ■ | ■ | ■ | ■ | ■ | ■ | | |
| **Disaster management: Outputs and capacity building** | | | | | | | ■ | ■ | | | ■ | ■ | | | ■ | ■ | | | ■ | ■ |

Figure 6: Timeline of a broad overview of proposed drone applications for disaster management – Mapping and assessment of impacts of hydro-meteorological and climatological hazards on major entities exposed

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*Application 7*

# UAV for Water Resources Management

## 1. Introduction and Background

The state of Maharashtra has approximately 3500 dams with varying capacities (small, large, medium, etc) and conditions (constructed, under construction and proposed). The total water storage capacity of 45 big reservoirs in the region is 4,505.36 million cubic meters (MCM). The state has 141 major dams and 3267 dams and irrigation projects in all. Of these, there are 10 major irrigation dams that supply water to the agricultural demands of the state [1] [2]. The command and catchment area of each dam is under tremendous stress due to the operational and management challenges in these dams. The operational and management challenges are aggravated due to the use of traditional systems and methods, such as physical measurements (time consuming and costly), data gaps (not all areas are monitored) and less capacity. The full potential of these dams is less used and there are many challenges on water resources management in the state such as (as per communication with WRD):

- **Irrigation water charges:** Estimation and effective mapping of agriculture area for effective water release, revenue generation and management. The Water Resources Department (WRD) uses historic data to assess water demands from irrigation dams and canals and processes payments on these terms. However, this may lead to under/overcharging and can lead to losses to the state when charted for water used by farmers for irrigation. Therefore, it is important to map the area under irrigation of the command area for each dam in Maharashtra. This will also help in more accurate revenue generation. It is expected that the area under irrigation to increase from its set figure of 18% when the real time picture is assessed. As per pilot plans, the government can use new tariffs based on irrigation area and the department can raise bills to the farmers according to the use of water.
- **Land management across the water resources:** Land Use Land Change (LULC) in the catchment and command area of irrigation projects can lead to reduced efficiency in the command area when water releases. These can be tackled if data is available for management. This will also lead to a framework for effective catchment area treatment on the upstream side of the reservoir.
- **Assessing dam breach during extremes:** Preparation of Disaster mitigation plan including inundation mapping due to floods and dam breach is necessary to effectively manage the water resources in the large reservoirs.
- **Assessment of water resources structures:** The water infrastructure needs periodic monitoring and evaluations for better managing the water. This is not possible due to outdated methods.

Most of the aforementioned problems could be tackled if data on water resources and land is available, however these data take long time to collect, is costly and need to be updated rapidly. On this note, new technologies are available to assist the state in managing the water resources, which are mentioned below.

## 2. State-of-Art Available Technology

The Water Resources Department (WRD) uses historic data to asses water demands from irrigation dams and canals and processes payments on these terms. However, this may lead to under/overcharging and can lead to losses to the state when charted for water used by farmers for irrigation. Therefore, it is important to map the area under irrigation of the command area for each dam in Maharashtra. The Maharashtra state now expects the area under irrigation to increase from its set figure of 18% real time picture is assessed. This will also help in more accurate revenue generation. As per pilot plans, the government will used new tariffs based on irrigation area, and the department will be raised bills to the farmers for use of water. They were given 15 days to raise objections, if any, but very few turned up to challenge the bills. On the other hand, when the authorities raised the bills, they realised that 15% more area than available on records, was under irrigation, and was not being paid for usage of water [3].

## 3. Potential Use Cases / Applications

In many regions, drones are used to monitor water availability and quality of water resource structures, e.g. canals, dams, check dams [4]. In addition, smaller water storage structures such s farm ponds can also be mapped and monitored from drones. Drones fitted with RGB visible, multi-spectral and thermal infrared sensors are capable of mapping water structures and aid in classifying the capacity and issues in management and maintenance of these structures [5]. In addition, after major natural calamities, it is noted that many of these water structures and supply systems are impacted, and it takes time to identify the issues and address them. With the use of drones, these issues can be identified and targeted efficiently and rapidly. Some of the available technologies include:

- **Irrigation Issues and Drone Solutions:** Irrigation problems like canal leaks, clogged channels and broken systems exist. Drones fitted with thermal sensor cameras can detect variations in ground temperature, indicating leaks. In addition, drones with multispectral sensors can identify areas where water recharge is less efficient due to clogs [6]. Addressing these issues rapidly, with use of drones will reduce losses.
- **Data driven applications:** Combined information on drone data with weather data and forecasts, soil type, and crop types can be used to create water supply schedule that reduces water waste and ensures optimal water supply [7].
- **Soil Moisture Assessment:** Even and timely water distribution is crucial for successful irrigation and charging water supply. Drones with thermal infrared and passive microwave radiometers can produce maps showing soil moisture level, and the need for irrigation and water supply. These maps can also highlight dry or wet regions within the field, enabling adjustments to irrigation plan [8].

  On this note, drones provide data for precision irrigation systems, wherein water is applied only when and where needed.

  Applications 2 and 3 have combined use with the agriculture department too as it can aid in precision irrigation and avoid wastage of water.
- **Water infrastructure Maintenance:** Drones make water infrastructure system maintenance easier. Drone based aerial views help to spot potential issues and damages rapidly and can aid in reducing logistic issues in identifying damages [9].
- **Accurate Assessment of elevations:** Elevation profiles are needed for better management of soil and sediments in the water infrastructure and in designing the gravity-based systems. RGB sensors and UAV lidar can be utilized to accurately map the topography of the terrain as they can produce comparatively higher spatial resolution than satellite based digital elevation models [10].

The likely end users include:

- Water Resources Department
- Rural Development and Panchayat Raj
- Agriculture Department
- Disaster Management, Relief, and Rehabilitation Department
- Urban Development

## 4. Proposed Activities and Plan

The MDM proposes to develop and test algorithms towards a multi-sensor, UAV based water-monitoring protocols that can be implemented in a seamless manner. We aim to thoroughly analyse the potential and limitations of available UAV-based remote sensing sensors and further to standardize operating procedures that can guide the end users across the state to perform UAV based data collection and analysis in a similar manner for Water resources conservation and management. The activities we plan to carry out under this mission are:

- Crop type and acreage mapping
- Crop phenology mapping
- Mapping crop water stress, irrigation supply and irrigation scheduling
- Crop yield forecasting and above ground biomass estimation
- Ancillary data Collection– Collection and development of database containing labelled images for different crops, acreage and phenological stages, meteorological data, root zone soil moisture and crop evapotranspiration.
- Data analysis strategy – Machine learning and deep learning-based image classification, Assimilating UAV data within a field scale hydrological model to simulate crop water use and requirements in a continuous manner.
- Mapping crop water stress, irrigation supply and irrigation scheduling
- Potential sensors – RGB visible, multispectral images (primarily NDVI), lidar, Multispectral, thermal infrared and passive infrared radiometer, lidar.

In addition to these, after any natural calamities leading to crop damages, a quick survey can be carried out using the developed algorithms to estimate the nature, extent and severity of crop damages. This can aid in providing relief measures and claim insurance. Agri-insurance companies too can use these algorithms to plan insurance premiums and provide settle insurance claims.

## 5. Expected Delivery / Outcomes

The expected deliverables from this project are as follows.

- Framework and methodology for using drones for estimating irrigation water charges. The application of the methodology will be tested for a given pilot area and comparisons made between current and drone-based water charges
- Specialized drone database and algorithm for estimating crop water requirements
- Multilevel LULC maps of pilot areas documenting catchment land management status and needs
- Drone based maps of water resource structures in the pilot areas, with reports on the assessment and status of the water resource structures
- Vulnerability assessment report of water resource structures in the pilot area
- Drone based analysis of dam breach during extremes

## 6. Yearly Milestones

- **Year 1:** Report on LULC and crop water needs
  - High resolution LULC mapping of a heterogenous agricultural land use district which gets water from the WRD department (one seasonal crop)
  - Analysis of water requirement based on the water needs per crop
  - Estimation of water released

- Comparison of water released vs water need as per drone estimates.

- **Year 2:** Report on crop yield and compensation
    - Estimation of crop yield and understanding of water demand allocation temporally versus annually (previous deliverable)
- **Year 3:** Framework report with drone feasibility case study
    - Framework with drone for Crop Compensation during climate change extreme events (e.g., Floods and droughts)
- **Year 4:** Drone based vulnerability report
    - Vulnerability assessment of Landslides on upstream of reservoirs and provide remedial action plan.
- **Year 5:** Drone based policy report
    - Formulating policies for use of Drone in Water Management, Project Planning, Construction management, project progress monitoring etc.

## 7. PERT/BAR Chart with Timeline

| UAV Application to Water Resources Management | Year 1 | | | | Year 2 | | | | Year 3 | | | | Year 4 | | | | Year 5 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Activities** | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 |
| **Hiring project staffs, finalizing specficiations** | ■ | ■ | | | | | | | | | | | | | | | | | | |
| **Finalization of study area** | | ■ | ■ | ■ | | | | | | | | | | | | | | | | |
| **Deployment of sensors in field** | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | | | | | |
| **Drone development for various use cases** | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | | | |
| **Data collection, cleaning, storage and analysis** | | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | |
| **Government and secondary data collection** | | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | |
| **Crop/LULC mapping using Drones** | | | ■ | ■ | | | ■ | ■ | | | ■ | ■ | | | ■ | ■ | | | ■ | ■ |
| **Satellite data augmentation and mapping** | | | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| **Groundtruthing data collection and validation** | | | ■ | | ■ | | ■ | | ■ | | ■ | | ■ | | ■ | | ■ | | ■ | |
| **Capacity building with WRD for drone feasibility assessment** | | | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| **Hydrologic/Crop modeling** | | | | | | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| **Reporting** | | | | ■ | | ■ | | ■ | | ■ | | ■ | | ■ | | ■ | | ■ | | ■ |
| **Policy recommendations** | | | | | | | | | | | | | | | | ■ | | ■ | | ■ |

Figure 1: Timeline of application of UAV to water resources management

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## *Application 8*

# Near-Real-Time Mapping in Urban Areas using Drones

### 1. Introduction and Background

More than half of the world's population resides in urban areas, which are responsible for over 80% of the global GDP and 70% of global carbon dioxide emissions [1]. However, as urbanization increases, urban areas face many challenges, including disasters, infrastructure deficits, and poor living conditions, particularly in slums [2].

For instance, though slum settlements can be easily distinguished by the unique built morphology, one of the many limitations of current approaches is the generalizability in different urban areas. The extracted texture and the developed rule sets may perform differently for various slums and may vary within each slum. The conventional approaches to urban planning that rely on satellite imagery may be unsuitable when large-scale, detailed mapping is required [3].

Further, in addition to high-resolution data and cost-effectiveness, drones' potential to carry diverse sensor types, opening them to a range of applications. As urban sprawl and the heat island effect threaten the energy security in urban areas, optimizing the energy consumption in cities is essential. Urban building energy models (UBEMs) offer the potential to model urban-scale energy patterns. However, the successful application of a UBEM requires near-real-time data pertaining to buildings' physical characteristics at a city- scale. The approximations and level of detail affect the reliability of prediction results [4].

Thus, the use of remote sensing coupled with machine learning techniques is essential for the accurate and efficient mapping, monitoring, and analysis of urban issues in the pursuit of sustainability and climate action. The developed methodology defines a system of using Unmanned Aerial Vehicles (UAV) like drones to overcome the existing issues associated with data acquisition and near-real-time mapping and decision-making. The methodology will aid in developing urban building databases to address climate change and identify slums and monitor their growth to enable real-time data-driven decision-making using UAV images and videos.

### 2. State-of-Art Available Technology

For next-generation smart cities, drones driven by various key sensor technologies as listed below are vital for advancing urban planning and infrastructure mapping and monitoring.

- **Synthetic Aperture Radar (SAR)**: SAR systems mounted onboard UAVs can aid in detecting and extracting building characteristics and contextual information with day/night and all-weather capability. The obtained data combined with AI has been used to estimate the height and age of buildings [5].
- **Light Detection and Ranging (LiDAR)**: LiDAR and digital surface models are widely used for creating 3D models for regions with high built-up density and mixed uses. The obtained images can also provide information related to land use, vegetation type etc [4] [6].
- **Infrared thermography (IRT)**: Thermal infrared (TIR) camera mounted on a UAV can be used to measure buildings' thermal characteristics like thermal coefficient or U- value [7].
- **RGB imagery**: Standard digital single-lens reflex camera attached to a drone can provide high-resolution RGB images which can be superimposed with thermal imagery to interpret relevant building features [8].
- **Multispectral imagery**: The imagery allows for identification and characterization of building materials.
- **Broadband and hyperspectral imagery**: The scans can be used to determine the patterns of lighting activity, lighting type of individual sources, and HVAC vent duty cycles in buildings.

## 3. Potential Use Cases / Applications

The potential use cases include:

- **Aerial Surveys and Mapping:** Drones equipped with high-resolution cameras can capture detailed aerial imagery to aid in urban planning. This information helps city planners assess land use, identify infrastructure needs, and plan for future development.
- **Mapping and GIS:** Drones can create accurate 3D maps and models of urban areas. This data is valuable for creating geographic information system (GIS) databases, which can be used for infrastructure planning.

## 4. Proposed Activities and Plan

The following activities will be undertaken on the way to the development of a complete near real-time urban drone mapping system-

- A communication network with UAVs in collaboration with partners to ensure high-resolution data transmission between the UAVs and the central data collection station
- Extracting data collected from multiple sensors mounted on drones like data related to the physical characteristics of buildings in a city.
- Training of computer algorithm for object detection- slums, built-up area, green cover and water using deep learning/ machine learning
- Developing a comprehensive framework for slum detection, which can be tailored and applied to any urban area. To monitor their growth and predict requirements for affordable housing, public transportation, and sanitation.
- To create a building energy model using microscopic and macroscopic data for selected urban areas and predict future energy pathways.

## 5. Expected Delivery / Outcomes

- City-scale dataset of the existing building stock to generate building energy models and predict future consumption patterns.
- Platform to simulate and analyse the existing building stock for cost-optimal energy-efficient retrofits and explore potential of integrating district- cooling in the future
- A transferable tool/system for slum mapping, and monitoring to local governing agencies.
- Proactive safety assessment through identification of hazard-prone settlements in a city.

## 6. Yearly Milestones

- **Year 1:** Drone network development and sensor procurement
- **Year 2:** Data acquisition and extraction
- **Year 3:** Algorithm formulation
- **Year 4:** Setting up test bed and UBEM platform
- **Year 5:** Mapping framework for other urban areas

## 7. PERT/BAR Chart with Timeline

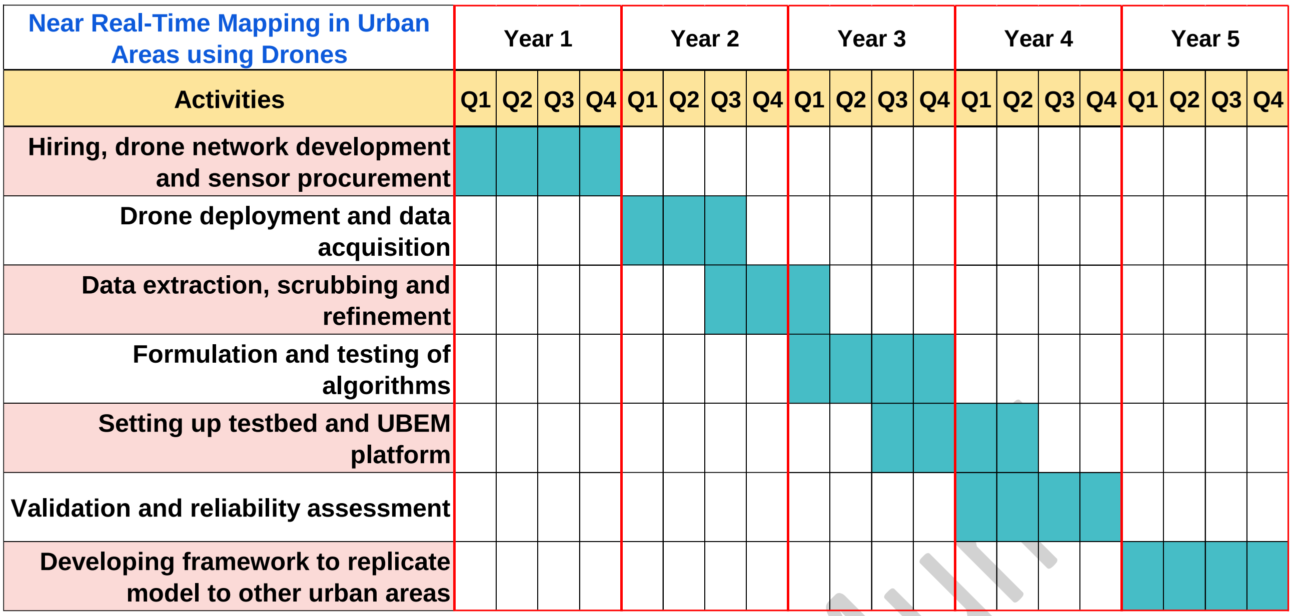


Figure 1: Timeline of near-real-time mapping in urban areas using drones

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# Mobile Command and Control Centre Enhanced with Drone Integration - Elevate and Command

## 1. Introduction and Background

With the rapid growth of unmanned aerial vehicles or drones in various industries such as aerial surveillance, disaster management, agriculture, and search and rescue, the need for an efficient and adaptable Mobile Command and Control Centre (MCCC) specifically designed for drone operations has become evident. MCCC is a specialized vehicle equipped with advanced communication and technology systems designed to serve as a mobile headquarters for emergency response, law enforcement, military, or other organizations that require rapid deployment and coordination of operations in the field. MCCC is typically used in situations, where traditional fixed command centres are impractical or unavailable.

The MCCC for drones will serve as a central hub to manage and coordinate drone operations during critical events and missions. It will enable real-time monitoring, data visualization, and communication with multiple drones simultaneously. While there are existing MCCC systems for various applications, a specialized MCCC tailored to drones will provide enhanced capabilities and flexibility in managing drone-based operations.

## 2. State-of-Art Available Technology

- Incident Command Post (ICP) Vehicles
- Emergency Operations Centre (EOC) Vehicles
- Mobile Military Command and Control Centres
- Mobile Disaster Management Centres
- Mobile Law Enforcement Command Posts
- Mobile Health Command Centres.

## 3. Current and Potential Use Cases / Applications

The potential use cases include:

- ***Enhanced Operational Efficiency*:** With the Mobile Command and Control Center, drone operators will experience improved coordination, streamlined workflows, and increased situational awareness, resulting in more efficient mission execution.
- ***Rapid Deployment*:** The mobility of MCCC solution allows for quick deployment to remote or disaster-stricken areas, enabling timely response and support during emergencies.
- ***Versatility*:** The Mobile Command and Control Center can be used to various drone models and missions, making it an adaptable solution for diverse industries and applications.

The potential end-users include:

- Emergency services and public safety
- Military and defence
- Disaster management
- Event management and public gatherings
- Industrial and energy companies
- Search and rescue (SAR) operations
- Border security

## 4. Proposed Activities and Plan

- ***Component Selection*:** Before making MCC components, the selection of various components is the primary and foremost step to cater to the challenges faced by the existing system. Based on the applications of MCC, the selection process of components will be carried out.
- ***Design of MCC*:** Once the component selection process is completed, we will start making the design of MCC to accommodate each hardware device by preparing a layout in CAD software.
- ***Development of UAVs*:** Customized UAVs will be developed to integrate with MCC equipped with a variety of payload options which include RGB, multispectral and thermal cameras, Lidar, etc.
- ***Precision Landing*:** MCC is equipped with a landing station equipped with various sensors that can be utilized to take-off and landing of drone directly on the MCC or near MCC.
- ***Field testing*:** Once all the components of MMC have been developed, then MMC will be deployed for various tests in different geographical conditions to test the actual performance of the system.
- ***Documentation*:** After the field test, proper set of documentation will be prepared which includes the SOP of the vehicle for utilization.

