सत्यमेव जयते

TELECOMMUNICATION ENGINEERING CENTRE
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Study Paper

On

Use Cases of Drones in Disaster Management

April 1, 2024

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CONTENTS

1.0 BACKGROUND

1.1 India is susceptible to various natural disasters including floods, droughts, cyclones, tsunamis, earthquakes, urban flooding, landslides, avalanches, and forest fires because of its particular geo-climatic and socioeconomic conditions. According to the National Disaster Management Authority's (NDMA) Annual Report for 2020–2021, 58.6% of the Indian landmass is vulnerable to earthquakes of moderate to very high intensity, and 12% of it is at risk of flooding and river erosion. Out of 7,516 km of Indian coastline, 5,700 km long stretch is vulnerable to cyclones and tsunamis. Further, 68% of India's arable land is drought prone, 15% of the landmass, including hilly regions, are vulnerable to landslides and avalanches.[1]

1.2 Increased vulnerabilities brought on by shifting demographic and socioeconomic conditions, unplanned urbanization, development in high-risk areas, environmental degradation, climate change, geological hazards, epidemics, and pandemics all contribute to the increased risk of disaster in India. Due to all of these factors, India's economy, population, and sustainable development are seriously at risk from disasters. In order to lessen the adversities caused by such disasters, it is crucial to manage resources and responsibilities for dealing with all humanitarian aspects of emergencies, especially preparedness, response, and recovery.

1.3 The Government has significantly improved its approach towards disaster management in the country from relief-centric to a holistic approach of preparedness, prevention, response, recovery, mitigation and capacity building. The Disaster Management Act, 2005 articulates the need for mainstreaming Disaster Risk Reduction (DRR) into development planning. The National Policy and National Plan on Disaster Management seeks to strengthen disaster risk reduction in the country.[2]

1.4 With advancements in technology, modernization in the field of disaster management and control is also needed so as to equip people with better methods to cope with disasters. In this way, technology penetrates the heart of the disaster management as a normative practice so as to offer creative solutions for prevention, mitigation, aid and relief from disasters. Drone technology has advanced significantly in disaster management and is on a scale of progress.

[1] https://ndma.gov.in/sites/default/files/PDF/Reports/NDMA-Annual-Report_20-21.pdf

[2] https://pib.gov.in/PressReleasePage.aspx?PRID=1944718#:~:text=With%20its%20continuous%20efforts%2C%20the,recovery%2C%20mitigation%20and%20capacity%20building.

Unmanned aerial vehicles (UAVs)/Drones offer exhilarating advantages, such as timely outcomes and precise data collection, which can prove to be beneficial in disaster management applications, hence contributing in saving lives and reducing damage. The key qualitative aspects of agility and flexibility make drone technology a potential candidate which can boost the effectiveness and efficiency of India's disaster management efforts.

Scope of the document

1.5 This document aims to cover the basics of drone technology and its various applications. It also gives an insight into the regulations as mandated by the government for the use of drones. The document particularly focusses on the role of drones in the disaster management aspect elaborating on applications like surveillance and mapping, logistics, restoring communication channel during disasters etc. Lastly, it mentions about the disaster specific use cases as per various natural disasters.

CHAPTER – 1

2.0 INTRODUCTION

According to the Directorate General of Civil Aviation (DGCA), an Unmanned Aerial Vehicles (UAVs) is defined as an aircraft that can operate autonomously or can be operated remotely without a pilot on board or can be a combination of both.[3] Essentially, a drone is a flying robot that works in conjunction with onboard sensors and a global positioning system (GPS). Accelerometers, gyroscopes, magnetometers and barometers are also common drone features. However, all drones have some basic components which have been mentioned in the following section.

2.1 **Major components of drone:**[4]

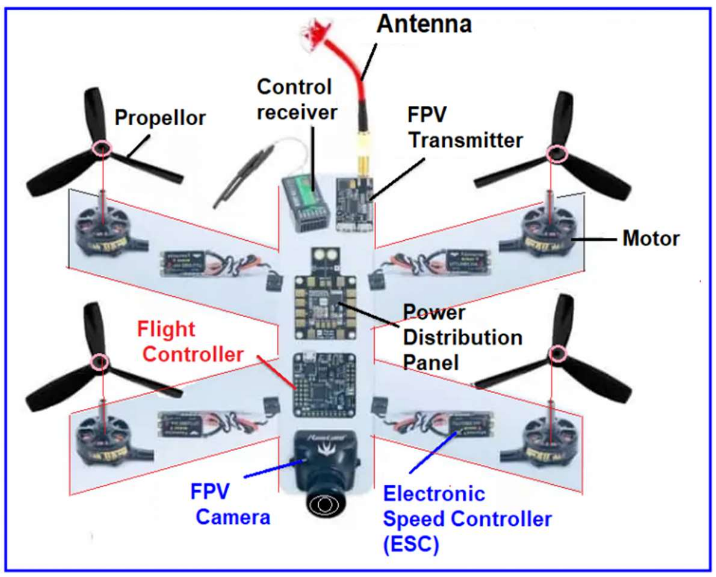

Fig. 1: General Components of Drone
(Source: https://cfdflowengineering.com/working-principle-and-components-of-drone/)

i. **Propellers:**

- The speed and load lifting ability of a drone depends on shape, size, and number of propellers.
- The long propellers create huge thrust to carry heavy loads at a low speed (RPM) and less sensitive to change the speed of rotation