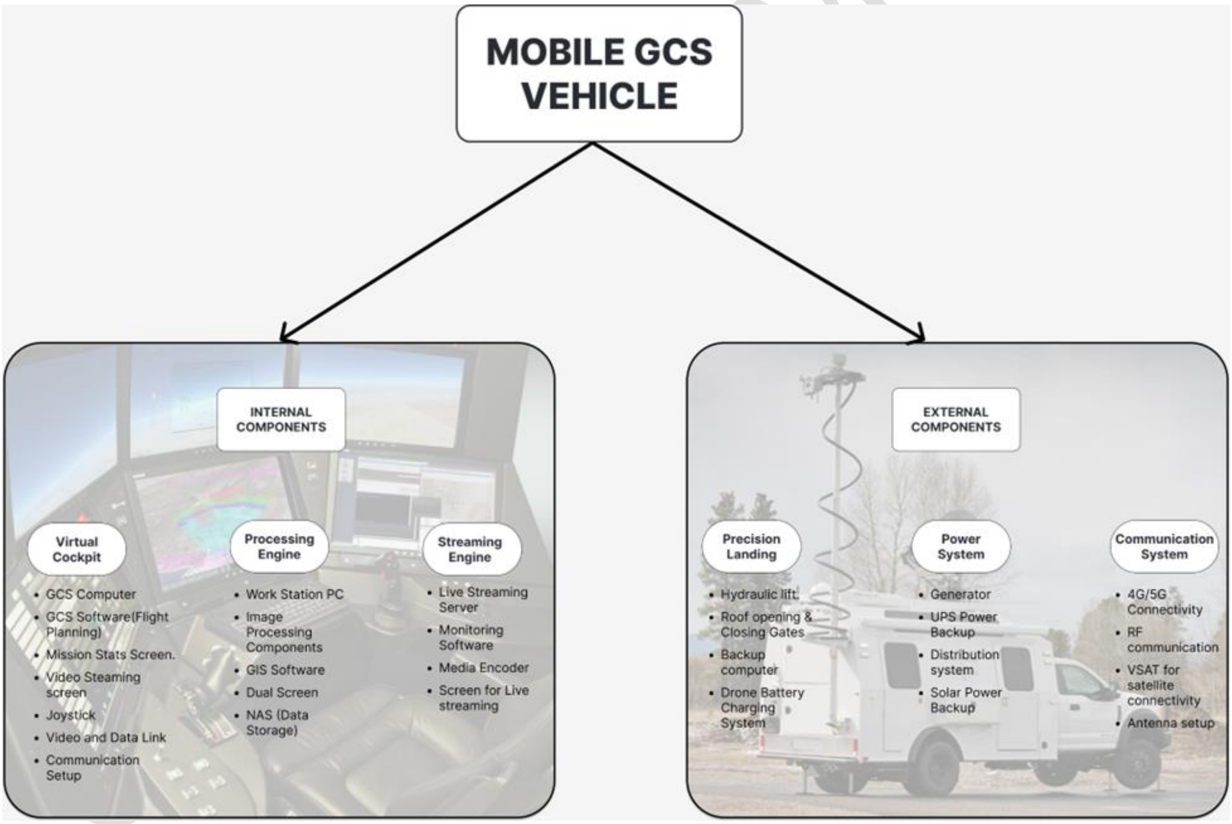


Figure 1: Components of mobile ground control station (GCS) vehicle


Figure 2: Proposed MCCC design, which is inspired by ground control station designed by DARC [1]

## 5. Expected Delivery / Outcomes

- ***Robust Communication Infrastructure***: The MCCC will be equipped with advanced communication technologies, including cellular, and radio communication, ensuring constant connectivity between the ground control team and the drones in flight.
- ***Centralized Drone Management System***: The platform will offer a user-friendly interface that allows operators to manage multiple drones simultaneously. It will include features such as real-time tracking, telemetry data display, and mission planning tools.
- ***Data Processing and Analysis***: The centre will be equipped with computing capabilities to process data collected by drones. This feature will enable on-site data analysis, providing valuable insights and supporting real-time decision-making.
- ***Secure Data Storage***: To ensure data security and confidentiality, the system will incorporate encrypted storage options to safeguard sensitive information collected during drone missions.
- ***Power and Energy Management***: The Mobile Command and Control Centre will be equipped with sustainable power solutions, such as solar panels and energy-efficient batteries, reducing the need for external power sources.

## 6. Yearly Milestones

- **Year 1:**
  - MCCC component selection
  - Specification of components
  - Design of vehicle
  - Precision landing platform design
  - Precision landing system development
  - Design and development of UAVs

- **Year 2:**
  - Development of vehicle
  - Integration of component
  - Field testing
  - Deployment of vehicle to different conditions
  - Training of manpower
  - Documentations

## 7. PERT/BAR Chart with Timeline

| Mobile Command and Control Centre | Year 1 | | | | Year 2 | | | |
|---|---|---|---|---|---|---|---|---|
| **Activities** | **Q1** | **Q2** | **Q3** | **Q4** | **Q1** | **Q2** | **Q3** | **Q4** |
| **Component selection** | ■ | | | | | | | |
| **Specification of components** | ■ | ■ | | | | | | |
| **Design of vehicle** | | ■ | ■ | | | | | |
| **Precision landing design and development** | | ■ | ■ | | | | | |
| **Design and development of UAVs** | | ■ | ■ | | | | | |
| **MCCC developement** | | | ■ | ■ | ■ | | | |
| **Integrcation of omponents** | | | | | ■ | ■ | | |
| **Field testing of MCCC** | | | | | | ■ | ■ | |
| **Deployment, training, testing** | | | | | | | ■ | ■ |
| **Documentation** | | | | | | | ■ | ■ |

Figure 3: Timeline of mobile command and control vehicle enhanced with drone integration



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*Appendix B*

# R&D Works Done by IIT Bombay

Various preliminary investigations on design and development of drones and associated systems as well as their multiple applications executed by the institutes collaborating in this proposal.

## 1. System development

Development of small UAVs with autonomous capability work was started in 2006. At that time in-house autopilot system was developed and implemented on small vehicles. Prior to this manually controlled aerial vehicles for videography and flight data acquisition were developed. Some of the pictures related to the past work is shown below in Figure 1 and Figure 2 [1] [2] [3].

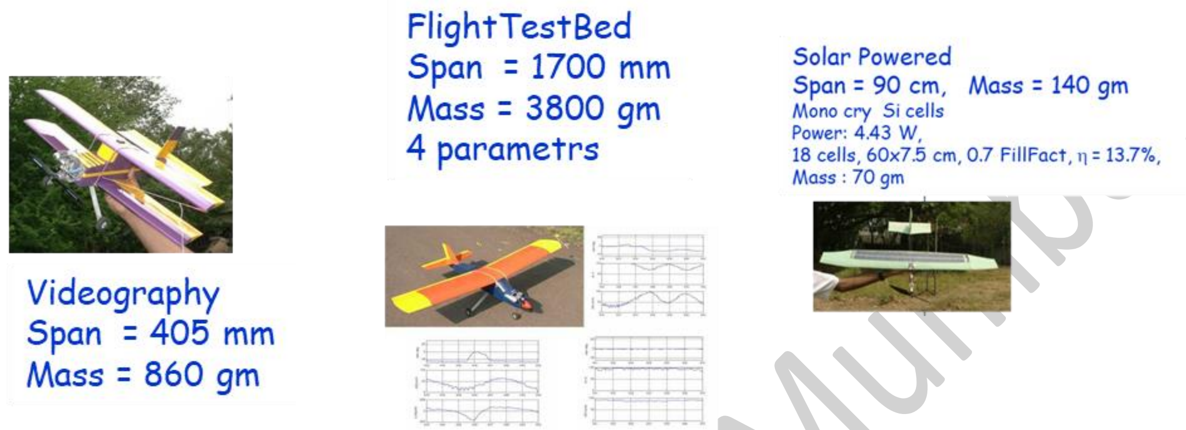



Figure 1: Manually controlled UAV – IC engine powered and solar powered

Figure 2: Autonomous electric powered UAS ~ 300 mm wing span

Later, work on fully autonomous co-operative missions was started, initial work was on demonstrating three vehicles which will form a circle in a co-ordinated fashion. Flight trajectory and vehicles used are shown in Figure 3.


Figure 3: Three vehicles collaborating to fly in circle and maintain it during the flight

Hexacopter was developed for delivery of 2 kg payload capacity at 2 km distance for 20 minutes endurance achieved in a realistic scenario. Payload delivery system with intermediate communication node for beyond visual line of sight (BVLOS) operations was performed, as shown in Figure 4.

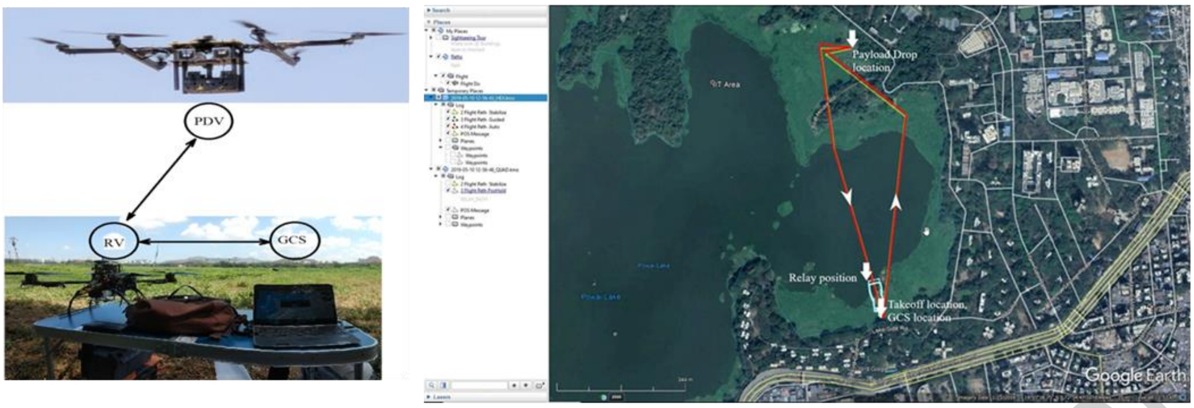



Figure 4: Payload delivery system with intermediate communication node for BVLOS operations

Recent work is towards extending the co-operative flying work for search and rescue missions. In this work there are multiple scout vehicles and a payload delivery vehicle. This work was implemented in ROS framework for integrating MAV-ROS eco system for co-operative flying. Nvidia GPU was used as companion board for ROS implementation. It was also used for detection of the target. Mission demonstrated is two scout vehicles searches a given area, once the target is identified, information is shared with the ground station. At ground station mission is planned for payload vehicle to deliver the given payload at identified target. Pictures pertaining to the system is given in Figure 5.

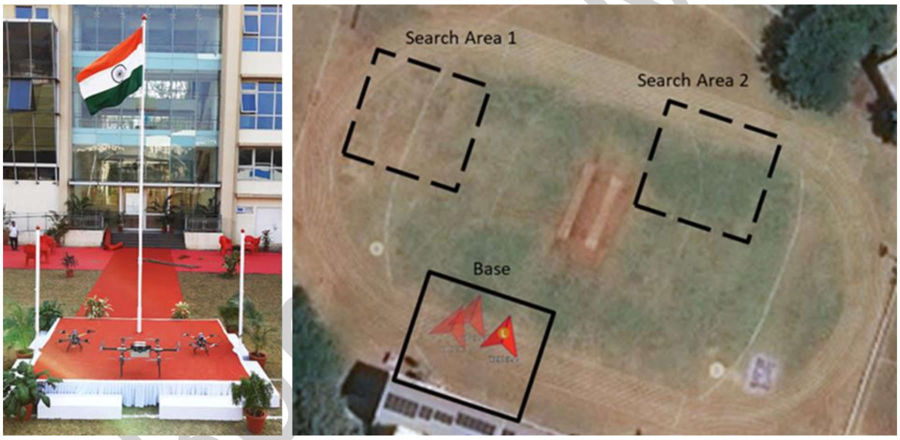



Figure 5: Scout vehicle and payload deliver vehicle (left), Mission (right)

## 2. Hardware-in-loop-simulation

At Aerospace Engineering Department, IIT Bombay, Hardware-In-Loop-Simulation (HILS) work was started in the year 2003. First HILS was developed using RT-Linux, it consisted of flight mechanics executed @ 1 msec update, GPS strings were simulated using another computer due to limitation of the computer at that time. This work was further extended to simulate two aircrafts using a single computer. Schematic of the Simulator is shown in Figure 6 [4].

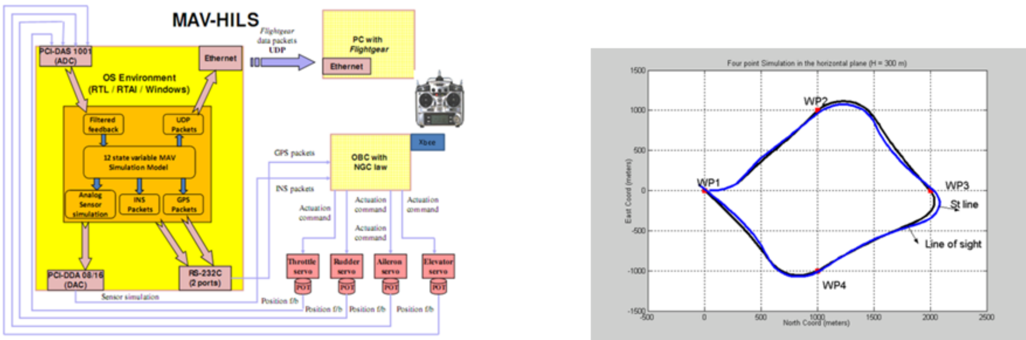



Figure 6: Two aircraft simulation using RT-Linux and waypoint navigation autonomous mission

Later there was need for including more number of aircraft in HILS to support research in co-operative missions / swarming algorithms. Four aircraft real time simulator executing on a single computer was developed based on MATLAB environment. Two of such simulators were used to simulate a mission consisting of eight aircraft. During this computation resource auditing was also studied, each flight simulation was taking close 100 micro second for one step. There was scope to include more than 4 aircraft on a single computer but it was limited by the DAQ driver support provided by MATLAB. Schematic of the HILS and simulated mission consisting of eight aircraft is shown in Figure 7 [5].

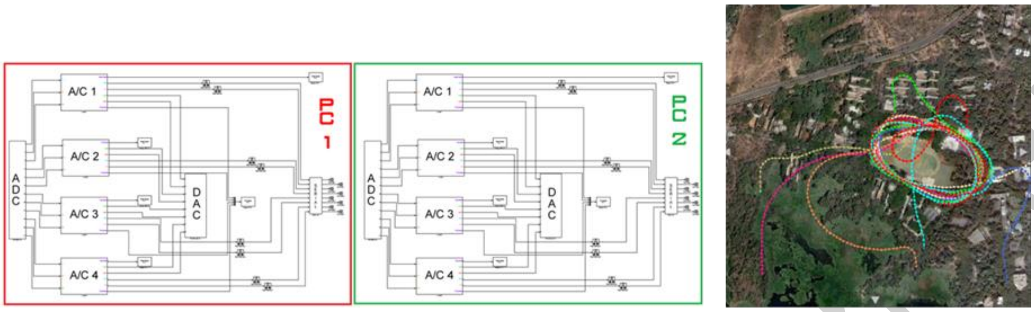



Figure 7: Eight aircraft simulation using MATLAB environment and cyclic pursuit autonomous mission

Considering the limitation of MATLAB drivers and cost involved in MATLAB procurement, low-cost HILS based on General purpose operating system (GPOS) was developed. It consisted of 16 aircraft simulation on single computer, there was spare computational power available but the DAQ hardware limitation restricted the number of aircraft to sixteen. Schematic of the GPOS based 16 aircraft HILS is shown in Figure 8 with a mission executed in the laboratory [6].

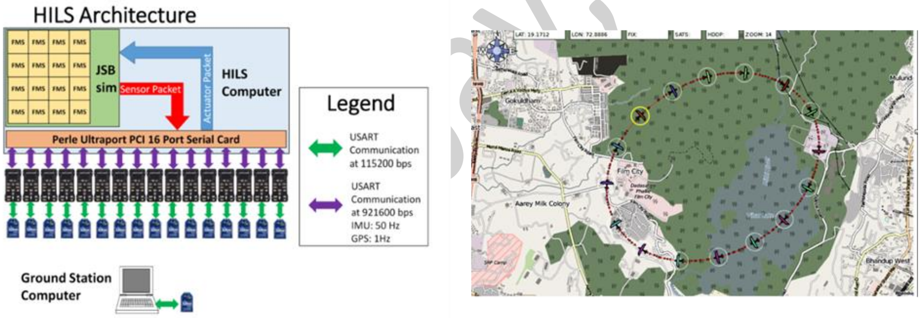



Figure 8: Sixteen aircraft simulation using GPOS environment and cyclic pursuit autonomous mission

CPU usage and simulation pacing is shown in Figure 9(a). Dual core CPU computer was used, and Figure 9(a) shows CPU usage above 100%, which is less than 200%. It may be noted that in this simulator GPOS was used and the current capabilities of GPOS can handle timing requirements quite well. Figure 9(b) shows the pacing of the simulation computation. Each line represents initiation of flight mechanics computation.

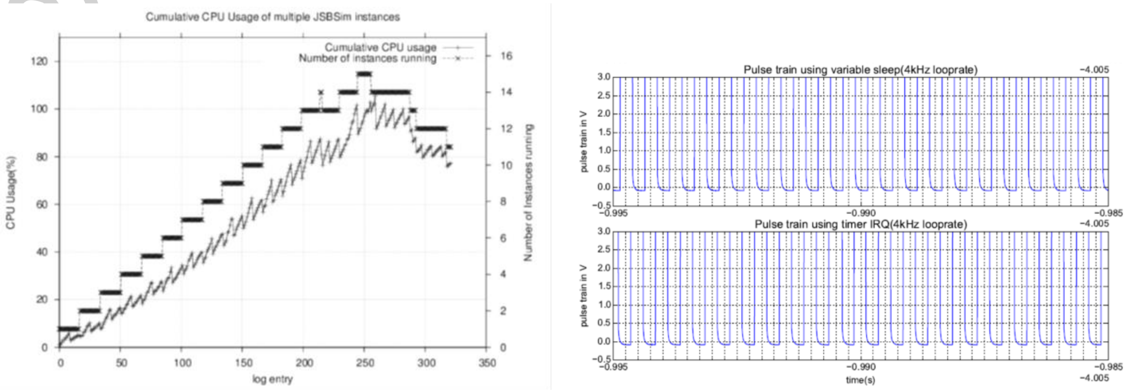



Figure 9: (a) Dual core CPU usage (b) Pacing of the simulation

## 3. Path planning for UAVs with obstacles and geofencing constraints

The availability of a swift, reliable and efficient algorithm to design the path of UAVs is very critical in overall mission planning of any task. This design utilises the concept of fluid analogy to plan smooth paths of multiple UAVs in presence of static and dynamic obstacles as well as geofencing constraints in a 3D environment, as shown in Figure 10. It has been structured around the improved and modified version of Interfered Fluid Dynamical System (IFDS). After generating the path devoid of obstacles and geofencing constraints fulfilling the given constraints, the control laws are computed to enable the UAVs to accurately track the desired paths [7].

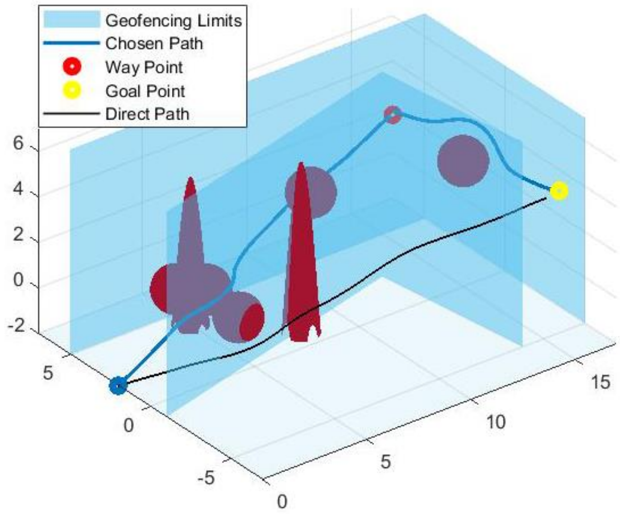



Figure 10: UAV path planning with obstacles and geofencing constraints

## 4. Swarm of drones

The objective of swarm of UAVs here, worked done at IIT Bombay, is to get a fleet of UAVs to converge to spatial configuration around a point called rendezvous point. This is achieved through finding optimal trajectories of each UAV. This swarm is designed in 3D environment laden with threats and terrain constraints. The trajectory of UAV, which is generated by the design, is tracked by local controller of UAV. Thus, UAVs organize themselves in swarm following trajectory of virtual leader and simultaneously avoiding collisions among themselves, which are shown in Figure 11. This design is tested for different patterns and initial conditions [8] [9].

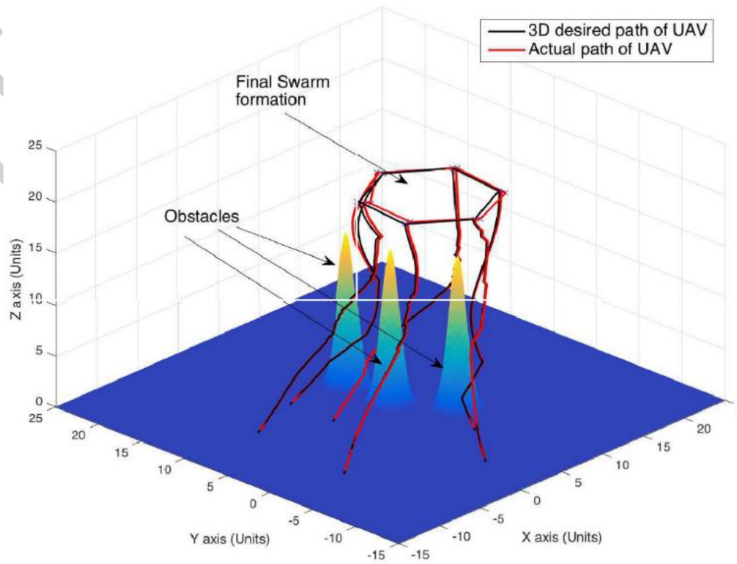



Figure 11: Swarm of drones

## 5. Safe landing of impaired aircraft

A flight of an impaired aircraft can be safely continued, if a feasible trajectory within its available envelope to be followed complies with the remaining physical capabilities of the aircraft. To address this problem, the available reduced envelope, which is a subset of the original envelope, is predicted. Then, within the predicted flight envelope, a novel feasible real-time trajectory generation for safe landing of the impaired transport aircraft can be obtained using a robust nonlinear optimal method, while considering all the practical constraints in the presence of damages and wind disturbances, as shown in Figure 12 [10]. For the flight control, nonlinear adaptive control methods can be used [11] [12] [13] [14].

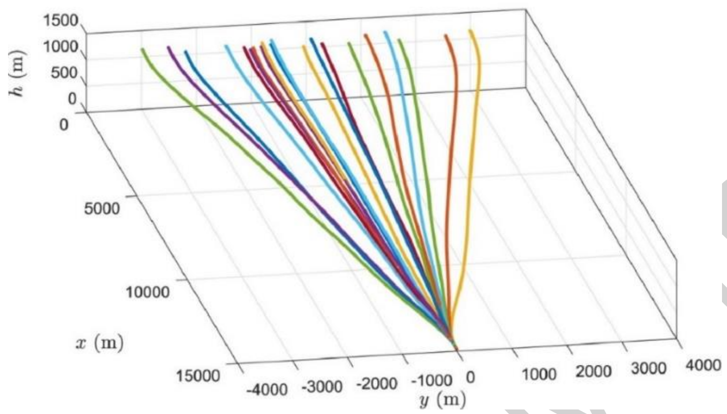



Figure 12: Impaired aircraft landing

## 6. Reconfigurable drone formation

We have proposed trajectory planning strategies for reconfiguration of a multi-agent formation on a Lissajous curve to address multiple objectives like repeated collision-free surveillance and guaranteed sensor coverage of the area with the ability for rogue target detection and trapping. The developed strategies are decentralized and hence scalable [15] [16] [17].

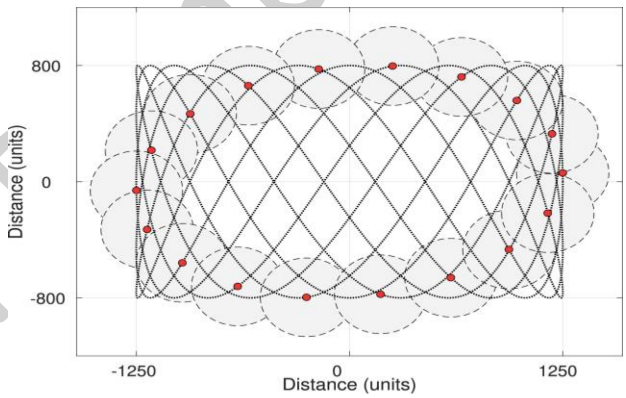



Figure 13: Reconfigurable drone formation

## 7. Convoy monitoring

This work involves tracking a convoy using a drone. The path of the convoy is not known. A novel vector field-based guidance scheme is proposed which first computes a time-varying ellipse that encompasses all the targets in the convoy and then ensures convergence of the aerial agent to a trajectory that repeatedly traverses this moving ellipse [18] [19].

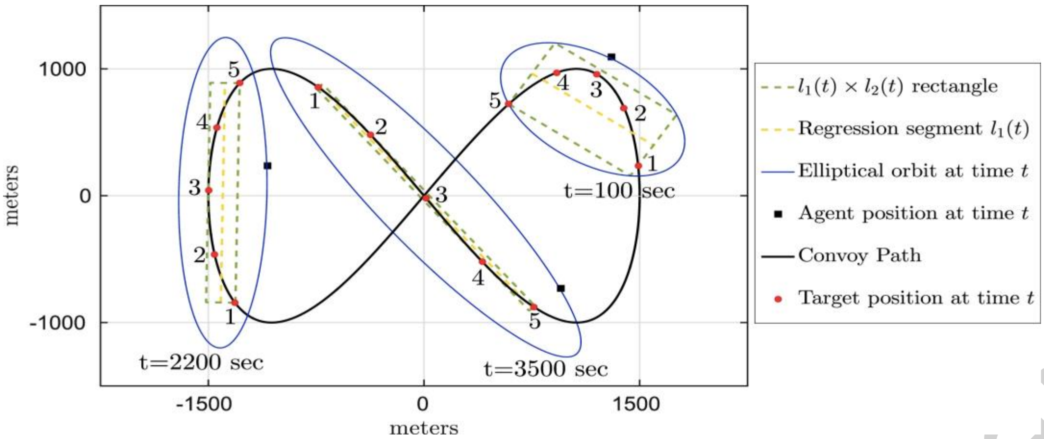



Figure 14: Convoy monitoring

## 8. Decentralized multiagent mapping

We propose a decentralized multi-robot graph exploration strategy where each robot takes an independent decision without any robot-to-robot communication. The information exchange happens through the beacons placed at the vertices. The proposed technique guarantees finite-time exploration of an unknown environment. New condition for declaring completion of exploration is proposed using a modified incidence matrix [20] [21] [22].

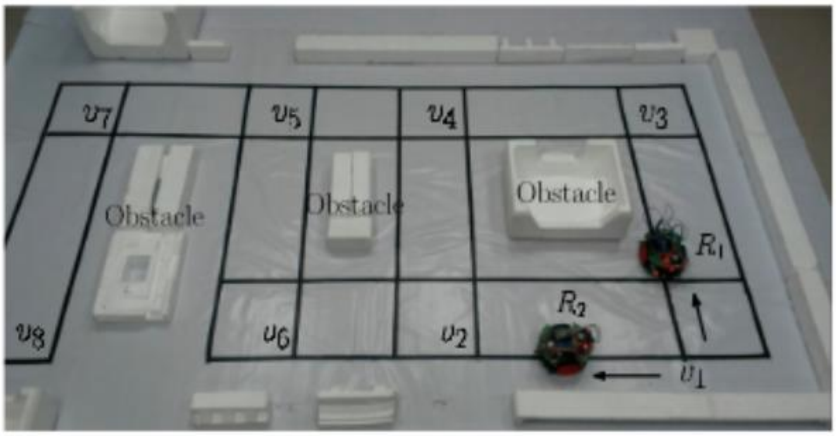



Figure 15: Decentralized multiagent mapping

## 9. Target tracking with multiple UAVs

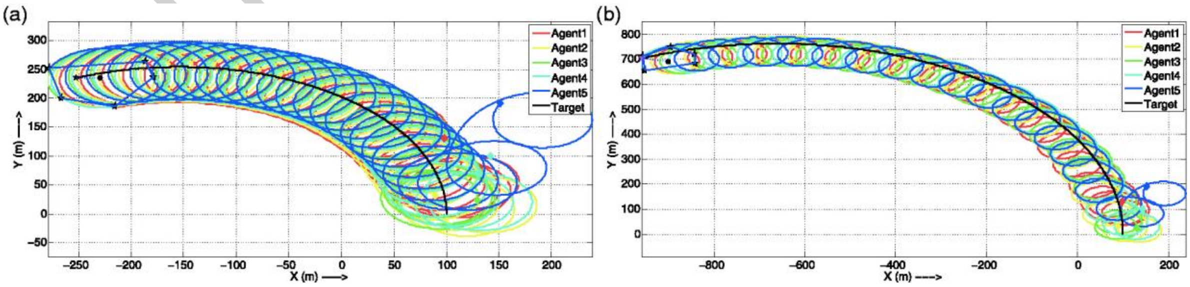



Figure 16: Target tracking with multiple UAVs

In many applications like convoy protection, multiple micro aerial vehicles need to cooperatively track a ground vehicle. The controllers have to be designed taking into account the scalability and robustness issues. However, this is not enough to have a successful operation since there can be problems in communication, sensing and actuations. Some confidence can be achieved by testing on a Hardware-in-loop simulator, which was the ultimate goal of this research [23] [24] [25] [26] [27] [28] [29] [30] [31] [32] [33] [34] [35] [36].

## 10. Span extension and inflatable wings for a morphing UAV

The shape of the wing of an aircraft can be optimized for only a specific operating condition, e.g., either take-off or cruise or dash. Changing the shape of the wing during flight to conform with the optimum shape required at any instant would allow a significant improvement in performance. The benefits need to be weighed against the additional complexity and weight which the shape changing mechanism would need. This project has identified the design parameters for the shape changing mechanism for a large range of aircrafts. Novel ideas for fabrication and deployment of these mechanisms have also been developed and demonstrated through large scale lab-based models [37].

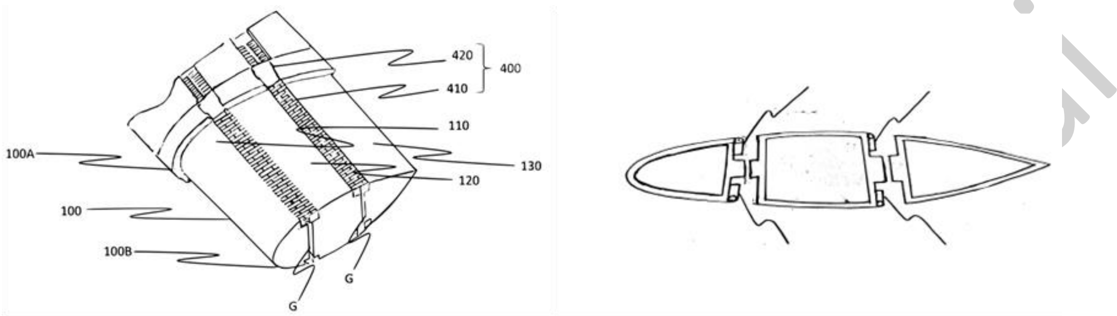



Figure 17: Span extension and inflatable wings for a morphing UAV

## 11. Applied control theory for swarm application and digital algorithm

While Swarm application considers algorithm design at a high level, the digital algorithms are designed for embedded platforms. The algorithm design, when combined with stability results from control theory, results in novel designs. This approach has been demonstrated for two applications: 1) a swarm application where multiple robots reach a destination without any communication between them and 2) hardware architecture design for a popular digital algorithm CORDIC (COordinate Rotation DIgital Computer) [38].

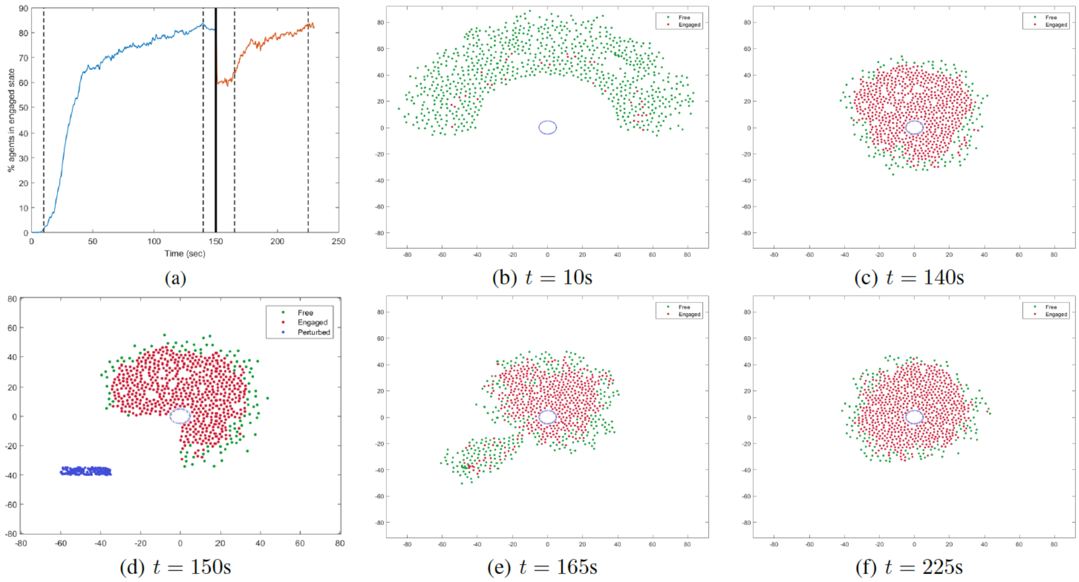



Figure 18: Applied control theory for swarm application and digital algorithm

## 12. Vision based motion planning

A novel approach in solving this problem considers coarse but accurate information extraction from images so that convergence of the robot's position at home position is guaranteed. Proposed methods are based on a probabilistic and nonlinear framework. Ensuring convergence in the presence of dynamic obstacles that corrupt the information in images and inaccuracies in actuation has been a major objective.

Figure 19: Vision based motion planning

**13. 2D nodding LIDAR for sparse data processing for simultaneous shape and velocity estimation**

In order to enhance the capabilities of commercially available 2D LIDAR, a nodding mechanism with mirror assembly is developed that registers unique pointcloud and provides reconfigurability to deal with collection of 3D sparse data. Like Simultaneous Localization and Mapping (SLAM) problem, the shape and velocity estimation of a dynamic obstacle/vehicle is a chicken-and-egg problem. This estimation problem is even more challenging when available data is sparse [39].

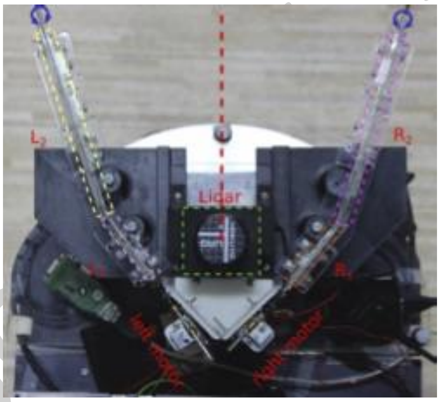



Figure 20: 2D nodding LIDAR for sparse data processing for simultaneous shape and velocity estimation

**14. Drone and remote sensing for agriculture applications - IIT Bombay**

**Drone sensing in precision agriculture aspects**

- The LAI model has introduced the concept of vertical leaf area distribution factor (VLADF), using which near-to-true LAI values can be calculated using drone-based RGB images.

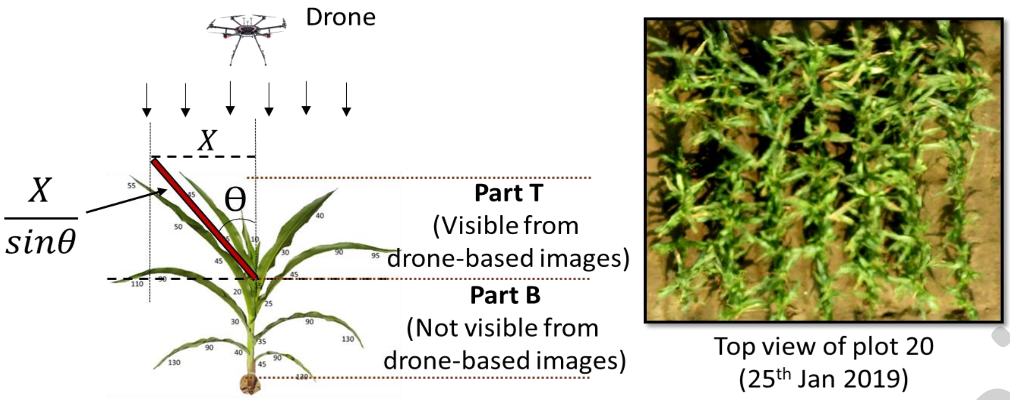



Figure 21: VLADF - Vertical leaf area distribution factor

- Height estimation model has shown that for flat and sparse canopy, crop height can be calculated with use of only DSM data.

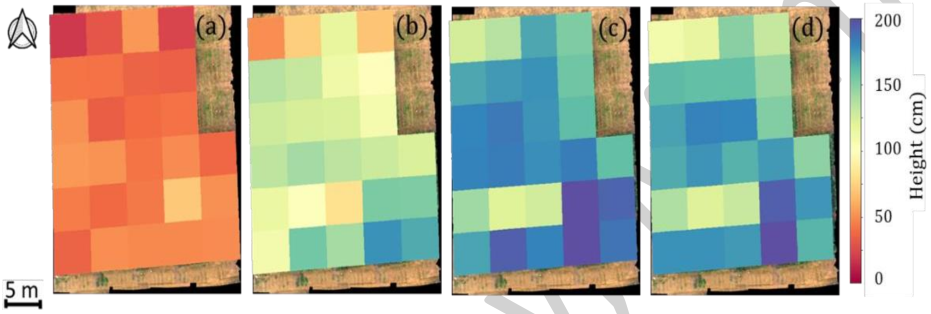



Figure 22: Average canopy height of plots at (a) early vegetative stage, (b) pre- tasselling stage, (c) silking stage, and (d) dough stage.

- Leaf water and nitrogen content estimation models have performed with high accuracy even for early growth stages of the crop with Hyperspectral data.

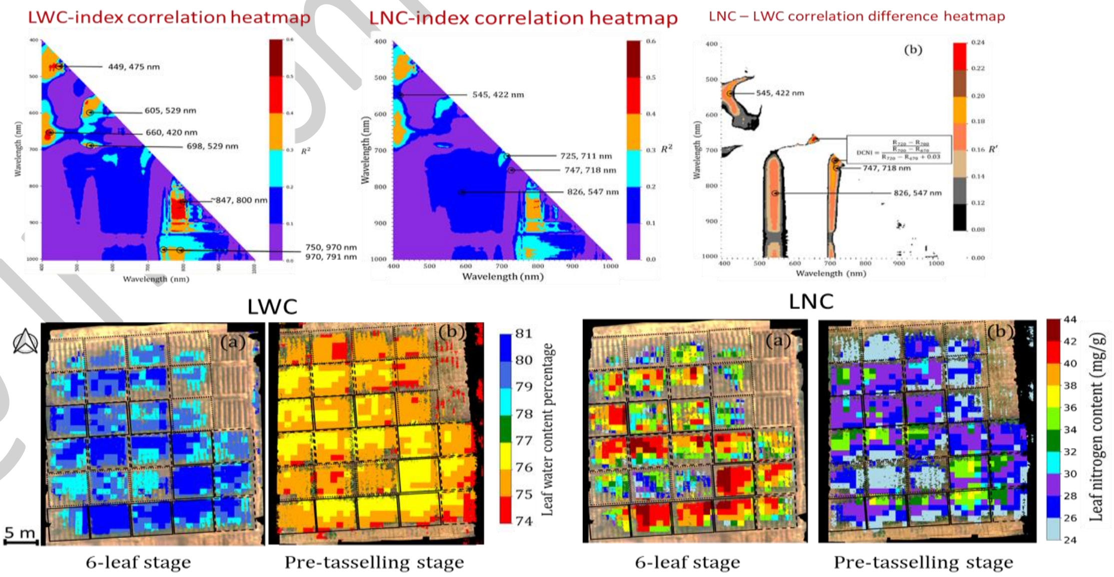



Figure 23: Estimated canopy LAI at (a) early vegetative stage, (b) pre-tasselling stag

- Temporal crop stress map of maize farm has been generated using Hyperspectral data with AI.

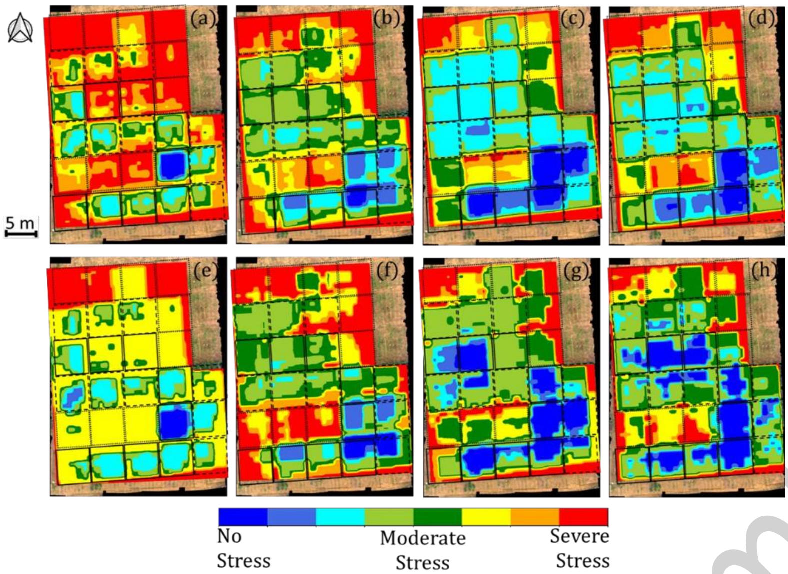



Figure 24: Temporal crop stress maps using random forest model (a-d) and linear model (e-h).

A. The maps are in sequence starting from early vegetative stage, tasselling stage, silking stage, and dough stage.

B. The fusion of leaf water and nitrogen content models were able to distinguish between the water and nitrogen stress areas precisely in the water stress regions.

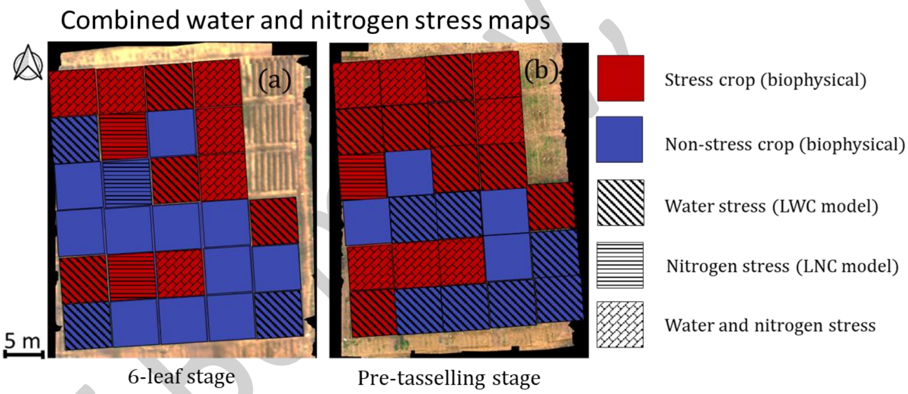



Figure 25: Combined water and nitrogen stress map for (a) 6-leaf stage and (b) pre-tasselling stage of 2018-19 Rabi season

**Remote sensing for agricultural applications**

In regard to remote sensing for agricultural applications, we are working on research data analytics for optimal crop management [40] [41] [42], climate resilient precision agriculture [43] and plant phenotyping [44] [45] [46]. In addition, we are also working on thermal infrared remote sensing [47], which is an important input in evapotranspiration mapping [48] crop water use management [49], crop water stress identification and irrigation estimation.