[3] https://www.dgca.gov.in/digigov-portal/jsp/dgca/homePage/viewPDF.jsp?page=InventoryList/headerblock/drones/Drone%20Rules%202021.pdf

[4] https://cfdflowengineering.com/working-principle-and-components-of-drone/

- Short propellers carry fewer loads. They change rotation speeds quickly and require a high speed for more thrust.

ii. **Motor:**
- Both brushless and brushed type motors can be used for drones.
- A brushed motor is less expensive and useful for small-sized drones.
- Brushless type motors are powerful and energy very efficient. But they need Electronic Speed Controller (ESC) to control their speed. The brushless motors are widely used for racing freestyle drones, traffic surveys and aerial photography drones.

iii. **ESC (Electronic Speed Controller):**
- ESC is used to connect the battery to the electric motor for the power supply. It converts the signal from the flight controller to the revolution per minted (RPM) of motor
- ESC is provided to each motor of the drone

iv. **Flight Controller (FC):**
- It is the computer processor which manages balance and telecommunication controls using different transmitter
- Sensors are located in this unit for the accelerometer, barometer, magnetometer, gyrometer and GPS
- The distance measurement can be carried out by an ultrasound sensor

v. **Radio Transmitter:** sends the radio signal to ESC to pilot to control motor speed.

vi. **Radio Receiver:** Receives the signal from the pilot. This device is attached to the quadcopter

vii. **Battery:** High-power capacity, Lithium Polymer (LiPo) is used for most drones. The battery can have 3S (3 cells) or 4S (4 cells).

When the pilot or autonomous system gives the drone a command, the flight controller sends signals to the motors to spin the propellers. The speed and direction of the motors and propellers are adjusted to achieve the desired movement. The sensors provide data to the flight controller, which uses it to stabilize the drone in the air and adjust its movement.

Drones can be controlled manually using a remote controller or programmed to fly autonomously. Autonomous drones use sensors and pre-programmed instructions to fly to a specific location, perform a task like taking photos or delivering a package, and return to their starting point.

2.2 **Types of drones**

i. **Based on weight:**

- **Nano drone:** These weigh less than or equal to 250 grams. They generally have a very less flight time of about 5 minutes, which is extendable upto 30 minutes (by using batteries). The range of nano drones can be upto 60-100 m.[5] The speed in level flight is generally upto 15 m/s and the maximum attainable height can be about 15 m.[6]

- **Micro drone:** These weigh greater than 250 grams and less than or equal to 2 kilograms. Micro drones can be launched by hand or they take-off vertically, hence require short or no runways. They are capable of flying by themselves and gathering information with minimal human intervention. They highly useful across a wide range of applications such as precision agriculture, assistance to first responders, and safe inspection of crucial infrastructure such as oil and gas pipelines, among others.[7]

- **Small drone:** These weigh greater than 2 kilograms and less than or equal to 25 kilograms.

- **Medium drone:** The weight of these drones lie between 25 kilograms and less than or equal to 150 kilogram

- **Large drone:** The weight of these drones are more than 150 kilograms

ii. **Based on aerial platform[8]**

- **Single Rotor Drone (SRD):** A Single rotor drone (SRD) consist of only one rotor with a small tail to control it direction. This drone is similar to a helicopter but carries less load.

- **Multi Rotor Drone (MRD):** Multi Rotor Drone uses multiple propellers (blades) for navigation and flying in space. Such drones have common uses for photography and video surveillance. Multi rotor drones are further categorised based on number of propellers.

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[5] https://mydroneprofessional.com/nano-drones/#:~:text=The%20Best%20Nano%20Drone%20with%20a%20Camera&text=The%204DV2%20also%20has%20a,quality%20improve%20in%20coming%20years.

[6] https://digitalsky.dgca.gov.in/assets/files/UasRules.pdf

[7] https://mydroneprofessional.com/nano-drones/#:~:text=The%20Best%20Nano%20Drone%20with%20a%20Camera&text=The%204DV2%20also%20has%20a,quality%20improv

[8] https://cfdflowengineering.com/classification-and-application-of-drones/

- **Fixed Wing Drone (FWD):** Fixed Wing drones have wings in place of propellers just like an airplane. They cannot hover at one place. They fly on the set course until their energy source is functional.

- **Fixed Wing Hybrid Vertical Take-off Landing (VTOL):** VTOL stands for Vertical take Off & Landing. Fixed Wing Hybrid VTOLs uses propeller(s) to lift off and wings for gliding. Multiple configurations are used for fixed wing hybrid drones. Quad-copter is the most popular fixed wing drone.