## 15. 5G Test-bed

During the years 2018-2021, IIT Bombay worked on the 5G test-bed development, a project of national importance, along with other IITs and IISc. The goal of the 5G test-bed project was to develop an end-to-end 5G system comprising of the 5G Core, 5G next generation RAN and Wi-Fi integration with the 5G Core. It was successfully completed and a successful demonstration of the system was also made to the honourable Minister of Electronics and Information Technology, Govt. of India recently in May 2022.

As part of this project, IIT Bombay team was instrumental in the development of the 5G Core network and Wi-Fi integration with 5G Core network (interworking) functionality. The scope of work for IIT Bombay has been shown pictorially in the figure below. Technology transfer of the IPRs, source code, modules and components developed as part of the project has also been done to a big Indian industrial house recently. Discussion on technology transfer to other organizations in the country are also ongoing currently.

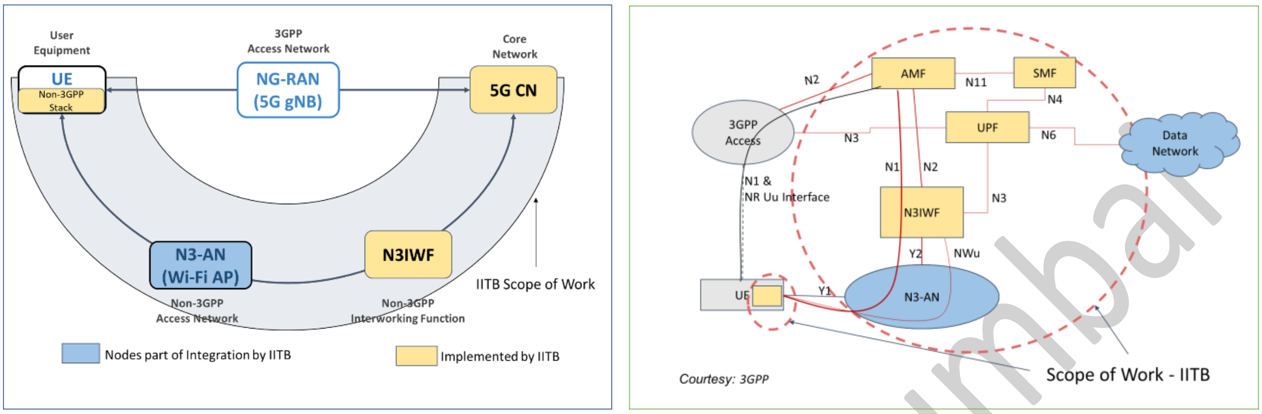



Figure 26: 5G Testbed - Scope of Work IIT Bombay

## 16. Networked communication system

IIT Bombay is working on various Device to Device/ Machine to Machine, wired, wireless, cellular, mmwave networks, improving the efficiency (in terms of time, power consumption thereby reducing cost) in various networked communication sys. These works include:

- Scheduling, holding and sending of data packets in networks [50] [51]. In these work an algorithm has been designed which incurred lower avg. cost than Maximum weight scheduling and Weight Fair Scheduling strategies. He has also implemented and evaluated these in wireless networks too.
- Developing different algorithms and evaluating the improvement they bring onto cellular network system functioning [52] [53] [54] [55].
- Working on improving Device to Device (D2D) and Machine to Machine (M2M) network, communication, which included using game theory [56], designing or changing MAC protocol [57] , node cardinality, etc.
- Designed and implemented shortest path tree-based energy efficient data collection wireless sensor network comprising of 24 sensors nodes in a 3-acre Maize farm to sense various parameters. The sensors utilised were all in house developed low-cost sensors [58].

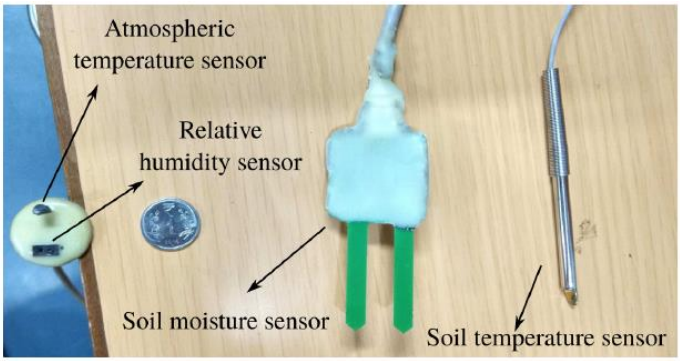
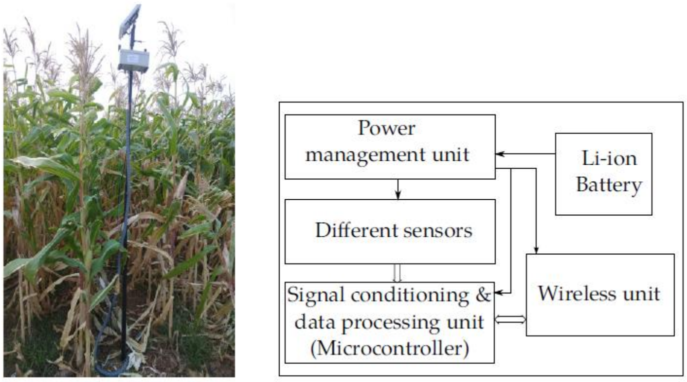



Figure 27: Different sensors in the system




(a) Sensor node in the field (b) Internal structure of the node

Figure 28: Sensor node

Follow up work [59] comprised of designing and implementation of a wireless sensor network (WSN) for agricultural monitoring applications using a multi-hop tree-based architecture.

## 17. Cybersecurity

- A Wireless Intrusion Detection System for 802.11 WPA3 Networks [60]:
    - This work included identifying additional vulnerabilities in WPA3 to the known vulnerabilities.

Table 1: Known attacks on WPA3 (1-7), newly identified attacks (8-9)

| No. | Attack | Impact of attack | AP vulnerable? | IDS Result |
|---|---|---|---|---|
| 1) | SAE Authentication flood attack | Denial-of-service | Yes | Not Detected |
| 2) | Try to make a client use WPA2 | Denial-of-service | Yes | Not Detected |
| 3) | Downgrade to WPA2 attack | Client connects using WPA2 instead of WPA3 | Yes | Not Detected |
| 4) | SAE commit out of range attack | Denial-of-service | Yes | Not Detected |
| 5) | SAE unsupported group attack | Denial-of-service | Yes | Not Detected |
| 6) | Downgrade group attack | Less secure connection | Yes | Not Detected |
| 7) | Timing side channel attack | Leaks information about the password | No | Not Detected |
| 8) | Deauthentiction attack | Denial-of-service | Yes | Not Detected |
| 9) | Beacon/ Probe frames flood attack | Confuse clients in trying to find the legitimate AP | Yes | Not Detected |

    - Successfully carrying out several attacks on an enterprise Access Point (WPA3 based) without being detected by IDS.

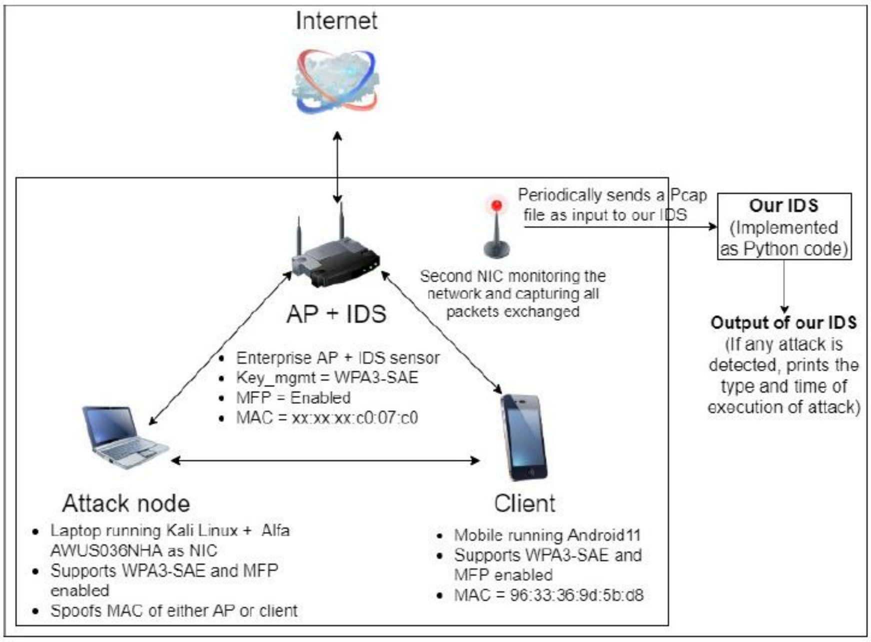



Figure 29: Experimental setup

- Proposed a signature-based IDS to detect all the attacks. Tested the efficacy of the same and got positive results.

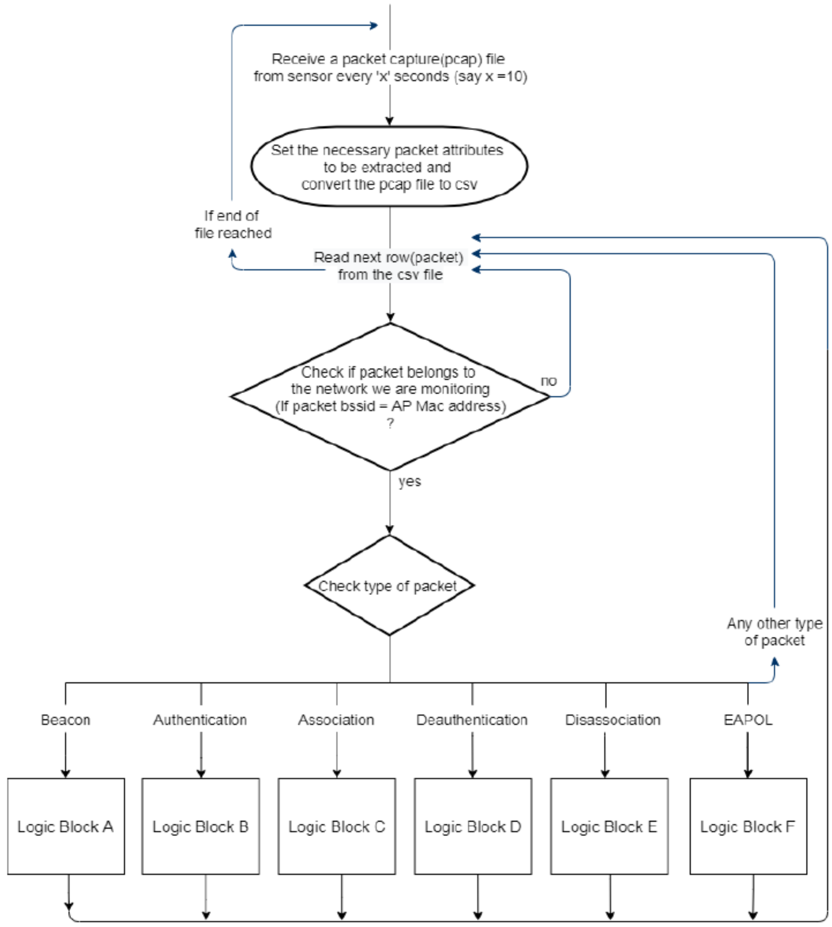



Figure 30: High level design of IDS

- Secure, Anonymity-Preserving and Lightweight Mutual Authentication and Key Agreement Protocol for Home Automation IoT Networks [61]:

  In this work, the authors provided

  - A cybersecurity solution scheme of authentication and key agreement protocol for a home auto network based on ZigBee standard.
  - The Scheme achieved confidentiality, message integrity, anonymity, unlinkability, forward/backward secrecy and availability. Most importantly the scheme is resource efficient (reduced time, communication cost and storage cost).

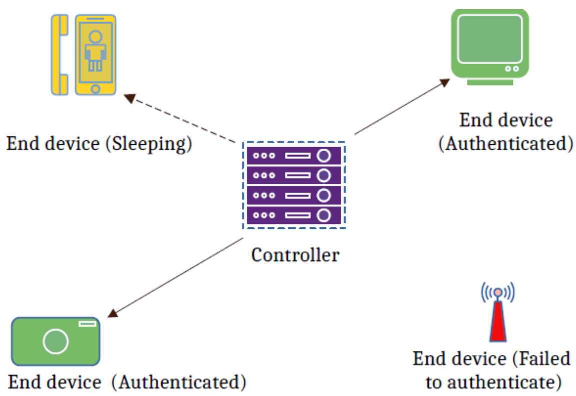



Figure 31: Authentication and Agreement Protocol for Home Automation IoT Networks

Table 2: Notation description

| Notation | Description |
|---|---|
| $SA$ | System Administrator |
| $C$ | Controller |
| $N_i$ | IoT end device $i$ |
| $ID_i$ | Real identity of device $N_i$ |
| $AUTH\_REQ$ | Authentication Request for a new session |
| $r_i$ | Random number generated by $N_i$ |
| $CC_i$ | The counter shared between $N_i$ and $C$ |
| $h(\cdot)$ | Hash function |
| $CC_{i,L}$ | Last $L$ bits of $h(CC_i)$ |
| $K_i$ | Symmetric key with $C$ for device $i$ |
| $HMAC$ | Keyed-hash message authentication code |
| $DDC_{ij}$ | The counter shared between $N_i$ and $N_j$ |
| $TK_{ij}$ | Temporary shared key between $N_i$ and $N_j$ |
| $MI_i^C$ | Masked identity of $N_i$ for Controller |
| $MI_C^i$ | Masked identity of Controller for $N_i$ |
| $MI_i^j$ | Masked identity of $N_i$ for $N_j$ |
| $OTP_i$ | One-Time Password for $N_i$ |
| $PoB_i$ | Proof of Belonging for device $N_i$ |
| $PoC$ | Proof of Controller |
| $\|$ | Concatenation |
| $\oplus$ | Bitwise XOR |

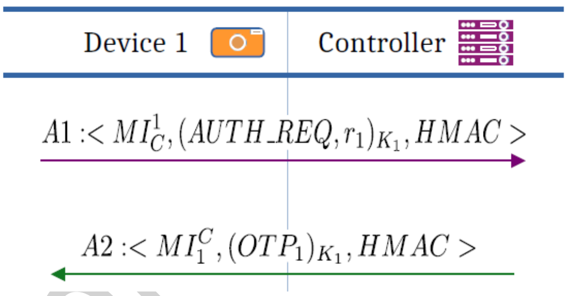


Figure 32: Mutual authentication between device and controller

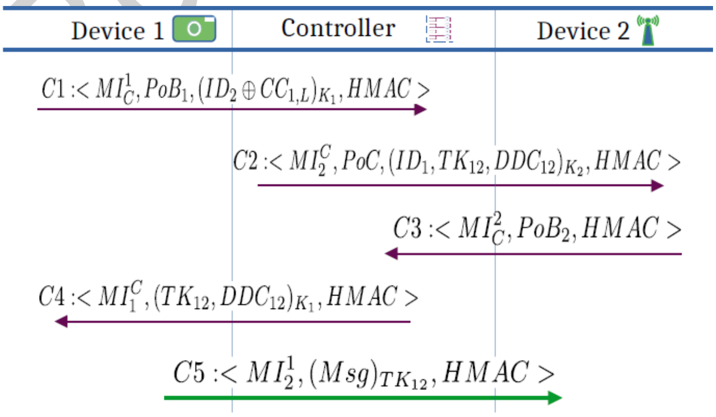


Figure 33: Device to Device (D2D) communication

- *Efficient, flexible and secure group key management protocol for dynamic IoT settings*:

  Group key Management (GKM) involves the handling, revocation, updation and distribution of cryptographic keys to multiples devices of IoT. Classical GKM schemes are inefficient in dynamics of IoT (wherein nodes frequently leave or join). Recent schemes proposed for GKM in dynamic IoT faced limitations of being computationally expensive, vulnerable to collision attacks and having a threat to the backward secrecy. Authors designed, proposed and evaluated a GKM scheme which maintained forward and backward secrecy, which was computationally inexpensive and completely resistant to collision attack [62].

- Game Theory in reducing energy expenditures of cellular users [53] [56] have been studied and employed. It is foreseen that Game Theory can be helpful in enhancing the cyber security aspects.

**18. Composite Signal control Strategy (CoSiCoSt-2G)**

A composite signal control strategy (CoSiCoSt) was developed for a distributed network model that addresses the low level of traffic discipline and high mix of traffic on Indian roads. CoSiCoSt-2G is a client which communicates with the server to optimize the signal timings of each junction in order to achieve synchronization, management, and reduce delay per vehicle. It takes input from the ATCS server and sends back new timings for signal heads. There is a network communication between the ATCS server and junction controller. This module does not communicate directly to signal heads. Figure 34 shows the overall architecture of the system.

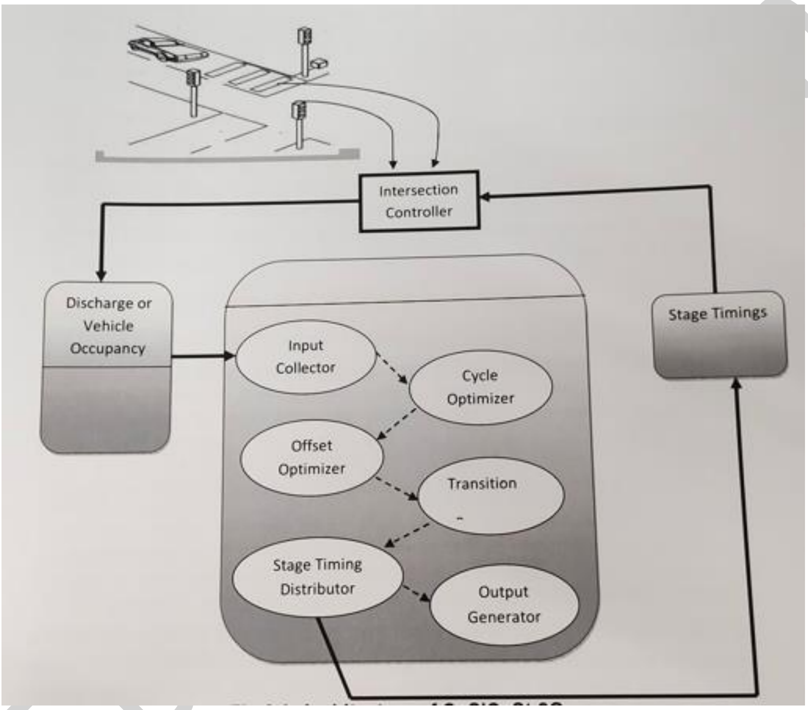



Figure 34: Architecture of CoSiCoSt

The overall project outcomes are:

- Control algorithm for isolated junction
- Control algorithm for corridor (Reinforcement learning)
- Control algorithm for corridor (Heuristics using discharge)
- Control algorithm for corridor (Heuristics using green time)
- Dynamic offset model for corridor
- SiMTraM – A traffic simulator for heterogeneous traffic condition
- Interface to VISSIM with ATCS, network creation, etc.

CoSiCoSt has been implemented in 38 intersections in Pune and at one corridor (9 junctions) in Jaipur. It has to be further implemented at 3 corridors (31 junctions) in Ahmedabad on a pilot scale. The CoSiCoSt system is performing satisfactorily in the cities where it has been implemented.

## 19. Real time Transit Trip Planner and Route Information System

The main objective of this project was to demonstrate a real time and intelligent public transport route information and trip planner capturing user preferences and GPS tracking enabled online GIS system.

The specific objectives were:

- the development of a static trip planner
- GPS based real-time trip planner
- web interface for the users and,
- Route information system.

### System Architecture

The following steps explains the overall architecture of the system (refer Figure 35).

- Collection of the GIS database of the route network information
- Identification of the interface for the route and schedule modification
- Fitting of online GPS system in the buses and GPS data collection
- Selection of the current trip plan by using the route data, schedule and user preferences
- Selection of the web interface for the front end of the system

The user interface is a web-based system on a GIS platform. The graphical interface consists of the map of the urban area covered by the transit company. The user can pick his origin and destination from the map or input text. The system will ask for some information on the proposed date and time of travel, preference for direct route, or with transfer, whether he would like to minimize time, cost, or inconvenience, etc.

If the user wants to travel 'now', the system will search through the route data base and the real time information coming from the bus and propose a best plan with one or two alternatives. If it is for a 'future' time, the system will predict the best possible route with few alternatives based on the travel time reliability computed from the historical data.