Fig. 2: Types of Drones based on Aerial Platform
(Source: https://cfdflowengineering.com/classification-and-application-of-drones/)

2.3 Drone airspace map (in India):[9]

The Ministry of Civil Aviation vide gazette notification dated August 25, 2021 published the **Drone Rules, 2021** and launched an online airspace map of India to help citizens know where they can fly their drones and what paperwork is required to fly drones in certain areas. The entire airspace map is marked in **green**, **yellow** and **red zones**.

i. **Green zone** is the airspace upto 400 feet that has not been designated as a red or yellow zone; and upto 200 feet above the area located in between 8-12 km from the perimeter of an operational airport. In green zones, no permission is required for operating drones with an all-up weight upto 500 kg.

[9] https://pib.gov.in/PressReleaseIframePage.aspx?PRID=1757850#:~:text=Green%20zone%20is%20the%20airspace,all%2Dup%20weight%20upto500%20kg.

ii. **Yellow zone** is the airspace above 400 feet in a designated green zone; above 200 feet in the area located between 8-12 km from the perimeter of an operational airport and above ground in the area located in between 5-8 km from the perimeter of an operational airport. Restricted drone operations in yellow zone require permission from the concerned air traffic control authority – AAI, IAF, Navy, HAL etc. as the case may be. In an update. Yellow zone has been reduced from 45 km to 12 km from the airport perimeter.

iii. **Red zone** is the 'no-drone zone' within which drones can be operated only after a permission from the Central Government.

iv. Coverage of drones under the rules has been increased from 300 kg to 500 kg. This will cover drone taxis too.

CHAPTER – 2

3.0 APPLICATIONS OF DRONES[10]

With the development of drone technology, the application of drones is becoming more and more wide-ranging. Drone industry is moving into fast lane with accelerated involvements across industries. Drones offer benefits such as low-cost access, effortless data collection, high efficiency, fewer hazards to humans, and logistical support. Major trends in multi-directional drone applications include intelligent flight, broadband transmission, and diversified functions, can possibly lead towards the Internet of Drones. Drones are driving numerous and evolving use cases, and creating transformative socio-economic benefits.

Applications of drone include but are not limited to the following:

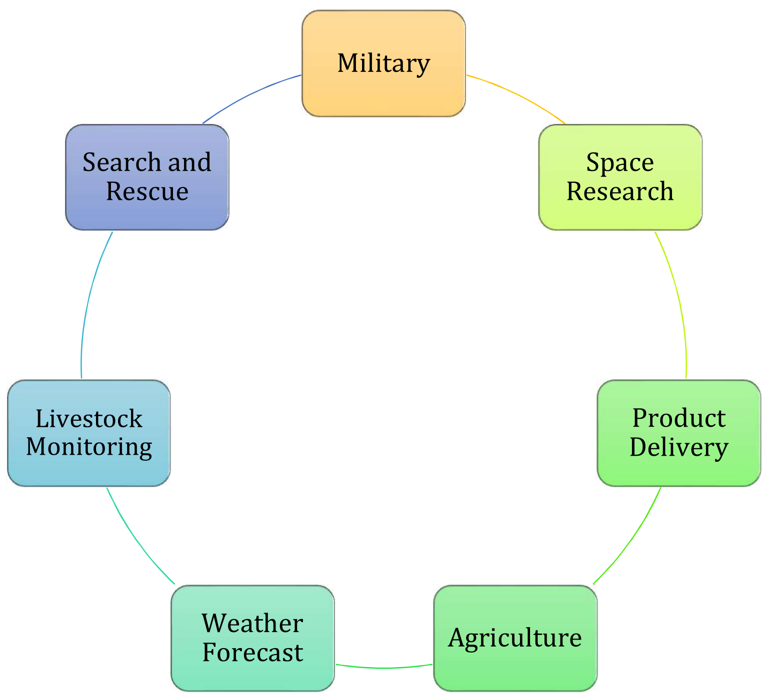

Fig. 3 Applications of Drone

3.1 **Military :** Drones help in military activities like air threat defence, target tracking, aerial photography, surveillance, and reconnaissance. Drones lessen the risk of a pilot or military personnel being killed. Class I UAVs, which are less than 150 kgs, are used for

[10] https://cfdflowengineering.com/classification-and-application-of-drones/

surveillance missions and do not carry weapons. Class II UAVs, between 150 kg to 600 kg, are of a 'tactical' nature and can be employed for carrying multiple payloads. In addition, they are largely unarmed but some can be loaded with lightweight ordinance. Class III UAVs, which are more than 600 kg in weight, are considered to have better endurance in terms of surveillance and payloads, and can carry multiple weapons.[11]

NewSpace Research and Technologies Pvt. Ltd., a Bengaluru-based start-up has delivered SWARM drones to Indian Army, which, as per some reports, makes Indian Army the first major armed force in the world to operationalise these high-density SWARM drones.[12] As reported, the swarm of 100 drones can hit targets at least 50 km away into enemy territory.

3.2 **Space Research :** The use of drones for interplanetary exploration is becoming increasingly more common. As technology continues to improve, drones are proving to be invaluable tools for exploring the solar system. Many space research institute like NASA use drone for space applications. In April 2021, a small helicopter named "Ingenuity" took off from the surface of Mars, and became the first aircraft to fly in the in the atmosphere of another planet. It may have also unlocked future possibilities for how NASA explores the surfaces of distant planets. The drone initially landed on Mars inside the NASA rover "Perseverance" on February 18, 2021.[13]

The Dragonfly mission of NASA, set to launch in 2026, will use a small autonomous drone to explore the moon's surface. The drone will be able to fly from location to location, taking pictures and collecting samples along the way.

The European Space Agency is also using drones for interplanetary exploration. The agency is developing a small drone to explore the surface of Venus. The drone, called Venera-D, is scheduled to launch in 2026. It will be used to take pictures of the surface, as well as to measure the composition of the planet's atmosphere.[14]

[11] https://www.idsa.in/system/files/jds/jds-16-4_Pintu-Kumar-Mahla_15.pdf

[12] https://swarajyamag.com/defence/indian-army-gets-worlds-first-fully-operational-swarm-drone-system-capable-of-hitting-targets-50-km-away

[13] https://www.cbsnews.com/news/nasa-drone-mars-60-minutes-2022-07-03/

[14] https://ts2.space/en/drones-in-space-the-future-of-interplanetary-exploration/

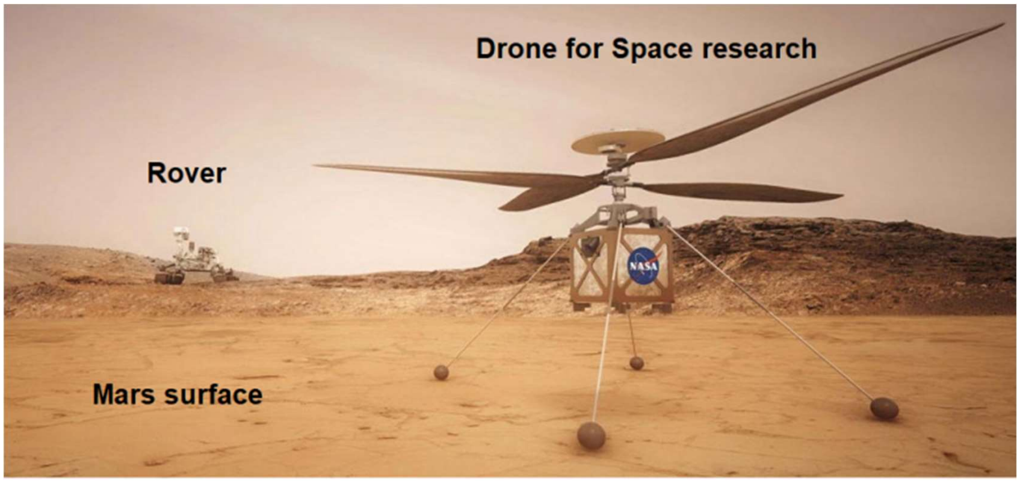

Fig. 4: Drones used for Space Research
(Source: https://cfdflowengineering.com/classification-and-application-of-drones/)

3.3 **Product Delivery :** The food and product delivery industry is one of the most popular industry. Growing consumer demand and the business requirement of delivering a superior customer experience require supply chains to be more efficient, seamless, and cost and time effective. To tackle the inefficiencies in last-mile logistics, a growing number of logistics stakeholders are turning to drone technology as it can control operational costs, overcome traffic bottlenecks and reduce vehicular emissions while satisfying the customer appetite for on-demand and instant delivery.

Worldwide, e-commerce giants have already started drone deliveries and are looking at penetrating rural and remote areas with drone deliveries. According to estimates by Fortune Business Insights, global drone package delivery market size will reportedly grow from $1.5 billion in 2021 to an estimated $31.2 billion by 2028 at a CAGR of 53.94 per cent.[15] The first made-in-India heavy-lift drone, HL-150—estimated to transport 150 kilograms of cargo over 150 kilometres—can also redefine logistics in India.[16]

[15] https://economictimes.indiatimes.com/small-biz/sme-sector/is-drone-delivery-the-future-of-logistics/articleshow/95347079.cms?utm_source=contentofinterest&utm_medium=text&utm_campaign=cppst

[16] https://economictimes.indiatimes.com/small-biz/sme-sector/is-drone-delivery-the-future-of-logistics/articleshow/95347079.cms?utm_source=contentofinterest&utm_medium=text&utm_campaign=cppst

Fig. 5: Drone used for Logistics
(Source: https://news.utdallas.edu/business-management/drone-delivery-study-2020/)

3.4 **Agriculture :** Drones are used for multiple applications in farming including but not limited to soil and crop monitoring, seed planting, spraying pesticides, irrigation monitoring and management. According to some reports, the agricultural drone market is expected to grow from a $1.2 billion (USD) industry in 2019 to $4.8 billion in 2024. The data collected from drones recording fields help farmers plan their planting and treatments to achieve the best possible yields. Some reports indicate that using precision farming systems can increase yields by as much as 5%, which is a sizeable increase in an industry with typically slim profit margins. Drones can also be used to spread micronutrients in the agriculture sector, thus saving time and ensuring the anticipated results. They are also being used for field monitoring to monitor the health of soil and field conditions.