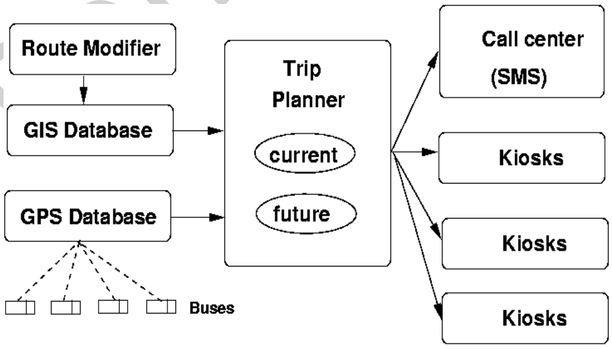



Figure 35: System architecture of the trip planner

## 20. Real time traffic counting and monitoring system

An accurate and continuous traffic count is vital for all transportation planning purposes. Specifically, planning for the future expansion needs a good estimate of traffic both in terms of the cumulative and peaking in a day or during special events. Currently these needs are met by manual count for very limited time periods. In addition, the growth of vehicular traffic is exerting pressure of the limited road infrastructure. The optimal usage of the existing facilities requires an accurate monitoring. This can be achieved by a real-time traffic counting and monitoring system (RTCMS).

The main objective of the project was to develop a real time road traffic counting, classifying, and analyzing system along with monitoring of the traffic.

The specific objectives of the project were:

- Customizing the Loop detectors for Vehicle count in Indian traffic condition which is heterogeneous and with limited lane discipline
- Exploring the efficacy of video-image processing to detect, count, classify, and determine the speed of the vehicles
- Develop an intelligent tool to supply the historic traffic information for transportation planners
- Develop and deploy an intelligent online web interface to exhibit the current traffic condition and congestion level on a given travel corridor as part of Advanced Travelers Information System (AITS). This control unit will act as a pilot control unit for various governmental agencies like NHAI. These agencies currently resort to manual and intuitive methods for their data requirement. Needless to say to that these are both expensive and unreliable. However, they are not in a position to adopt the solution successfully developed abroad due to the traffic conditions prevailing in India, typically absence of lane discipline and heterogeneity of vehicles.

**System architecture**

The architecture of the RTCMS was implemented in two phases as shown in Figure 36. The first module has two blocks integrated: loop detector based vehicle count and classification system, and an online monitoring system.

***First phase***

The first block comprises of a set of loop detectors placed to cover the entire width of the road and associated controllers to interpret the detector into count, and classification of vehicles. Loop detectors are sensors placed underneath the road and are actuated when a vehicle passes over. The signals are brought to a third server and processed to give the actual count of the vehicle. This server will have a web interface to show the real-time and historic traffic data.

The second block is vehicle monitoring using video cameras. A single digital video camera will installed at the key location in the field. The data from the camera will be brought to the TMCC using dedicated data cable and will be displayed on the primary server. The primary server will host the video processing software. This has the capability of pan, zoom, etc of the camera from the control unit. In addition, the software will archive the data on a secondary server.

***Second phase***

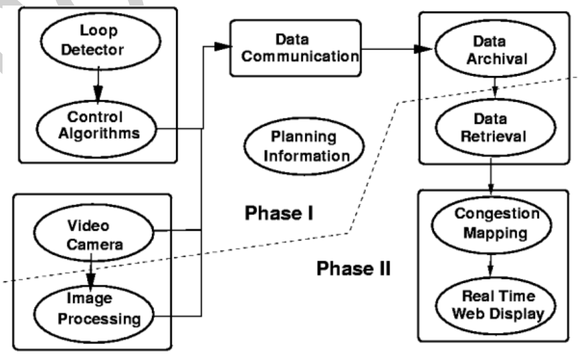


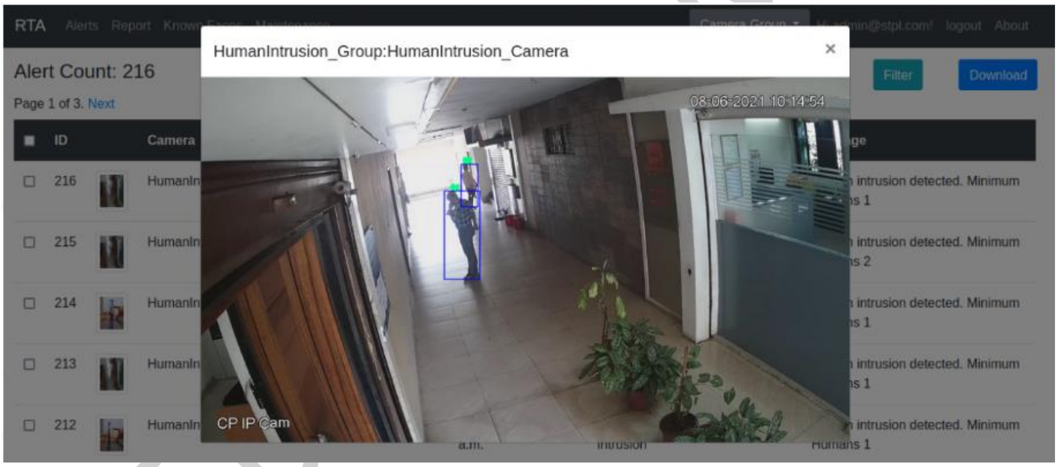

Figure 36: System Architecture of Real time traffic counting and monitoring system

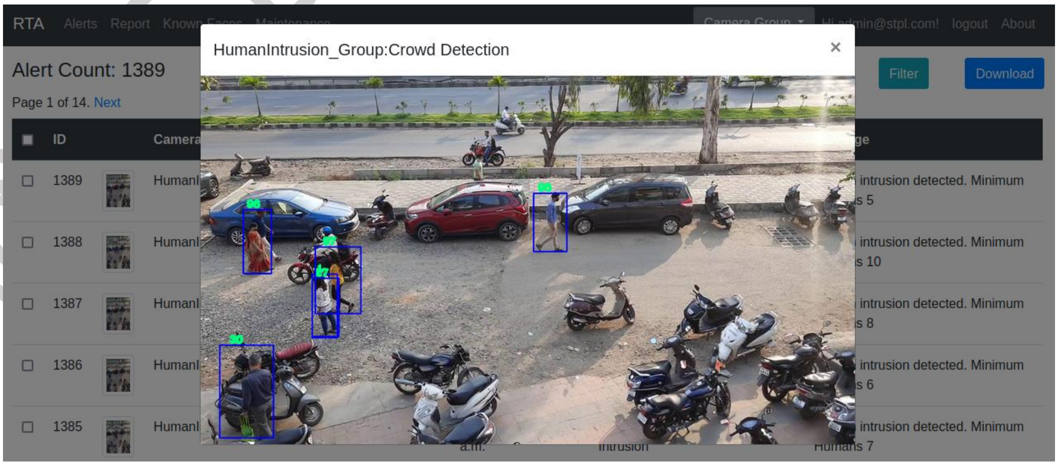
This module has vehicle detection from video data and data analysis and online display system. The optimized counting and monitoring system was installed at major travel corridors of the city. The image that is captured by the video shall be used for vehicle detection. The video image processor in addition to count, classification can also extract the vehicle speed, and thus has potential to give complete traffic characteristics. It also has intelligent data retrieval capabilities, congestion mapping and real time web display.

## 21. Video Analytics for Safety, Security and Compliance Applications

One of the prominent uses of technology in today's world is deployment of smart cameras at various public places or within organizations with an intent to monitor safety, security and/or compliance. However, most solutions do not offer satisfactory results in terms of real-time analysis or in facilitating post-hoc analysis. For example, in the unfortunate event of a crime, the authorized personnel today have to manually go through hours and hours of footage to be able to get some clues. This is error-prone and becomes practically infeasible beyond a point. Through state of the art research we have developed video analytics solutions that address some of these issues. Specifically, we have developed technology for efficient training of machine learning models and video summarization and used them for developing software solutions for real-time analytics (generating alerts) and post mortem analysis (video search, summarization and compliance analysis) of surveillance videos (https://www.cse.iitb.ac.in/~vidsurv)

Efficient Machine Learning: State of the art AI and Deep Learning needed by Video Analytics are data hungry. This comes at significant cost including costly resources (multiple expensive GPUs and cloud costs), training times, and human labeling costs and time. Because of this, effective video analytics solutions were still not a reality. We have created a framework called Decile (https://decile.org/) which attempts to address this problem. Our novel subset selection methods based on submodular optimization (implemented in an open source library called SUBMODLIB - https://github.com/decile-team/submodlib developed by us) allow for efficient training of machine learning models which is typically seen as one of the main challenges in developing video analytics solutions.




Video Summarization: Video summarization enables one to consume hours of video in minutes. This serves as an essential component of a video analytics solution. However, video summarization technology today faces certain challenges making it difficult to apply it in real-world settings. Through our work VISIOCITY (https://visiocity.github.io/), we attempt to make video summarization more realistic. The VideoSummy software available for download from http://bit.ly/video-summy applies subset selection through submodular optimization to summarize videos.

Use of technologies in the project and the purpose of usages are as follows:

| Name of Technology | Purpose | Observed Impact |
|---|---|---|
| Suraksha Vyuha for real-time video analysis | Ability to ensure safety and security of citizens by facilitating real-time monitoring through alerts instead of having to go through tons of CCTV footages post-incidence. | Is being used for IIT Bombay campus surveillance, Covid behavior compliance, Naval Dockyard, Visakhapatnam and is being piloted at various army and police establishments. |
| Video Summarization | Ability to watch hours of videos in minutes. Otherwise finding something in tons of videos is like finding a needle in haystack. For example, if we know through eye-witnesses that a person wearing a yellow shirt was involved in the crime, our novel video search technology allows for searching for "person wearing yellow shirt" in hours of videos. Our technology also supports summarizing the videos even without any specific query by eliminating redundant information and retaining only what matters. This leads to efficient consumption of videos. | Is being used for IIT Bombay campus surveillance, Covid behavior compliance, Naval Dockyard, Visakhapatnam and is being piloted at various army and police establishments. It is also being used to analyze the teacher behaviour in classrooms by watching the summary of the classroom videos. |
| Drishti for compliance and quality monitoring | Our unique dashboard built on top of the video analytics solution can provide a 360 degree view of the compliance status of various remote centers. For example in a skilling programme like DDU-GKY, the Government wants to ensure that the training is being imparted by the third partner implementing agencies in compliance with the laid down SOPs. | Being piloted at the various skill development centers of the DDU-GKY scheme under Ministry of Rural Development. |

**22. Drone based Topographic Measurements**

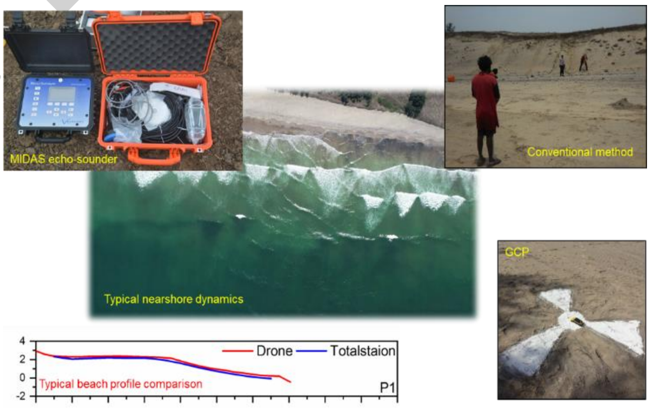



Figure 37: Glimpses of demonstrative study along Malgund Beach, Ratnagiri district, Maharashtra

The best use of drone based topographic measurements and satellite imagery based nearshore bathymetry estimation have successfully been demonstrated in various research studies. Customized algorithms are developed, in-house, to derive nearshore bathymetry from satellite imageries and validated with in-situ echo-sounder readings.

## 23. Drone corridors

We are currently working on a concept of operation which can be implemented for an unmanned aerial system traffic management (UTM) as shown in Figure 38. Drone passages are nothing but flight lanes. Lanes facilitate safe and efficient 2-way movement of the drones between 2 points. Drones shall not be allowed to travel in undesignated corridors. Using this proposed concept, drone flying can be ensured within the limits at unavoidable intersections, where there will be no collisions and also efficient flow of traffic. It is evident the inspiration for the same is drawn from the road transportation. Though a direct adaptation from road transportation to air transportation is not possible due to various complexities, the primary being the latter is a 3D problem while the prior is a 2D problem, there are some concepts which can be adapted.

Figure 38: Drone corridors

## 24. Drone docking system

Drone docking system includes various services like facilities to house, take-off, and landing base for drone, to provide routing information for optimum path for a specific mission, package handling facilities. It can act as a delivery hub and facilities drones by providing recharging stations, for maintenance, etc. There are various ways to automatic recharging for drones like wireless charging methods, wired charging mechanisms, swapping of batteries of UAV, etc, as shown in Figure 39. Currently, we are working on an autonomous wired charging mechanism, which has advantages over wireless charging or battery swapping method and can ensure minimum human intervention in the entire process. It also incorporates advanced robotic system which auto-swaps batteries and minimizing downtime.

Figure 39: (a) Drone docking with wireless charging pad [63] (b) Battery swapping mechanism [63]

## 25. Multirotor aerodynamic interactions study

Multirotor drones are widespread and being used for variety of applications. The physics of aerodynamic interactions between the rotors, however, is still not understood enough to address the efficiency, noise, and vibration problems that affect utility of such multirotor drones. This knowledge gap was partially addressed [64] [65] [66] [67] [68] [69] [70] involving experiments on an unsynchronized low-Re bi-rotor setup. The study established the existence of some of the prominent phenomena in multirotor wake resulting from vortex-vortex, vortex-blade, vortex-duct, and vortex-box interactions. Some of such interactions are presented in Figure 40 and Figure 41.

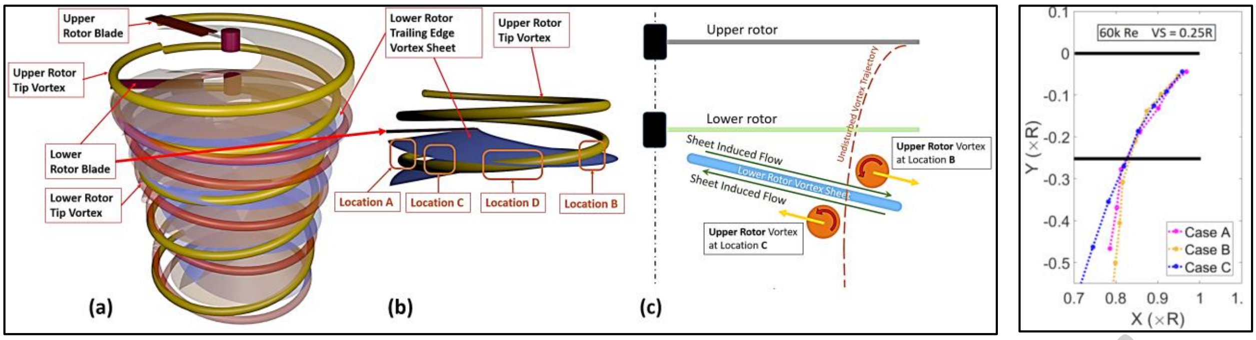


Figure 40: Vortex trajectories in coaxial rotor arrangement and model explaining observations [68]

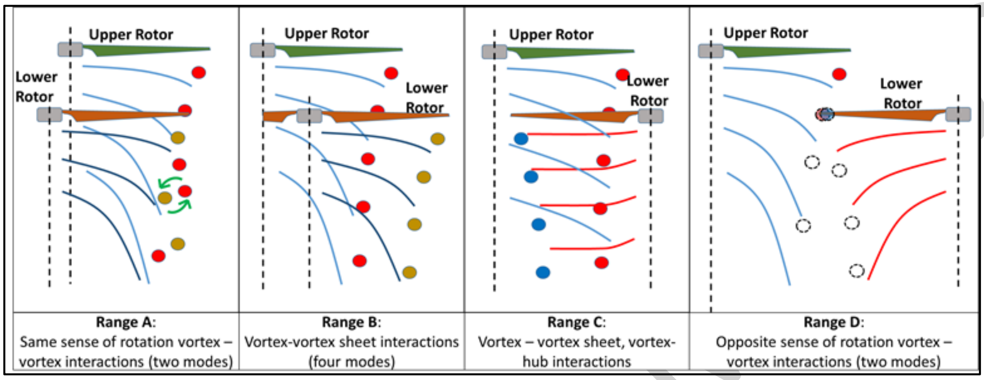


Figure 41: Schematic diagram depicting the observed modes of interactions for tandem rotor configuration [69]

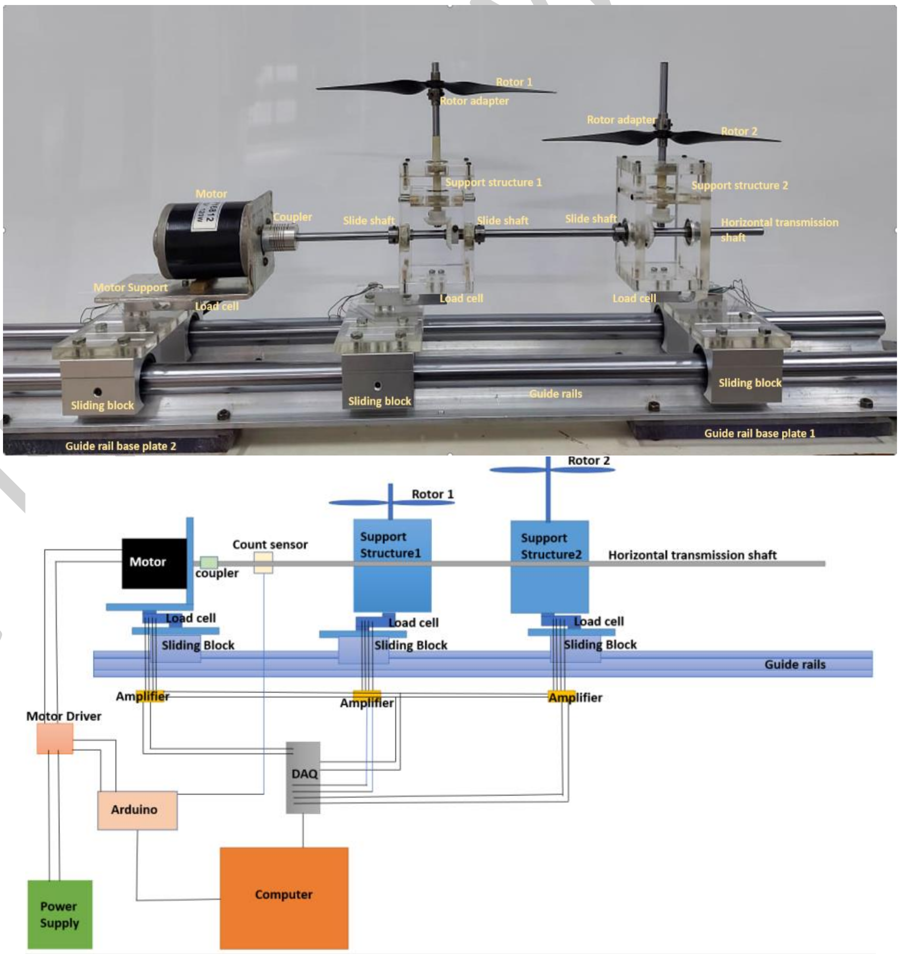


Figure 42: Photograph of synchronized twin rotor up with schematic

The ongoing work aims at refining the knowledge further through phase-locked multirotor experiments and simulations, exploring each of the prominent interaction modes up to a level where they and their effects can be modelled accurately for use in design and optimization of multirotor drones. Figure 42 is a photograph of the setup developed at IIT Bombay for the phase-locked experiments. The simulation work has been done [71]. Higher fidelity simulations and experimental tests are underway.

### 26. Reconfigurable drone

Each drone application poses its own set of requirements, needing the drones to possess very different features and specifications to serve them. For a drone operator serving a range of customers, this variation in desired specifications means significant investment in procurement of variety of drones, associated logistics, and maintenance.

The concept of reconfigurable drones aims at addressing this high cost and effort of serving diverse applications. This involves development of drone platforms that are amenable to significant modifications in terms of scale and capabilities, through physical combination of individual drones in easy modular fashion. Some preliminary work has been done on the concept during his graduate studies at Georgia Institute of Technology. Figure 43 is a photograph of a prototype under development that combined four separate drones into one larger flying machine, supporting up to four times the payload of the individual drones.

Figure 43: Reconfigurable drone prototype photograph

### 27. Development of a Desktop Based Driving Simulator for a Non-lane Based Mixed Traffic System

In order to solve the transportation problems of safety as well as congestion, solution need to found both in operation as well as policy level. The solutions for transportation problems are more and more being solved with technological interventions like intelligent transportation systems. ITS uses computing and communications technology to solve transportation related problems. But, no matter what ITS based solution is proposed or developed, we need to understand its impact in terms of how humans/users adapt and change their driving and travel behaviours. Thus, behavioural studies are an integral part of transportation research.

In the recent past, the use of driving simulators to address several aspects of transport, including driving behaviour, testing ITS applications, road safety, and road design has gained a lot of traction. Transportation researchers and engineers have been using two different types of simulators for different purposes. One is the microscopic traffic simulator for Traffic operation evaluation and the other is Driving simulator for evaluating the response of individual drivers in a virtual environment. Both of these two types of simulators individually have some limitations. Traffic simulator models does not have driver behavior realism since there are based on idealistic car following models. They also pay little regard to safety considerations. Driving simulators suffer from lack of traffic authenticity and traffic network realism since majority of driving simulators are preprogrammed and does not react according to real time actions of the driver. In addition, driving simulators are limited to small set of driving scenarios. Therefore, there is a need for integrating the Traffic simulator and Driver simulator to provide a realistic representation of transportation network with authentic real time driver behavior input.