Fig. 6: Drone used for Spraying Pesticides
(Source: https://cfdflowengineering.com/classification-and-application-of-drones/)

Drones equipped with special imaging equipment called Normalized Difference Vegetation Index (NDVI) use detailed colour information to indicate plant health. This allows farmers to monitor crops as, they grow so any problems can be dealt with fast enough to save the plants. The image below illustrates simply how NDVI works.[17]

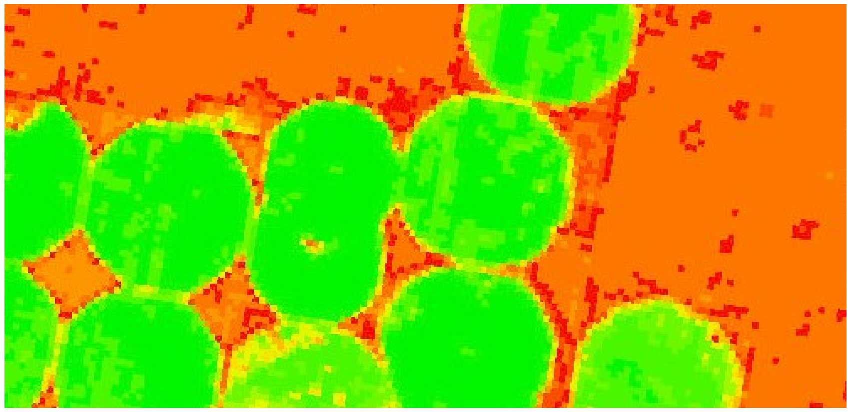

Fig. 7 Field monitoring via NDVI
(Source: https://gisgeography.com/ndvi-normalized-difference-vegetation-index/)

Bright green indicates high NDVI, whereas red has low NDVI. Therefore, it is quantifying vegetation by measuring the difference between near infrared (which vegetation strongly reflects) and red light (which vegetation absorbs).

3.5 **Livestock Monitoring :** Wildlife control is necessary for obtaining information about position and condition of the livestock. One of the most efficient ways to do that is via wildlife drones.

Wildlife drones are often used to monitor wildlife populations and track migration patterns. They have the ability to survey larger areas, even during the night. The low noise footprint helps in a more convenient monitoring system. In addition, UAVs can gather footage and compare the results over time, allowing trends and patterns to be identified. In fact, a UAV wildlife survey is often much more effective than those carried out on the ground by conservationists. Equipped with high-resolution cameras and thermal imaging, drones can cover large areas and capture detailed data, making them an invaluable tool for conservation efforts.

Apart from this, drones also help to combat poaching activities. Poaching is a major threat to many species of wildlife, particularly in Africa where animals like elephants and rhinos are killed for their

[17] https://www.croptracker.com/blog/drone-technology-in-agriculture.html

ivory and horns. In contrast to traditional anti-poaching methods, drones allow much quicker and more effective response to poaching threats.

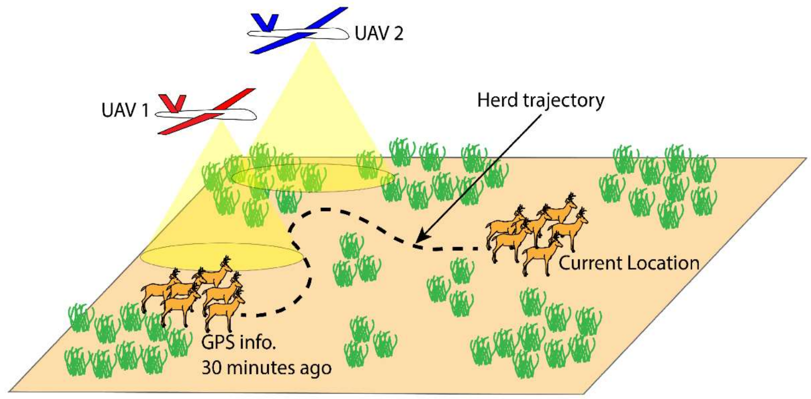

Fig. 8: Depiction of wildlife monitoring using UAVs
(Source: https://www.mdpi.com/2076-3417/11/9/4070)

One of the UAV design and manufacturing company provides drones, which features thermal, and 10x optical zoom sensors for wildlife monitoring applications[18] and are engineered for long-range and high endurance missions.

3.6 **Weather Forecasting :** Severe weather conditions such as thunderstorms, strong winds, fog and hail affect the economy and the public safety on a large scale. Lack of accurate weather prediction devices that can monitor the atmospheric boundary layer, where a majority of the weather occurs, makes it difficult to predict and avoid such weather phenomena. Drones come handy in this situation as they are also capable to record weather conditions and collect data on moisture, air pressure, temperature, humidity, wind speed, wind direction and more.

Weather drones called meteodrones, can travel throughout the entire boundary layer of the earth's atmosphere. They are generally quadcopters or hexacopters. Because of their manoeuvrability, meteodrones can capture weather data more accurately. Large, fixed-wing meteodrones that fly hours or days at a time can measure glacier activity, volcanoes, and valley fog, all of which weather can negatively influence. With powerful sensors and video cameras attached, meteodrones collect important information on the weather and deliver the data to meteorologists. Weather drones can be

[18] https://nextech.online/wildlife-and-game/#:~:text=Drones%20are%20becoming%20a%20popular,on%20the%20ground%20by%20conservationists
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programmed to communicate with neighbouring weather drones, satellites, and other forecasting systems for predictions. Unlike traditional weather data tools, meteodrones travel farther and higher, and can return to their original location.

It is mainly beneficial for recording data for the lower air layers (up to approximately 2 km above ground), since there is practically very less data available for this altitude.[19]

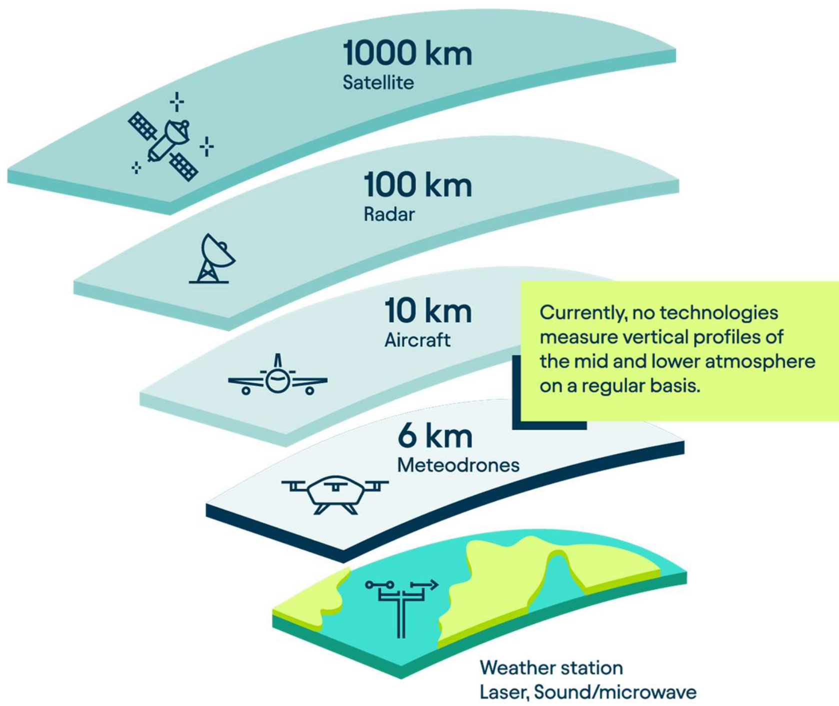

Fig. 9: Meteodrones

(Source: https://www.meteomatics.com/en/meteodrones-weather-drones/)

One of the meteodrone manufacturing company, specifically designs drones to collect weather observations from the lower and middle atmosphere. Their drones can collect data up to 6 kilometres above ground and are capable of hyperlocal measurements for a specific location, even at night.

3.7 **Search and Rescue during Disasters :** Drones are useful in search and Rescue (SAR) operations in remote and mountain areas. They can also patrol larger areas as compared to an individual. In April 2015, when Nepal experienced one of its worst earthquakes in years,

[19] https://www.meteomatics.com/en/meteodrones-weather-drones/#weatherdrone-work-en

several aid organizations used drones for search and rescue operations.[20]

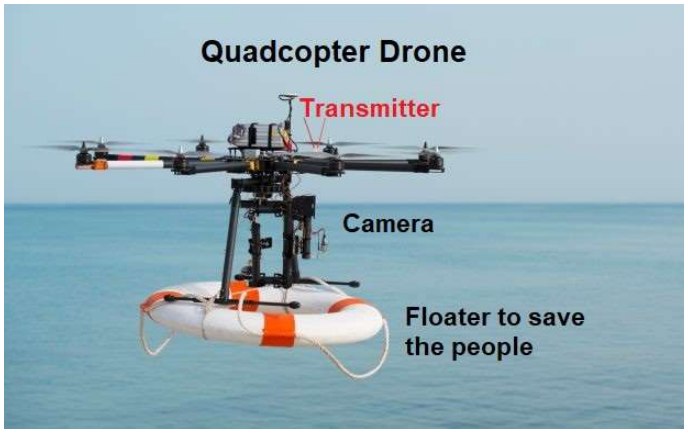

Fig. 10: Drone used for SAR Operations

(Source: https://cfdflowengineering.com/classification-and-application-of-drones/)