Moreover, most driving simulators are developed for evaluating the behaviours of only car drivers in lane-based environment. However, the traffic conditions that exist in developing countries like India are characterised by the presence of multiple vehicle types (two-wheelers, auto-rickshaws, buses and trucks along with cars) and absence of lane discipline. The goal of this project is to develop an interactive driving simulator integrated with a microscopic traffic simulator capable of representing the non-lane based mixed traffic scenarios and use it for conducting driver behavioural studies and testing ITS applications.

The overarching goal of this project is to develop a driver-centric simulator integrated with a general-purpose traffic simulator representative of non-lane based traffic systems. The specific objectives are:

- To calibrate a microscopic traffic simulator that represents non-lane-based mixed traffic conditions.
- To integrate high-end simulator with a microscopic traffic simulator for modelling traffic and driver behaviour of non-lane based mixed traffic conditions. For this, a module will be developed that enables real-time two-way interaction between the traffic simulator and the purchased driving simulator.
- To develop a desktop-based low-cost driving simulator for driver safety training and licensing purposes.
- Preparation of driver safety modules for the desktop simulator. The modules will be based on various safety-related experiments involving local drivers.

The proposed framework is shown in Figure 44.



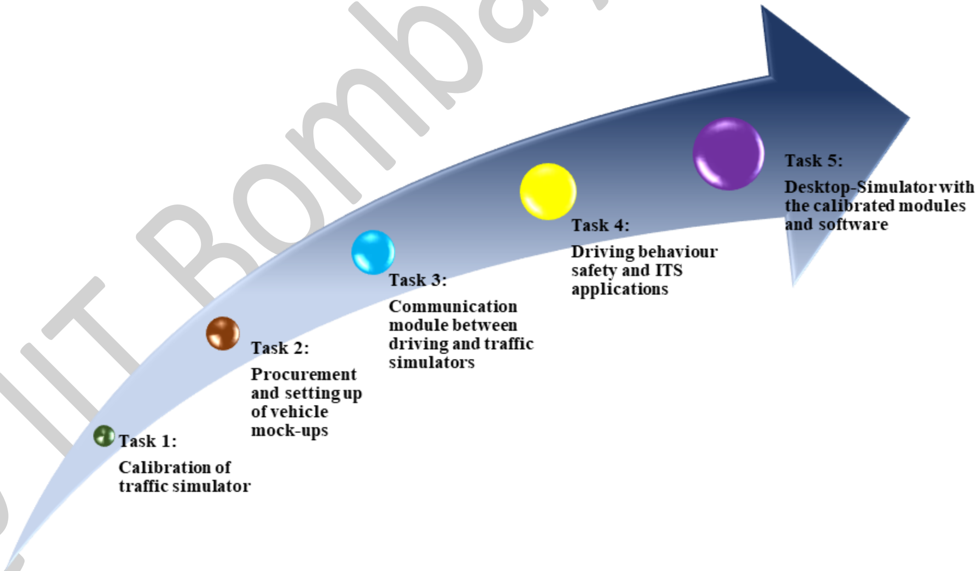



Figure 44: Proposed framework

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## *Appendix C*

## Drone Operation Permissions for IIT Bombay from the Ministry of Civil Aviation (MoCA) and Airport Authority of India (AAI)

**AV-29017/55/2021-SDIT-MoCA**
**Government of India**
**Ministry of Civil Aviation**
***

**Rajiv Gandhi Bhavan, New Delhi**
**15th September 2023**

## ORDER

**Subject: Permission for extension of duration for research, development and testing of drones to Indian Institute of Technology, Bombay (IIT-B) in own premises**

1. Whereas, IIT Bombay ('the Applicant') had, vide email dated 11 September 2023 sought permission for the afore-mentioned purpose.
2. Whereas, the Applicant shall seek permission from CISF, Indian Navy, Ministry of Home Affairs (MHA), Government of Maharashtra, National Technical Research Organisation (NTRO) and subject to airspace clearance from concerned Air Traffic Clearance (ATC) regarding drone operations in red zone for the afore-mentioned purpose.
3. Now, therefore, the Ministry of Civil Aviation, vide Rule 22 (1) of Drone Rules, 2021, grants permission to the Applicant for the afore-mentioned purpose. This permission shall be subject to the terms and conditions of the said permissions from CISF, Indian Navy, MHA, Government of Maharashtra, NTRO and subject to airspace clearance from concerned Air Traffic Clearance (ATC) regarding drone operations. This permission shall be valid for period of one year or until further orders, whichever is earlier.

Manoj 15/09/2023

**(Manoj Kumar Yadav)**
Under Secretary to Govt. of India
sdit.div-moca@gov.in

To:

1. Director, IIT Bombay
2. Chief Secretaries/Administrators of Maharashtra
3. DGPs/ Heads of Police of Maharashtra
4. Lt. Yash Agrawal, DGMO, South Block, IHQ of Ministry of Defence
5. Chairman, National Technical Research Organisation (NTRO), New Delhi
6. Captain J. M. Mulik, Indian Navy, New Delhi
7. Shri R. Makwana, DIG, ICG Regional Headquarters, MoD (Army), New Delhi
8. Additional Secretary (Internal Security), Ministry of Home Affairs (MHA), New Delhi
9. Chairman, Airports Authority of India (AAI), New Delhi

# Standard Operating Procedures (SOP) for Operation of Drone Ecosystem for IIT Bombay, Mumbai

1) The Nodal Officers from IIT Bombay will be a) Prof. Sudarshan Kumar (HoD, Aerospace Engineering), b) Prof. Arnab Maity (Aerospace Engineering), c) Prof. Dhwanil Shukla (Aerospace Engineering). Their contact details are as below.

    a) Telephone number – 2576 7101, Mobile - 98331 61200, Email: hod@aero.iitb.ac.in,

    b) Telephone number – 2576 7136/8136, Mobile – 9986526336, Email – arnab@aero.iitb.ac.in,

    c) Telephone number – 2576 7119, Mobile – 6358808144, Email – dhwanil@aero.iitb.ac.in

    The Nodal officer from Mumbai ATC will be WSO with telephone numbers Landline – 20888088, 26819332, 26819449 and Mob – 9869062250 and E-mail id: vabb.wso@aai.aero.

    Any update in the nodal officer contact details on either ends (Mumbai ATC and IIT Bombay) shall be communicated immediately.

2) The area of drone operations shall be confined to the premises of IIT Bombay and a part of Powai lake (refer to Annexure 1). The closest point of the area is 3.95 km from the perimeter of Mumbai airport and the farthest point is 6.15 km from the airport perimeter. The region marked in Green color in Annexure 1 (South of pipeline) denotes the area, where the drone operations can take place without coordination with Mumbai ATC within the approved altitude and hours. Drone operations in the region marked in Red color (North of pipeline) requires coordination with Mumbai ATC.

3) As per the Drone Rules 2021, the area up to 5 km from the airport perimeter is Red Zone, where drone operations are permitted only with the approval of Central Government. The Ministry of Civil Aviation vide order dated 10th September 2021 (copy enclosed as Annexure 2) has exempted IIT Bombay from the provisions of the Drone Rules 2021 subject to airspace clearance from AAI.

4) IIT Bombay is permitted to conduct drone operations in the area as described in the point number 2, up to an altitude of 300 ft. AMSL between 0700 Hrs IST to 1800 Hrs IST daily without real-time coordination with Mumbai ATC, subject to the condition that fair weather conditions prevail in the vicinity of the permitted area.

5) Any drone operations beyond the permitted area and/or above 300 ft. AMSL or beyond approved hours shall be coordinated with Mumbai ATC on case-to-case basis. The approval must be sought at least two hours in advance from Mumbai ATC. Mumbai ATC (WSO) shall coordinate with Juhu ATC before approving drone operations at higher altitude. Mumbai ATC shall clearly specify the maximum permissible height and duration, while granting permission for drone flying at higher altitude. Approval shall be conveyed through E-mail to IIT-B. Mumbai ATC shall take NOTAM for the additional drone activity.

6) Drones operating beyond hours of daylight shall be equipped with sighting enhancing devices such as flashing strobe lights.

7) Mumbai ATC will promulgate a NOTAM regarding drone operations in the approved area for maximum approved altitude of operations.

8) Mumbai ATC may instruct the nodal officers from IIT Bombay to terminate or restrict drone operations in case of any emergency or deviations by helicopters from routes due to inclement weather. IIT Bombay shall comply with instructions from Mumbai ATC immediately and in any case within 10 minutes and confirm to ATC of the same.

9) Any unauthorized drone activity observed within or in the vicinity of the approved drone flying area be brought to the notice of relevant Police station and ATC WSO by IIT Bombay.

10) Log of drone activity shall be maintained by IIT Bombay for reference during the last 12 months.

11) In case, a drone infringes the specified boundary of the drone ecosystem and becomes uncontrolled, the information shall be shared immediately with the WSO for necessary action.

12) IIT Bombay shall inform to the local police.

13) The drone operator shall be responsible to ensure safety of other aircraft, persons and property. The operator shall ensure that the drone is clear of all manned aircraft at all times.

14) The effective date of this SOP shall be 20th February 2022.

15) The SOP will be jointly reviewed after 3 months from the effective date.

***********

| | |
|---|---|
| [signature] | [signature] 03/02/22 |
| Signature of Authority<br>of IIT Bombay, Mumbai | Signature of Authority<br>of Airport Authority of India |
| Name and Designation<br>Prof. Milind Atrey | Name and Designation<br>राजीव मेहता/RAJEEV MEHTA<br>महाप्रबंधक (ए.टी.एम.)/General Manager (ATM)<br>भारतीय विमानपत्तन प्राधिकरण/Airports Authority of India<br>एटीएस काम्प्लेक्स/ATS Complex,<br>मुंबई/Mumbai - 400099 |
| Date 18.01.22<br>संकायाध्यक्ष, शोध एवं विकास<br>Dean, Research and Development<br>कृते निदेशक, आय आय टी मुंबई<br>For Director, IIT Bombay | Date |
| Official stamp | Official stamp |

Through the HoD, Aerospace Engg., IIT Bombay
[signature] 18.01.22

प्रा. सुदर्शन कुमार/Prof. Sudarshan Kumar
विभागाध्यक्ष/The Head
वायुआकाश अभियांत्रिकी विभाग
Aerospace Engineering Department
भारतीय प्रौद्योगिकी संस्थान मुंबई
Indian Institute of Technology Bombay
पवई, मुंबई-76 /Powai, Mumbai - 400 076.

## Annexure 1

## Annexure 2

AV-29017/55/2021-SDIT-MOCA
Government of India
Ministry of Civil Aviation

Rajiv Gandhi Bhavan, New Delhi
10 Sep 2021

**ORDER**

**Subject: Conditional exemption from Drone Rules, 2021 to Indian Institute of Technology, Bombay (IIT-B) for research, development and testing of drones in its own premises**

1. Whereas, IIT-B ('the Applicant') had, vide email dated 31 Aug 2021 sought an exemption from Drone Rules, 2021 for the afore-mentioned purpose.
2. Whereas, based on the undertaking provided by the Applicant, approval of the airspace clearance shall be obtained by the Applicant from Airports Authority of India (AAI) for the afore mentioned purpose.
3. Now, therefore, the Central Government, in exercise of the powers conferred by Rule 48 of the Drone Rules, 2021, grants conditional exemption from Drone Rules, 2021 to the Applicant for the afore-mentioned purpose. This exemption shall be subject to the terms and conditions of the said airspace clearance and shall be valid for a period of one year from the date of approval of the said airspace clearance or until further orders, whichever is earlier.

10. 9. 21

(Amber Dubey)
Joint Secretary to the Government of India

To:

1. All Ministries/ Departments of the Government of India
2. Chief Secretaries/ Administrators of all States/ Union Territories
3. DGPs/ Heads of Police of all States/ Union Territories
4. Additional Secretary (Internal Security), Ministry of Home Affairs (MHA), New Delhi
5. Joint Director, Intelligence Bureau (Shri Janardan Singh), New Delhi
6. Director, G-Wing, Ministry of Defence, New Delhi
7. Gp Cpt K.B. Mathews, Air Headquarters, IAF, New Delhi
8. DG, Directorate General of Civil Aviation (DGCA), New Delhi
9. DG, Bureau of Civil Aviation Security (BCAS), New Delhi
10. Chairman, Airports Authority of India (AAI), New Delhi
11. PS to HMoSCA (IC), Ministry of Civil Aviation, New Delhi
12. Sr. PPS to Secretary, Ministry of Civil Aviation, New Delhi
13. National Informatics Centre (NIC) team, Rajiv Gandhi Bhavan, New Delhi
14. Digital Sky Platform

***

*Appendix D*

## Potential Use Cases of Drones Shared by the Departments / Ministries of Government of Maharashtra

कृषि व पदुम विभाग/८-अे

1. **Name of the Ministry / Department** : **Department of Agriculture**
2. **Contact person information, including his/her email id and contact number :**

   Dy Director Project,Commissionerate of Agriculture,Pune 411001

   Email : ddainputs5@gmail.com

3. **Expected application / use case of drones pertaining to the Ministry / Department**
   - Use of Kisan Drones for Spraying of Pesticides and Crop & Soil Nutrients
4. **Problem statement in detail (Max. 750 words)**
   - Farmers face many problems like unavailability or high cost of labours, health problems by coming in contact with chemicals (fertilizers, pesticides etc.) while applying them in the field etc.
   - Pesticides are one of the important agri-inputs to address protection of crops against a large number of pests that can wash away entire investment of farmers and hence they act as an essential input that yields substantial returns to the farmers.
   - Conventional methods of pesticide spray application lead to excessive application of chemicals, lower spray uniformity, unnecessary deposition and non-uniform coverage; resulting in excessive usage, water & soil pollution as well as higher expenditure on pesticides. With conventional manual sprayers, the safety of operators is also a major concern.
5. **Anticipated benefit(s) of using drone in the given problem statement (Max. 750 words) :**
   - The use of drone technology as a modern farming technique is aimed at making production more efficient through precise spraying of pesticides and crop nutrients. This approach would not only ensure accuracy, uniformity in spray across the field, reduction in the overall use of chemicals within the area, but will also take care of the safety of the operators. The manned workload can be limited even further by aerial mapping feature of the drones thus helping farmers in surveillance and monitoring of their crops and in identifying presence of pests, soil condition or any crop damage.
6. **Where will the system be deployed?**
   - Konkan Region : Spraying of Pesticides & Crop nutrients on Paady and Mango/ Cashewnut Orchards
   - Western Maharashtra : Spraying of Pesticides & Crop nutrients on Paddy, Soybean, Sugarcane and Orchards ( Pomegranate, Mango, etc)
   - Marathwada & Vidarbh Region : Spraying of Pesticides & Crop nutrients on Cotton, Soybean, Paddy and Orchards (Orange)
7. **Any other information**
   - Mechanization & Technology and Plant protection Divisions of the Ministry of Agriculture & Farmers Welfare, GoI, in collaboration with various stakeholders have issued Standard Operating Procedures for use of drones in application of pesticides and crop/soil nutrients. This SOP would support and facilitate increase

in income of farmers with safer and efficient use of inputs as well as help users by providing them with guidelines for safe and controlled use of drone during spraying operations.

- The use of Drone technology has the potential to provide a sustainable solution in context of enhancing the productivity as well as efficiency of the Agriculture sector. Agriculture drone empowers the farmer to adapt to specific environments and make relevant choices in regulating crop health and crop treatments.
- In the vies of above, additional guidelines for providing agricultural services through drone application under Sub-Mission on Agricultural Mechanization (SMAM) has been issued by Mechanization & Technology Divisions of the Ministry of Agriculture & Farmers Welfare, GoI.
- As per the guidelines there is provision of financial assistance for Drone demonstrations and for Establishment /Upgrading the Custom Hiring Centers (CHCs)/Hi-tech Hub for providing agricultural services through drone application. Subsidy of Rs. 5 lakh is being provided to Agricultural Graduates and Rs. 4 lakh to farmers groups/ FPOs/ FPCs for establishment of Custom Hiring Center.
- During 2022-23 there was no approved programme for Drone demonstrations.
- However there was approved programme of Rs. 1.65Cr. regarding financial assistance for procurement of drones for Establishment/Upgrading the Custom Hiring Centres (CHCs)/Hi-tech Hub for providing agricultural services through drone application. In this target of 13 drones for Agricultural Graduates and 25 drones for other agencies was approved.
- Till date amount of Rs.36 lakh has been utilized for 8 drones ( 4 Agriculture Graduates and 4 CHCs). Some of the FPOs/ FPCs are reluctant to procure drones due to less subsidy amount.
- During 2023-24 there is proposed target of 160 drones ( subsidy of Rs. 6.40 Cr.) and 1000 hectares of demonstrations ( Rs. 60 lakh)

**Known Issues :**

- Drone technology is a new technology and being adopted as much.
- Kisan drones having high initial cost for drone and its accessories (propellers, battery pack, charging hub etc.)
- Limited of Battery life: Kisan drone can fly only for 8 to 10 minutes in single charge
- Technical knowledge: In case of Kisan drone, not only knowledge regarding flying of drone is required but knowledge regarding choosing pesticides, concentration of pesticides, time of spraying is also important factor.
- Drift losses may occur through wind
- Some of the FPOs/ FPCs are reluctant to procure drones due to less subsidy amount.

१) Name of the Ministry / Department : कृषी विभाग, महाराष्ट्र शासन

२) Contact person information, including his/her email id and contact number

कृषि संचालक (वि. व प्र.), कृषि आयुक्तालय, पुणे Email : ddainputs५@gmail.com

३) Expected application / use case of drones pertaining to the Ministry / Department

- कीटकनाशकांच्या व पीक आणि मातीतील पोषक घटकांच्या फवारणीसाठी किसान ड्रोनचा वापर

४) Problem statement in detail (Max. ७५० words) :

- मजुरांची अनुपलब्धता किंवा जास्तीची मजुरी, शेतात वापरताना रसायने (खते, कीटकनाशके इ.) यांच्या संपर्कात आल्याने आरोग्याच्या समस्या इत्यादी अनेक समस्यांना शेतकऱ्यांना सामोरे जावे लागते.
- मोठ्या प्रमाणात कीटकांपासून पिकांचे संरक्षण करण्यासाठी कीटकनाशके ही एक महत्त्वाची कृषी निविष्ठा आहे जी शेतकऱ्यांची संपूर्ण गुंतवणूक वाया घालवू शकते आणि म्हणूनच ते एक आवश्यक निविष्ठा म्हणून काम करतात ज्यामुळे शेतकऱ्यांना भरीव परतावा मिळतो.
- कीटकनाशक फवारणीच्या पारंपारिक पद्धतींमुळे रसायनांचा जास्त वापर होतो, फवारणीची एकसमानता रहात नाही; परिणामी जास्त वापर, पाणी आणि माती प्रदूषण तसेच कीटकनाशकांवर जास्त खर्च होतो. पारंपारिक मॅन्युअल स्प्रेअरसह ऑपरेटरची सुरक्षितता देखील एक प्रमुख चिंतेची बाब आहे.

५) Anticipated benefit(s) of using drone in the given problem statement (Max. ७५० words) :

- आधुनिक शेती तंत्र म्हणून ड्रोन तंत्रज्ञानाचा वापर करून कीटकनाशके आणि पीक पोषक घटकांच्या अचूक फवारणीद्वारे उत्पादन अधिक कार्यक्षम बनवणे हा आहे. हा दृष्टीकोन केवळ अचूकता, संपूर्ण क्षेत्रामध्ये फवारणीमध्ये एकसमानता, क्षेत्रामध्ये रसायनांचा एकंदर वापर कमी करणे सुनिश्चित करेल, परंतु ऑपरेटरच्या सुरक्षिततेची देखील काळजी घेईल. ड्रोनच्या एरियल मॅपिंग वैशिष्ट्याद्वारे मानवयुक्त कामाचा भार आणखी मर्यादित केला जाऊ शकतो ज्यामुळे शेतकऱ्यांना त्यांच्या पिकांचे निरीक्षण करण्यात आणि कीटकांचा उपद्रव, मातीची स्थिती किंवा कोणत्याही पिकाचे नुकसान ओळखण्यात मदत होते.

६) Where will the system be deployed?

- **कोकण विभाग** : भात पिकावर आणि आंबा, काजू यासारख्या फळबागांवर कीडनाशके व पिक पोषक द्रव्ये (नॅनो युरिया) फवारणी
- **पश्चिम महाराष्ट्र** : भात, सोयाबीन, ऊस यासारख्या पिकांवर आणि डाळिंब , आंबा यासारख्या फळबागांवर कीडनाशके व पिक पोषक द्रव्ये (नॅनो युरिया) फवारणी
- **मराठवाडा व विदर्भ** : कापूस, सोयाबीन, भात यासारख्या पिकांवर आणि संत्री, मोसंबी यासारख्या फळबागांवर कीडनाशके व पिक पोषक द्रव्ये (नॅनो युरिया) फवारणी

७) Any other information :

- कृषी आणि शेतकरी कल्याण मंत्रालय, भारत सरकारच्या यांत्रिकीकरण आणि तंत्रज्ञान आणि वनस्पती संरक्षण विभागांनी, विविध भागधारकांच्या सहकार्याने कीटकनाशके आणि पीक/माती पोषक द्रव्ये वापरण्यासाठी ड्रोनच्या वापरासाठी मानक कार्यप्रणाली जारी केल्या आहेत. या SOP मुळे निविष्ठांच्या सुरक्षित आणि कार्यक्षम वापरासह शेतकऱ्यांचे उत्पन्न वाढण्यास मदत होईल तसेच फवारणी ऑपरेशन दरम्यान ड्रोनच्या सुरक्षित आणि नियंत्रित वापरासाठी मार्गदर्शक तत्त्वे प्रदान करून वापरकर्त्यांना मदत होईल.
- उपरोक्त बाब  विचारात घेऊन, कृषी यांत्रिकीकरण उप-अभियान (SMAM) अंतर्गत ड्रोनद्वारे कृषी सेवा प्रदान करण्यासाठी अतिरिक्त मार्गदर्शक तत्त्वे कृषी आणि शेतकरी कल्याण मंत्रालय, भारत सरकारच्या यांत्रिकीकरण आणि तंत्रज्ञान विभागांनी जारी केली आहेत.
- मार्गदर्शक सूचनांनुसार ड्रोन प्रात्यक्षिकांसाठी आणि ड्रोनद्वारे कृषी सेवा प्रदान करण्यासाठी कस्टम हायरिंग सेंटर्स (CHCs)/हाय-टेक हबची स्थापना/अपग्रेडिंगसाठी आर्थिक मदतीची तरतूद आहे. कस्टम हायरिंग सेंटरच्या स्थापनेसाठी कृषी पदवीधरांना रु.५ लाख आणि शेतकरी गट/एफपीओ/एफपीसी यांना रु. ४ लाख अनुदानाची तरतूद आहे.
- सन २०२२-२३ मध्ये  ड्रोन प्रात्यक्षिकांसाठी कोणताही मंजूर कार्यक्रम नव्हता
- मात्र ड्रोनद्वारे कृषी सेवा प्रदान करण्यासाठी कस्टम हायरिंग सेंटर्स (CHCs)/हाय-टेक हबची स्थापना/अपग्रेडिंग करण्यासाठी ड्रोन खरेदीसाठी आर्थिक सहाय्य याकरिता रु.१.६५ कोटी निधीचा कार्यक्रम मंजूर झाला होता. यामध्ये कृषी पदवीधरांसाठी १३ ड्रोन व इतरांसाठी २५ ड्रोनचा लक्षांक मंजूर होता.
- आजपर्यंत ८ ड्रोनसाठी (४कृषी पदवीधर आणि ४  CHC) रु.३६ लाखांचा खर्च करण्यात आला आहे. काही एफपीओ/एफपीसी कमी अनुदानाच्या रकमेमुळे ड्रोन घेण्यास नाखूष आहेत
- सन २०२३-२४ मध्ये  १६० ड्रोन (रु. ६.४० कोटी अनुदान) आणि १००० हेक्टर प्रात्यक्षिकांचे (रु. ६० लाख रुपये) प्रस्तावित लक्ष्य आहे.

८) **निदर्शनास आलेल्या त्रुटी** :

- ड्रोन तंत्रज्ञान हे संपूर्णपणे नवीन असून त्याचा अद्याप अपेक्षेप्रमाणे स्वीकार करण्यात येत नाही.
- किसान ड्रोन व त्याचे सुटे भाग (प्रोपेलर, बॅटरी पॅक, चार्जिंग हब ) यासाठी मोठ्या भांडवलाची आवश्यकता असते. भांडवली खर्चाच्या तुलनेत कमी अनुदान मिळत असल्याने काही लाभार्थी ड्रोन खरेदी करण्यास टाळाटाळ करतात.
- मर्यादित बॅटरी क्षमता: एका चार्जिंगमध्ये किसान ड्रोन केवळ ८ ते १० मिनिटे उड्डाण करू शकतो.
- तांत्रिक कौशल्य : किसान ड्रोन साठी केवळ ड्रोन उडविण्याचे कौशल्य असून चालत नाही तर कीडनाशक औषधांची निवड, प्रमाण व फवारणीची वेळ याबाबत देखील ज्ञान असणे आवश्यक आहे.
- फवारणी करताना वाऱ्यामुळे कीडनाशक औषधे इतरत्र उडण्याची शक्यता आहे.

**<u>Case study for Drone Application (Snail infestation)</u>**

1. **Expected application / use case of drones pertaining to the Ministry / Department:** Assessment of cadastral level crop damage caused by snail infestation in three villages of Latur and Osmanabad districts using Drone/UAV data on experimental basis.

2. **Problem statement in detail (max 750 words):** During the kharif season 2023 in the month of July second week heavy attack of conical snails are evident in Osmanabad and Latur districts, particularly infesting soybean crop. It was requested by Department of Agriculture, Govt. of Maharashtra, to carry out the drone survey for cadastral level damage assessment on pilot basis, three villages are selected.

   Mirror less DSLR camera (Sony Alpha 6000) with Red, Green and Blue (RGB) having a special resolution of less than 5cm and each photo of 6000 X 4000 pixels in dimension were captured both in JPEG and Raw format. UAV were flown during the period of 17th August to 24th August 2022 amidst frequent rain spells. Drones were equipped with RTK/PPK for precise image location capturing. DGPS points @10 points per village were taken with proper paint markings on ground before commencing flights.

3. **Anticipated benefits of using drone in the given problem statement (max 750 words):** Cadastral level crop damage is assessed using the UAV data and results are produced in terms of maps and statistics. All the three villages and their individual parcels were categorised into more than 33 % crop damage and less than 33 % crop damage and are colour coded accordingly. Results were provided to Agriculture department.

4. **Where will the system be deployed?**
   Considering the time and expenditure incurred does not support use of drone for large scale area assessment.

5. **Any other information**
   **PPT Attached for details**

**For any query, please contact: Prof. Arnab Maity, Dept. of Aerospace Engg., IIT Bombay, Mumbai**
**Email: arnab@aero.iitb.ac.in / arnab.maity@iitb.ac.in , Mobile / WhatsApp: +91 9986526336**

1. **Name of the Ministry / Department**

   Public Health Department, Government of Maharashtra.

2. **Contact person information, including his/her email id and contact number**

   **Name -** Dr. Vijay Kandewad, Joint Director (Hospitals), Directorate of Health Services, Aarogya Bhavan, St. George's Hospital compound, P.D'Mello road, Mumbai-400001.
   **Email ID -** vijayjyoti23@gmail.com
   **Contact No. -** 9326893673

3. **Expected application / use case of drones pertaining to the Ministry / Department**

   i. **Drug Delivery to Remote Location**: Drones can be used to deliver drugs/medicines to remote locations, especially hilly areas, forest areas, state border etc. Location can be a) Sub Centre or PHC b) hamlets (Tanda) where accessibility to nearest health outpost is far 3) any other location where the medical camp may be organized . This may be for routine cases of stock distribution.

   ii. **Vaccine Delivery to Remote Location** : This is a special case of delivery where the payload has to be in COLD CHAIN. Depending on the type of vaccine, the temperature requirement may be higher. The simplest way to reduce the payload is via a Ice Box with approximately controlled temperature range with ice or dry ice etc. Higher version may be a thermostat controlled refrigerated container.

   iii. **Anti Snake Venom and Anti Rabies shot** : This a emergency use, where the qualified doctor can administer the ASV in case stock is not there at the location of the patient. The ASV stock can be sent by drone in short time.

   iv. **Emergency reconnaissance** : In case of emergency / calamity the drone can reach remote location or site of calamity accident and take stock of injured or casualty.

   - The assessment can be a planning tool to effectively understand medical interventions needed. This can be followed through by a payload of medicines/ essential drugs etc.
   - **Drone with VIDEO Camera**: This ER Drone can be equipped with VIDEO recorder – So the affected persons can record videos into this and send to base – that can be a way to receive authentic status.
   - **Drone with 2 Way Audio Communication** : Drone can also be fitted with 2 way radio frequency transmitters for remote locations to communicate. The Drone can also **be fitted with Loudspeaker** if needed to **give announcements**.
   - Issue : in case of no cellular connectivity alternate connectivity infrastructure has to be figured in.

   v. **Construction Tracker** : Drones can be used to videograph ongoing construction of hospitals, site selection assessment can also be done.

4. **Problem statement in detail (Max. 750 words)**

There are few areas of Maharashtra where there is very poor or no road connectivity, hilly or forest areas, or villages cut off by rivers, where there is unavailability of bridges etc, where the logistics supply is difficult or takes time or is sometimes impossible due to seasonal reasons. The villages may be far away distance from PHC or Subcentre . Secondly, in Monsoon many areas are cut off. Thirdly, there are emergency uses like train accident, bus accident site where fast response can be done via drone assessment and sending of emergency personnel ( First Responder ).

5. **Anticipated benefit(s) of using drone in the given problem statement (Max. 750 words)**

   i. Timely delivery in shortest time.
   ii. Reaching unreacheable location and people.
   iii. Getting information during emergency. This will save time and lead to lives being saved in emergencies.
   iv. Construction tracker will enable timely monitoring of large building sites by higher officials to assess progress.

6. **Where will the system be deployed?**

   - Remote locations like Melghat ( Can be deployed off Pandarkhavda, Dt. Amravati ). Various locations in Nandurbar, Palghar. Some parts in South Konkan where large waterbodies make road travel longer than direct flying time, also due to hilly terrain.

7. **Any other information**

   Nil.

# Maharashtra Drone Mission

***Establishing a World Class Drone Hub***

## Template for Survey of Application / Use Case Specific Requirements

**For any query, please contact: Prof. Arnab Maity, Dept. of Aerospace Engg., IIT Bombay, Mumbai**
**Email: arnab@aero.iitb.ac.in / arnab.maity@iitb.ac.in , Mobile / WhatsApp: +91 9986526336**

1. Name of the Ministry / Department

Disaster Management Unit, Relief & Rehabilitation, Govt. of Maharashtra, India

2. Contact person information, including his/her email id and contact number

Shri. Hitendra Dufare, Under Secretary, Relief & Rehabilitation, Govt. of Maharashtra, India

Mobile Number - +91 94047 39083 | Email ID - director.dm@maharashtra.gov.in , hitendra.dufare@gmail.com

3. Expected application / use case of drones pertaining to the Ministry / Department

**Pre-Disaster**

1. Periodical monitoring and mapping of drought prone areas.
2. Pre-monsoon mapping flood prone areas.
3. Mapping of the terrain to acquire high resolution images for detailed land use and land cover mapping.
4. Detection of forest fire hotspots.
5. Alert the population that are likely to at risk due to some natural calamities (Early warning dissemination)

**During Disaster – Mapping, Detection, and Damage and Loss Assessment**

1. Mapping of the disaster affected area, irrespective of the disasters, to acquire real time imagery to carry out damage and loss (agriculture, house, communication infra, and important route) assessment.
2. Detection of human and animal body trapped in debris and in an inaccessible area.
3. Provide access to internet services using wifi hotspot.
4. Payload drones can be used to spray disinfectant to expel locusts from agriculture fields.

**Surveillance & Live Video Streaming**

1. Provide real time access of data to relief agencies such as NDRF, SDRF, ARMY, and decision-making authorities to provide quick assistance to the victims to save **(Search and Rescue)** their lives.
2. Provide access to the public through Social Media platforms, *given the good internet bandwidth.*
3. Capturing movement of the people and situation (Including relief distribution) during the emergency period to take necessary action as per the law and order.
4. Identify the safe space for temporary shelter establishment.

**Public Awareness**

1. Create public awareness to take necessary actions to reduce the mounting risk during the emergency.

**Delivery of essentials**

1. Delivery of consumable items, medicine, and personal protective equipment.

**Supply Chain Management**

1. Provide alternate and safe routes to access the warehouse in disaster affected areas.

**Post – Disaster**

1. Mapping of the disaster affected area to restore the essential services providing institutions and points.
2. Periodical monitoring of the development work during the recovery phase.

4. Problem statement in detail (Max. 750 words)

Every year, Maharashtra State experiences both anticipated seasonal disasters and unforeseen calamities. However, the process of accurately assessing the extent of damage and losses faced by disaster victims has proven to be arduous and challenging for the disaster management unit of Relief and Rehabilitation. This has resulted in delays in providing timely assistance to those affected. In some cases, the magnitude of the disaster creates a harrowing situation for the disaster management authorities and relief agencies, making it difficult to reach the affected population, individuals, and communities during the critical initial hours. Successful disaster management relies on effective coordination among multiple agencies, but the lack of real-time data exacerbates the severity of the situation. The absence of up-to-date information hinders the agencies' ability to coordinate search and rescue operations, as well as the distribution of essential supplies such as food and non-food items. Transmitting real-time data from the affected areas has always been a challenge, impeding crucial decision-making processes that support government agencies, individuals, volunteers, and humanitarian organizations in effectively managing the emergency. The absence of a comprehensive perspective on the scale of the disaster further complicates matters. During emergencies, the disruption of vital communication and transportation services severely hampers the response efforts, resulting in inadequate assistance to those most severely impacted.

5. Anticipated benefit(s) of using drone in the given problem statement (Max. 750 words)

1. Precise damage and loss assessment.
2. Decreased in number of casualties.
3. Access to real time situation.
4. Reaching out last mile within the affected area.
5. Transmission of real time information to possible district and state level authorities.
6. Forming critical decision without delay.
7. Reducing risk through essential public awareness (acoustic system).
8. Avoid duplication of efforts.
9. Provide space and opportunity to all disaster management agencies including humanitarian to respond to disasters effectively.
10. Identifying invisible casualties.
11. Able to start the operation during the nighttime.
12. Provides perspective view of the disaster affected areas.
13. Provides data about safe and alternate routes to reach the relief camp in the least possible time.

14. Where will the system be deployed?

1. Wherever there will be a disaster occur.

2. Any other information

NO

## Template for Survey of Application / Use Case Specific Requirements

**For any query, please contact: Prof. Arnab Maity, Dept. of Aerospace Engg., IIT Bombay, Mumbai**
**Email: arnab@aero.iitb.ac.in / arnab.maity@iitb.ac.in , Mobile / WhatsApp: +91 9986526336**

1. **Name of the Ministry / Department**

   Water Resources Department, Government of Maharashtra

2. **Contact person information, including his/her email id and contact number**

   **Mrs. Namita Baser, Deputy Secretary, WRD, Maharashtra**

3. **Expected application / use case of drones pertaining to the Ministry / Department**

   i. Estimation of Crop yield, including mapping of agriculture area for effective water management

   ii. Carry out Land Use Land Change (LULC) studies in the catchment and command area of irrigation project

   iii. Provide framework for effective catchment area treatment on the upstream side of the reservoir.

   iv. Providing framework for assessing the Crop Compensation during climate change extreme events (e.g. Floods and droughts)

   v. Preparation of Disaster mitigation plan including inundation mapping due to floods and dam breach – Carry out pilot study for Pune city

   vi. Carry out vulnerability assessment of Landslides on upstream of reservoirs and provide remedial action plan

   vii. Provide framework for dam and canal asset management including mapping of acquired land, dams, canal, pipelines, hydro projects infrastructure and provide good quality images of the dams, canal structures etc.

   viii. Assist WRD for formulating policies for use of Drone in Water Management, Project Planning, Construction management, project progress monitoring etc.

   ix. Implementation of R&D in this area for effective and efficient water and agriculture management.

   x. Development of road map for development of Hydro-electric projects in the Maharashtra

   xi. Development of road map for development of tourism near water resources projects in the Maharashtra

4. **Problem statement in detail (Max. 750 words)**

   The tentative list of potential drone applications in the domain of water management is mentioned above. We are open to discuss these topics in order to finalize the feasibility, decide the roles & responsibilities of the parties associated with this project and deciding the priority of activities.

5. **Anticipated benefit(s) of using drone in the given problem statement (Max. 750 words)**

   The tentative list of potential drone applications in the domain of water management is mentioned above. We are open to discuss these topics in order to finalize the feasibility, decide the roles & responsibilities of the parties associated with this project and deciding the priority of activities.

6. **Where will the system be deployed?**

   At various offices of the WRD

7. **Any other information**

   Nil.

# Maharashtra Drone Mission

*Establishing a World Class Drone Hub*

## Template for Survey of Application / Use Case Specific Requirements

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Email: arnab@aero.iitb.ac.in / arnab.maity@iitb.ac.in , Mobile / WhatsApp: +91 9986526336

1. **Name of the Ministry / Department**

   PUBLIC WORKS DEPARTMENT.

2. **Contact person information, including his/her email id and contact number**

   1) Shri. P. S. AUTI,
      CHIEF ENGINEER, PUBLIC WORKS REGION, NASHIK
      Email: nashik.ce@mahapwd.gov.in
      Contact No.: 8483907907

   2) Smt. A. M. SHARMA,
      SUPERINTENDING ENGINEER, PUBLIC WORKS CIRCLE, NASHIK
      Email: nashik.se@mahapwd.gov.in
      Contact No.: 9923281333

3. **Expected application / use case of drones pertaining to the Ministry / Department**

   a) Precise measurements related to existing roads and bridges,
   b) Stockpile volumetric measurements,
   c) Inspection of inaccessible areas particularly under bridges and water bodies, bed data
   d) Accurate and exhaustive data related to road levels and bridge levels,
   e) Horizontal curve details, alongwith measurements,
   f) Details of vertical grades and hilly areas boundaries,
   g) Ground features.
   h) Catchment area calculations.
   i) Traffic count & Study.

4. **Problem statement in detail (Max. 750 words)**

   a. Ground features which are hard to recognize or clarify which are covered by, forest or other tall buildings and wooden areas.
   b. River bed details, tunnels, details under bridge, slope measurement details need to be precise.
   c. Bench mark references are difficult to relocate for field engineers if further work to be added/ continued.

5. **Anticipated benefit(s) of using drone in the given problem statement (Max. 750 words)**

   a. Reduce field time.
   b. Survey cost shall be minimum.
   c. Provide accurate and exhaustive data.

d. Mapping of inaccessible areas.
e. Relocation of location of bench marks considered (GPS).
f. Accessibility to river bed irrespective of season
g. Real time site update.

6. **Where will the system be deployed?**

a. State road development works, preparation of Detail Project Report,
b. Bridge conditions, slope protection works,
c. Ghat road details,
d. Forest area markings,
e. Road details passing through villages/ towns,
f. Existing drainage & water supply scheme details.

7. **Any other information**

1) To make a model for execution.
2) It is needed to make presentation before Hon.Addl.Chief Secretary, P.W.D., Govt. of Maharashtra on 03/08/2023.
3)

**(P.S. AUTI)**
Chief Engineer,
Public Works Region, Nashik

**For any query, please contact: Prof. Arnab Maity, Dept. of Aerospace Engg., IIT Bombay, Mumbai**
**Email: arnab@aero.iitb.ac.in / arnab.maity@iitb.ac.in , Mobile / WhatsApp: +91 9986526336**

1. Name of the Ministry / Department-

   Anti-Terrorism Sqaud, Maharashtra, Mumbai

2. Contact person information, including his/her email id and contact number-

   1) Name- Shri. Ashok Virkar, Superintendent of Police (Tech), Maharashtra State, Mumbai
   2) Email-ID- dcp.ats@mahapolice.gov.in
   3) Contact Number- 9922287928

3. Expected application / use case of drones pertaining to the Ministry / Department

   - Aerial photography for journalism and film
   - Express shipping and delivery
   - Gathering information or supplying essentials for disaster management
   - Thermal sensor drones for search and rescue operations
   - Geographic mapping of inaccessible terrain and locations
   - Building safety inspections
   - Precision crop monitoring
   - Unmanned cargo transport
   - Law enforcement and border control surveillance

4. Problem statement in detail (Max. 750 words)

1) The Drone manufacturer in India should have software and firmware which are compatible with the DigiSky platform. There should be a provision in the software to modify it as per the changes in the Digisky Platform.

2) The red zones in DigiSky Platforms are subject to change. The drone manufacturers should provide a feature to download the map of red zone, even if it is so commanded.

3) The arming status of the drone and the information regarding drone activation location should be made available on DigiSky platform.

4) There should be an inbuilt security feature to ensure that a drone cannot be armed in the Red Zone.

5) Each drone is fitted with a tracker, which relays the drone Id and its GPS coordinates. Presently, it is possible to tamper the tracker of a drone. The manufacturer should ensure that the installation of tracker is tamper proof. Likewise, the GPS System fitted in the drone should be tamper proof.

6) The information regarding the flying drone should be passed from the control panel to the DigiSky and the same should be made available to security agnecies on real – time basis.

7) Every control panel should have authentication features by way of Password, Fingerprint of Facelock to avoid unausthorised use of an unregistered or stolen drone.

8) The information regarding the speed and payload of the drone can be estimated from the telemetry data. This telemetry data of a flying drone should be available to Law Enforcement Agencies on the Digisky Platform.

9) ‘ Fail-Safe’ mode of the drone should have the only option of RTH ( Return to Home). There should not be option of ‘ Hovering’ or ‘ ‘Free-Fall ‘

5. Anticipated benefit(s) of using drone in the given problem statement (Max. 750 words)

1) The Drone manufacturers should provide a feature to download a map of red zones so for it can be useful for drone pilot and it can prevent entry of unauthorized drones in Red Zone.

2) The arming status of Drone and information regarding drone activation location should be made available, so that can help to provide information of authorized flying drones.

6. Where will the system be deployed?

1) Portable Anti-Drone System to secure Vital Installations, Hot Spots, Vulnerable Locations, VVIPs meeting areas or places.