Also after the 2010 earthquake in Haiti, the International Organization for Migration since 2012 widely used drones to capture and analyse the damage caused.[21]

[20] https://www.allerin.com/blog/drones-for-disaster-response-and-management

[21] https://igdrones.com/blog/drones-in-assessing-the-damage-caused-by-earthquake#:~:text=In%20Nepal%2C%20several%20agencies%20have,heritage%20sites%20and%20devastated%20homes.&text=%2D%20Faine%20Greenwood%2C%20Research%20Assistant%20on%20Drones%2C%20Harvard%20Humanitarian%20Initiative.

Chapter – 3

4.0 DRONES FOR DISASTER MANAGEMENT

In contrast to their traditional roles, drones are now extensively being used in various new sectors because of their agility and quick deployment methods. Apart from the earlier mentioned applications, drones have also been found to have the potential in improving the disaster management efforts. In the aftermath of a disaster, where time is of the essence, drones can significantly reduce the time taken to gather crucial information, potentially saving lives and minimizing damage. Eg: As per JOUAV, an aircraft manufacturing company, its drones can move quickly, that is, taking off to landing in only 7 minutes, and have completed 100,000 sq. kilometres of aerial photography, which can be of great significance for the race against time for post-disaster rescue work.[22]

In addition to their use in the immediate aftermath of a disaster, drones can also play a crucial role in disaster preparedness and mitigation efforts. By providing high-resolution images and real-time data, drones can help authorities identify vulnerable areas, assess the effectiveness of existing infrastructure, and plan for possible future disasters. This information could be used to develop more effective and evidence based disaster management strategies, ultimately reducing the impact of disasters on communities and saving lives.

In India, the National Disaster Management Authority, a culmination body for disaster management, used drones for the first time during the Uttarakhand floods in 2013. Four unmanned aerial vehicles (UAVs) were deployed to scan areas that rescue and relief workers have not been able to reach in the flood-hit Himalayan foothills in Uttarakhand in what was described as a pioneering operation. The UAVs made reconnaissance of 50 areas in Uttarakhand, at least 20 of which were locations that rescuers hadn't been able to reach to assess damage.[23]

Though drone usage is mainly used in disaster response currently, a new report highlights the benefits of using drones in disaster through all four stages of the disaster life cycle: prevention, mitigation, response and recovery.[24]

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[22] https://www.jouav.com/blog/applications-of-drones.html
[23] https://www.livemint.com/Politics/ZDib5YWR1G2Mcuth1kbwyO/Drones-scan-floodhit-Uttarakhand.html
[24] https://igdrones.com/services/disaster-management

4.1 Phases of Disaster Life-Cycle

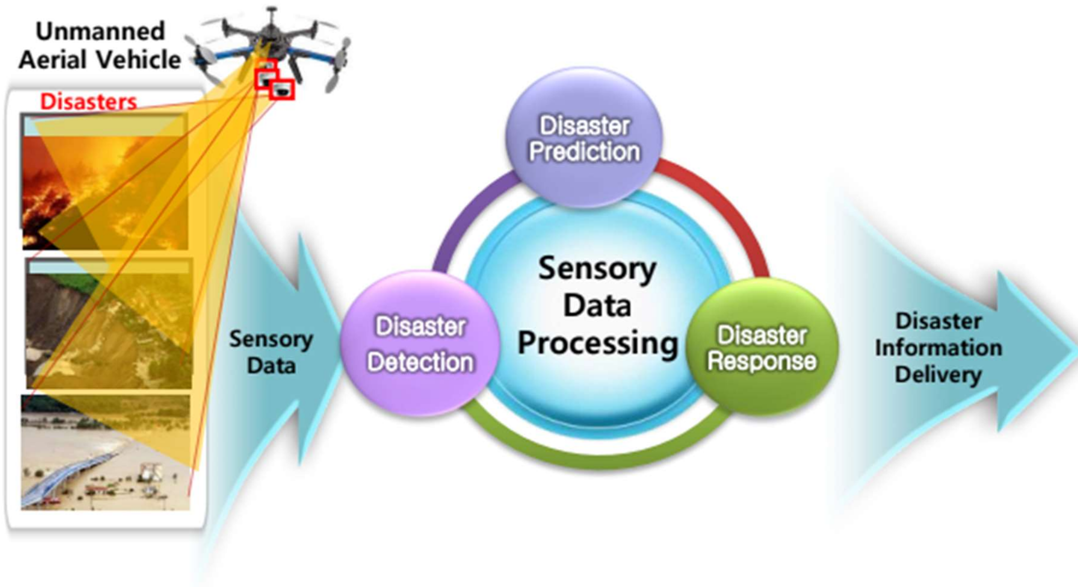

Fig. 11: Utility of drones in Disaster Management
(Source: https://www.itu.int/dms_pub/itu-t/opb/tut/T-TUT-DIS-2018-UAV-PDF-E.pdf)

i. **Disaster Prevention:** One of the best investments in terms of handling disasters is prevention. This is especially true for disasters relating to or affecting infrastructure objects like bridges, power lines, gas pipes, etc.