2) Vehicle Mounted Anti-Drone Systems for VVIP security or VVIP meetings Venue.

7. Any other information

## Maharashtra Drone Mission

*Establishing a World Class Drone Hub*

## Template for Survey of Application / Use Case Specific Requirements

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**Email: arnab@aero.iitb.ac.in / arnab.maity@iitb.ac.in , Mobile / WhatsApp: +91 9986526336**

### 1. Name of the Ministry / Department

**Urban Development Department 1 (UD 1)**

### 2. Contact person information, including his/her email id and contact number

Mr. Jitendra Bhople, Joint Director, Urban Development Department 1 (UD 1), Govt. of Maharashtra

Mobile: +91 99672 91943

### 3. Expected application / use case of drones pertaining to the Ministry / Department

Drones play a significant role in urban development, offering various applications that contribute to planning, monitoring, and managing urban areas more effectively.

**A. Aerial Surveys and Mapping:**

- **City Planning:**
  Drones equipped with high-resolution cameras can capture detailed aerial imagery to aid in urban planning. This information helps city planners assess land use, identify infrastructure needs, and plan for future development.
- **Mapping and GIS:**
  Drones can create accurate 3D maps and models of urban areas. This data is valuable for creating geographic information system (GIS) databases, which can be used for infrastructure planning, environmental monitoring, and disaster response.

**B. Infrastructure Inspection:**

- **Building Inspections:**
  Drones can be used to inspect the structural integrity of buildings and infrastructure. This is particularly useful for identifying maintenance needs, potential safety hazards, and ensuring compliance with regulations.
- **Bridge and Road Inspections:**
  Drones equipped with sensors can inspect bridges and roads for signs of wear, damage, or potential issues. This data helps in prioritizing maintenance and infrastructure improvement projects.

**C. Environmental Monitoring:**

- **Air Quality Monitoring:**
  Drones can carry sensors to monitor air quality in different parts of the city. This information is crucial for assessing pollution levels, identifying sources of contamination, and implementing measures to improve air quality.

- **Green Space Management:**
  Drones can monitor the health of parks and green spaces, providing insights into vegetation health, water features, and overall environmental conditions.

**D. Traffic Management:**

- **Traffic Flow Analysis:**
  Drones can capture real-time footage of traffic patterns and congestion. This data can be analyzed to optimize traffic signal timings, plan for new roadways, and improve overall traffic management.

- **Emergency Response:**
  In the event of accidents or emergencies, drones can provide real-time situational awareness to emergency responders, helping them assess the situation and plan their response more effectively.

**E. Disaster Response and Management:**

- **Post-Disaster Assessment:**
  After natural disasters, drones can quickly survey affected areas, providing crucial information on the extent of damage. This aids in planning and prioritizing response efforts.
- **Search and Rescue:**
  Drones equipped with thermal imaging cameras and other sensors can assist in search and rescue operations, especially in urban environments where traditional methods may be more challenging.

**F. Public Safety:**

- **Surveillance and Monitoring:**
  Drones can enhance public safety by providing surveillance in crowded areas, monitoring events, and assisting law enforcement in various situations.
- **Emergency Communication:**
  Drones equipped with communication systems can provide temporary connectivity in areas with disrupted communication networks, enhancing the ability to coordinate emergency responses.

## 4. Problem statement in detail (Max. 750 words)

**A. Limited Flight Time:**

**Issue:** Drones typically have limited battery life, restricting the amount of time they can spend in the air during a survey mission.

**Impact:** Reduced coverage area and the need for frequent landings and take-offs, leading to inefficiencies in surveying and mapping operations.

**B. Weather Dependency:**

**Issue:** Adverse weather conditions such as strong winds, rain, or low visibility can impede drone flights, affecting survey schedules.

**Impact:** Delays in data collection, increased operational risks, and challenges in maintaining consistent survey quality.

**C. GPS Signal Interference:**

**Issue:** Urban environments often have structures that cause GPS signal interference, leading to inaccurate drone positioning and compromised mapping precision.

**Impact:** Reduced accuracy in survey data, affecting the reliability of maps and models created from drone-collected information.

**D. Obstacle Avoidance:**

**Issue:** Drones may encounter obstacles such as buildings, trees, or power lines during flight, posing a risk of collisions.

**Impact:** Safety concerns, potential damage to the drone, and disruptions in surveying activities due to the need for manual intervention to avoid obstacles.

**E. Data Transmission and Storage:**

**Issue:** Large volumes of data collected by drones need to be transmitted and stored efficiently for processing and analysis.

**Impact:** Slow data transfer, potential loss of information, and challenges in managing and storing data during and after survey missions.

**F. Sensor Calibration and Accuracy:**

**Issue:** Ensuring the proper calibration of sensors (e.g., cameras, LiDAR) on the drone to maintain data accuracy.

**Impact:** Inaccurate sensor readings leading to distorted maps, 3D models, or other survey outputs, affecting the reliability of the collected data.

**G. Regulatory Compliance:**

**Issue:** Adherence to complex and evolving regulations related to drone flights, airspace restrictions, and permits for surveying activities.

**Impact:** Legal challenges, delays in obtaining necessary approvals, and potential fines for non-compliance, hindering surveying operations.

**H. Communication Issues:**

**Issue:** Loss of communication between the drone and the ground control station, especially in urban environments with signal interference.

**Impact:** Loss of control over the drone, safety risks, and potential damage to the equipment.

**I. Privacy Concerns:**

**Issue:** Privacy issues arising from the collection of aerial imagery in urban areas, leading to public resistance or legal challenges.

**Impact:** Negative public perception, potential legal actions, and challenges in gaining community acceptance for drone surveying activities.

**J. Limited Payload Capacity:**

**Issue:** Drones have limitations in terms of the weight they can carry, affecting the type and number of sensors that can be deployed.

**Impact:** Constraints on the versatility of surveying equipment, limiting the range of data that can be collected during a single flight.

**K. Varying Terrain and Altitude:**

**Issue:** Surveying areas with diverse terrain and elevation changes can pose challenges in maintaining consistent altitude and data quality.

**Impact:** Inconsistent survey data, affecting the accuracy of maps and models, especially in areas with significant elevation variations.

**L. Uneven Terrain and Altitude Changes:**

**Issue:** Hilly terrains present constant changes in elevation, making it challenging to maintain consistent drone altitude during survey flights.

**Impact:** Inaccuracies in mapping data due to varying distances from the terrain, affecting the quality of elevation models and topographic maps.

**M. Limited Line-of-Sight:**

**Issue:** Hilly landscapes often result in limited line-of-sight for both the drone and the remote pilot, potentially leading to communication and navigation challenges.

**Impact:** Increased risk of signal loss, difficulty in maintaining visual contact with the drone, and heightened safety concerns during flights.

**N. Wind Gusts and Updrafts:**

**Issue:** Hilly regions are prone to unpredictable wind patterns, including gusts and updrafts, affecting drone stability.

**Impact:** Reduced flight stability, potential loss of control, and compromised data quality due to the impact of wind on the drone's path.

**O. Data Occlusion and Shadows:**

**Issue:** The uneven terrain can result in data occlusion, where certain areas are hidden from the drone's sensors, and shadows can obscure details.

**Impact:** Incomplete survey data, reduced accuracy in mapping, and challenges in creating comprehensive 3D models of the terrain.

**P. Precise Terrain Following:**

**Issue:** Ensuring the drone follows the natural contours of the terrain accurately to maintain a consistent distance from the ground.

**Impact:** Inaccuracies in elevation data, potential collisions with the terrain, and compromised safety during flights over hilly landscapes.

**Q. Battery Management in Elevation Changes:**

**Issue:** Managing drone battery life becomes more challenging in hilly terrains due to increased energy consumption during altitude changes.

**Impact:** Limited flight time, the need for frequent battery changes, and potential disruptions in surveying operations.

**R. Limited Accessibility:**

**Issue:** Hilly regions may have limited access points, making it difficult to deploy and retrieve drones for surveying missions.

**Impact:** Increased logistical challenges, longer preparation times, and potential delays in reaching and surveying specific areas.

**S. Optimal Survey Route Planning:**

**Issue:** Planning efficient survey routes that consider the topography, minimizing the impact of elevation changes on data collection.

**Impact:** Suboptimal survey coverage, longer mission times, and challenges in creating cohesive and accurate maps of hilly landscapes.

**T. Sensor Calibration for Sloped Surfaces:**

**Issue:** Ensuring that sensors are properly calibrated to account for sloped surfaces in hilly terrains.

**Impact:** Inaccuracies in sensor readings, leading to distorted elevation data and potential errors in topographic maps.

**U. Limited Landing Sites:**

**Issue:** Identifying suitable and safe landing sites in hilly areas with restricted flat spaces.

**Impact:** Increased risk of accidents during landing, potential damage to the drone, and challenges in completing survey missions.

## 5. Anticipated benefit(s) of using drone in the given problem statement (Max. 750 words)

Using drones in the context of surveying and mapping in hilly regions brings forth several anticipated benefits that can significantly enhance the efficiency, accuracy, and safety of such operations:

**A. Cost Efficiency:**

Drones provide a cost-effective alternative to traditional surveying methods, reducing the expenses associated with manpower, equipment, and logistics. This is particularly advantageous in hilly terrains where ground-based surveys might be more challenging and costly.

**B. Rapid Data Collection:**

Drones can cover large areas quickly, enabling rapid data acquisition even in hard-to-reach or remote hilly regions. This speed is crucial for timely decision-making in various applications, including land development and disaster response.

**C. High-Resolution Imaging:**

Equipped with advanced cameras and sensors, drones can capture high-resolution imagery, allowing for detailed mapping of the terrain. This enhances the accuracy of elevation models, topographic maps, and 3D reconstructions.

**D. Improved Safety:**

Drones mitigate safety risks associated with traditional survey methods, especially in challenging terrains. They can navigate difficult landscapes without exposing human surveyors to hazardous conditions, reducing the likelihood of accidents.

**E. Precision and Accuracy:**

Drones equipped with GPS and advanced sensors can achieve high levels of precision in mapping elevation changes and capturing topographic details. This results in more accurate and reliable survey data, essential for various applications such as infrastructure planning and environmental monitoring.

**F. Flexibility in Survey Planning:**

Drones offer flexibility in planning survey routes, adapting to the contours of hilly landscapes. This flexibility allows for optimal coverage of the terrain and the ability to navigate areas that may be inaccessible to traditional survey methods.

**G. Real-Time Data Analysis:**

Drones can transmit data in real-time, enabling on-the-fly analysis of survey information. This immediate feedback is valuable for adjusting survey parameters, ensuring data quality, and making informed decisions during the survey mission.

**H. Environmental Monitoring:**

Drones facilitate effective environmental monitoring in hilly regions. They can survey vegetation, water bodies, and other ecological features, providing valuable data for conservation efforts, forestry management, and biodiversity assessments.

**I. Accessibility to Remote Areas:**

Drones can access remote and difficult-to-reach areas in hilly terrain, overcoming challenges associated with limited infrastructure or road access. This capability is crucial for comprehensive mapping and surveying in remote regions.

**J. Reduced Environmental Impact:**

Compared to traditional survey methods that may involve heavy machinery and ground disturbances, drones have a minimal environmental impact. This is particularly important in ecologically sensitive hilly areas where conservation efforts are prioritized.

**K. Community Engagement:**

The use of drones can enhance community engagement by providing visualizations and maps that are easily understandable. This can facilitate better communication between surveyors, planners, and local communities, fostering collaboration in development projects.

**L. Time-Saving:**

Drones significantly reduce surveying time, allowing for quicker project completion. This time-saving aspect is crucial for time-sensitive projects or emergency response situations in hilly regions.

## 6. Where will the system be deployed?

The deployment of the drone surveying and mapping system in hilly regions will be strategically planned to address specific needs and objectives. Potential deployment scenarios include:

**1. Environmental Conservation Areas:**

In hilly regions designated for environmental conservation, the drone system can be deployed to monitor and assess ecological features, biodiversity, and changes in vegetation over time.

**2. Infrastructure Planning and Development:**

The system can be deployed in hilly areas earmarked for infrastructure development projects, such as roads, bridges, and utility installations. This aids in efficient surveying and planning.

**3. Disaster-Prone Zones:**

In regions prone to natural disasters (e.g., landslides, floods), the drone system can be deployed for pre-disaster mapping, monitoring, and rapid post-disaster assessments.

**4. Remote and Inaccessible Locations:**

Hilly regions that are remote or difficult to access can benefit from drone deployment. These areas may include rugged landscapes with limited road infrastructure.

**5. Urban Development Projects:**

In urban areas with hilly terrain, the system can be deployed for detailed mapping and surveying in support of urban planning, infrastructure development, and construction projects.

**6. Forest Management Areas:**

Hilly forested regions can be surveyed to monitor tree health, assess forest cover, and gather data for sustainable forest management practices.

**7. Mining and Resource Exploration:**

In hilly regions with mining or resource exploration activities, the drone system can be deployed to survey geological features, assess terrain conditions, and monitor environmental impacts.

**8. Tourism and Recreation Zones:**

Hilly regions that attract tourists for recreational activities can benefit from drone mapping for trail planning, environmental impact assessments, and visitor management.

**9. Research and Academic Institutions:**

Academic institutions and research organizations can deploy the system for scientific research, environmental studies, and geographical surveys in hilly regions.

10. **Community-Based Mapping Projects:**
    Collaborative projects involving local communities can utilize the drone system for participatory mapping, land-use planning, and community development initiatives in hilly areas.
11. **Government Agencies and Municipalities:**
    Government bodies responsible for urban planning, disaster management, and environmental protection can deploy the system to enhance their decision-making processes in hilly regions.
12. **Conservation Reserves and Protected Areas:**
    In areas designated as conservation reserves or protected wildlife habitats, the drone system can assist in monitoring and safeguarding these regions.

The specific deployment location will depend on the project goals, whether it's for environmental monitoring, infrastructure development, disaster management, or other applications. Considerations will include the terrain characteristics, accessibility, regulatory requirements, and the objectives of the surveying and mapping initiative.

## 7. Any other information

1. **Community Engagement:**
   **Importance:** Informing and engaging local communities in drone surveying projects can foster understanding and cooperation.
   **Action:** Conduct community outreach programs, provide information about the purpose and benefits of the survey, and address any concerns or questions from the local population.
2. **Ecological Impact Assessment:**
   **Importance:** Assessing the potential ecological impact of drone operations on local flora and fauna is vital, especially in environmentally sensitive areas.
   **Action:** Conduct ecological impact assessments and implement measures to minimize disturbances to wildlife and ecosystems during drone operations.
3. **Collaboration with Stakeholders:**
   **Importance:** Collaborating with various stakeholders, including government agencies, NGOs, and local authorities, can enhance the success of drone surveying projects.
   **Action:** Establish partnerships, share project objectives, and collaborate on data-sharing agreements to ensure a holistic and integrated approach to surveying.
4. **Emergency Response Planning:**
   **Importance:** Having contingency plans for emergencies, such as equipment malfunctions or unexpected weather changes, is crucial for safety.
   **Action:** Develop and communicate emergency response plans, including procedures for drone malfunctions, unexpected weather events, and other potential risks.
5. **Data Accessibility and Transparency:**
   **Importance:** Ensuring that survey data is accessible and transparent can promote trust among stakeholders.
   **Action:** Consider open data principles, providing accessible and transparent data to relevant stakeholders while respecting privacy and security concerns.

मंत्रालयीन सेवा

सत्यमेव जयते

स्वातंत्र्याचा अमृत महोत्सव

**महाराष्ट्र शासन**
**सामान्य प्रशासन विभाग (माहिती तंत्रज्ञान)**
**७१९, वा मजला ७, मंत्रालय (विस्तार),**
**मादाम कामा मार्ग, हुतात्मा राजगुरु चौक,**
**मंत्रालय, मुंबई.०३२ ४००-**

**दुरध्वनी क्र.०२२ २२०२४१७७** **ई-मेल-do39-dit@mah.gov.in**

**क्र.संकीर्ण-१७२३/प्र.क्र.४१/से-५/३९** **दिनांक - ०१ ऑगस्ट, २०२३**

**प्रति,**

१) श्रीम.जयश्री भोज, व्यवस्थापकीय संचालक,महाअयटी.

२) प्रो.अर्नब मैटटी व इतर आयआयटी सदस्य.

**विषय** - महाराष्ट्र ड्रोन मिशनबाबतच्या बैठकीचे इतिवृत्त..

महोदय/महोदया,

प्रधान सचिव (मातं) यांच्या अध्यक्षतेखाली दि. १९/७/२०२३ रोजी दु. ०४.०० वा महाराष्ट्र ड्रोन मिशनबाबतची बैठक पार पडली. सदर बैठकीचे इतिवृत्त सोबत जोडून पाठविण्यात येत आहे.

आपला,

(अ.सा.चंदनशिवे)
उप सचिव, महाराष्ट्र शासन

**उप सचिव**
**सामान्य प्रशासन विभाग (माहिती तंत्रज्ञान)**
**महाराष्ट्र शासन**
**मंत्रालय, मुंबई - ४०० ०३२.**

**प्रत** - १) प्रधान सचिव (मातं) यांचे स्वीय सहायक, मंत्रालय, मुंबई ३२

२) उप सचिव (मातं) यांचे स्वीय सहायक, मंत्रालय, मुंबई ३२

३) निवडनस्ती.

## बैठकीचे इतिवृत्त

प्रधान सचिव (मातं) यांच्या अध्यक्षतेखाली महाराष्ट्र ड्रोन मिशन या विषयाबाबत दि.१९/०७/२०२३ रोजी दु. ०४.०० वा बैठक पार पडली. सदर बैठकीसाठी पुढील सदस्य उपस्थित होते.

१) श्री. पराग जैन-नैनुटिया, प्रधान सचिव, माहिती व तंत्रज्ञान
२) श्री.अंबादास चंदनशिवे, उप सचिव, माहिती तंत्रज्ञान
३) श्रीम. जयश्री भोज, व्यवस्थापकीय संचालक,महाअयटी
४) प्रो. अर्नब मैटटी, आयआयटी
५) प्रो. अदीनारायन जागरलपुडी, आयआयटी
६) प्रो.परमेश्वर उदमाले, आयआयटी
७) प्रो. ध्वनील शुक्ला, आयआयटी

**सदर बैठकीत चर्चा झालेले मुद्दे व त्यावर कार्यवाही करणारे विभाग/ कार्यालय पुढीलप्रमाणे आहेत.**

| अ.क्र. | मुद्दा | कार्यवाही करणारा विभाग/कार्यालय | कालमर्यादा |
|---|---|---|---|
| १ | महाराष्ट्र ड्रोन धोरण शासनास सादर करणे. | महाआयटी | ८ दिवस |
| २. | महाराष्ट्र ड्रोन मिशनमध्ये महाराष्ट्र शासनाची व आयआयटी संस्थेची भूमिका आणि महाराष्ट्र ड्रोन मिशनची टप्प्याटप्प्याने अंमलबजावणी (Phase wise Implementation) याबाबत अहवाल सादर करणे. कृषी, आरोग्य इ. विभांगामध्ये ड्रोनचा यशस्वीपणे वापर केला जाऊ शकतो अशा विभागांच्या सचिवांशी परस्पर संपर्क साधणे व प्रस्ताव तयार करणे. | आयआयटी | ८ दिवस |
| ३. | ड्रोनचा वापर महामार्गावर / द्रुतगती मार्गांवर निगराणी करण्यासाठी परिवहन विभागामार्फत करण्यात येईल. | परिवहन विभाग व आयआयटी | ८ दिवस |
| ४. | ड्रोनसह मोबाईल व्हॅन (Mobile Van with Dron Setup )बाबत अहवाल सादर करण्यात येईल | आयआयटी | ८दिवस |

८ दिवसांनंतर प्रस्तावासह पुढील बैठक आयोजित करण्याचे निर्देश देऊन व उपस्थितांचे आभार मानुन बैठक संपन्न झाली.

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उप सचिव
सामान्य प्रशासन विभाग (माहिती तंत्रज्ञान)
महाराष्ट्र शासन
मंत्रालय, मुंबई - ४०० ०३२.

**Maharashtra Drone Mission**

*Establishing a World Class Drone Hub*

Template for Survey of Application / Use Case Specific Requirements

**For any query, please contact: Prof. Arnab Maity, Dept. of Aerospace Engg., IIT Bombay, Mumbai**
**Email: arnab@aero.iitb.ac.in / arnab.maity@iitb.ac.in , Mobile / WhatsApp: +91 9986526336**

1. Name of the Ministry / Department

   Department of Rural Development and Panchyati Raj

2. Contact person information, including his/her email id and contact number

   Mr. Prashant Patil, Dy Secretary ~~Phone~~ Mobile No 9967329826

   Mr Valvi Joint Secretary mobile No - 9920768008

3. Expected application / use case of drones pertaining to the Ministry / Department

4. Problem statement in detail (Max. 750 words)

   (1) Rural Connectivity, Road condition and maintance

   (2) Asset mapping of villages.

5. Anticipated benefit(s) of using drone in the given problem statement (Max. 750 words)

   It will help in proper decision making.

   ~~Will~~ Asset mapping will ensure to avoid duplication work.

6. Where will the system be deployed?

   Expected at District level.

7. Any other information

   Problem stated in point no. 4 could be discussed further, Preliminary discussion had be done during VC with IIT Team,