In many cases, manual inspections of such objects are cumbersome and, unfortunately, performed with unacceptably low quality. The easy solution is deploying autonomous drones to monitor and scan for potential issues. Placing a network of drone-in-a-box solutions in critical areas and instructing them to run regular inspections can accumulate data on wear and tear, which is essential to forecasting potential disasters. Such drone infrastructure could be operating UAVs carrying payloads, such as LiDAR, sensors, cameras etc.

The Matrice 300 is DJI's latest commercial drone that offers 55 minutes of flight time, advanced AI capabilities, six directional sensing and more. It excels standards by combining intelligence and advanced performance with reliability. The M300 can hold up to three payloads simultaneously with a maximum payload capacity of 2.7kg.[25]

[25] https://geoslam.com/blog/2023/03/30/what-is-lidar-drone/#:~:text=Using%20a%20LiDAR%20drone%20to,no%20further%20than%20drone%20LiDAR.

Freefly's drones are suitable for a variety of solutions that benefit professional and industrial partners. The Alta X, for instance, can carry and fly payloads of up to 35lb and its flight time ranges from 10 to 50 minutes depending on the additional weight it is holding.[26]

Drones can conduct pre-disaster surveys and map at-risk areas, which can help officials to identify potential hazards and prepare response plans accordingly. They can also help train emergency responders for future disaster response operations.

Some of the solutions include:

- **Tethered drones** – Hovering at about 200m in the air, these can provide 24/7 video coverage of protected areas and beyond. Tethered systems can solve the power-supply challenge that many drones face if the tether provides a direct power supply. Eg: Elistair's Safe-T drone tethering station offers 2.5 kW power and can fly to heights of more than 200 feet, with data transfer rates of up to 200 Mbps.

- **Thermal cameras** – Trespassers often are most challenging to detect at night, but it's difficult to hide one's heat signature

Fig. 12: Surveillance by a thermal camera mounted on a drone

(Source:https://www.equinoxsdrones.com/promoting-effective-disaster-management-through-drones/)

- **Patrol drones** – Flying perimeter or point-to-point missions, these drones can traverse at 40km/hr+ speeds, capturing and analysing the situation along with AI.

[26] https://geoslam.com/blog/2023/03/30/what-is-lidar-drone/#:~:text=Using%20a%20LiDAR%20drone%20to,no%20further%20than%20drone%20LiDAR.

ii. **Disaster mitigation:** Mitigation means reducing the severity, seriousness, or painfulness of something. To reduce the severity of a disaster, which just struck, responders need to have as straightforward as possible understanding of the situation, whether it's on the ground or elsewhere. Having a drone infrastructure deployed and ready to react at a minute's notice is essential for a successful mitigation strategy:

- **Infrastructure monitoring** – drones can establish an ongoing monitoring view of the situation, which can help the responders keep track of the evolving situation. They allow users to get a bird-eye-view on the entire area/building and reveal concerns that would be impossible at ground level inspections. Geotagging capabilities of drone maps enable the capture of necessary area damage and helps in reliable decision-making.

- **Visibility** – especially when a disaster takes place at night, or there are other visibility issues, drones carrying light projectors or similar devices can lighten up the stricken area to support other activities.

iii. **Disaster Response:** Drones can provide invaluable help to both those who are responding on site as well as those responsible for the disaster response coordination:

- **Delivering aid** - In the aftermath of a disaster, drones can deliver essential supplies such as food, water, medicine, and blankets to victims in remote or inaccessible areas.

- **Search and rescue** - Drones equipped with cameras can quickly search and locate victims or survivors in hard-to-reach areas such as collapsed buildings, flood zones, or wilderness.

- **Impact analysis** – Often, the disaster effects will evolve. Drones can provide accurate information about the erosion of buildings and infrastructure objects in real-time. This, combined with AI capabilities, can help shape the response strategy.

iv. **Disaster Recovery:** In the case of disasters, a lot of the effort is based on situational awareness and planning the road ahead. It is often difficult to assess the long-term effects, so gathering as much information as possible is critical:

- **Damage assessment** - drones can help to accelerate the recovery process by conducting damage assessments, monitoring the progress of recovery efforts, and identifying areas that require additional resources or support

- **Planning and coordination** - Drones can help the planning and coordination efforts by providing real-time data and situational awareness to disaster recovery teams. This can help to ensure that recovery efforts are well-coordinated and effective and that resources are deployed where they are most needed.

- **Progress monitoring** – UAVs can help monitor the restoration of critical infrastructure such as power lines, roads, and bridges. Accountability is crucial; regular reports on progress from a stable drone-based infrastructure can help.

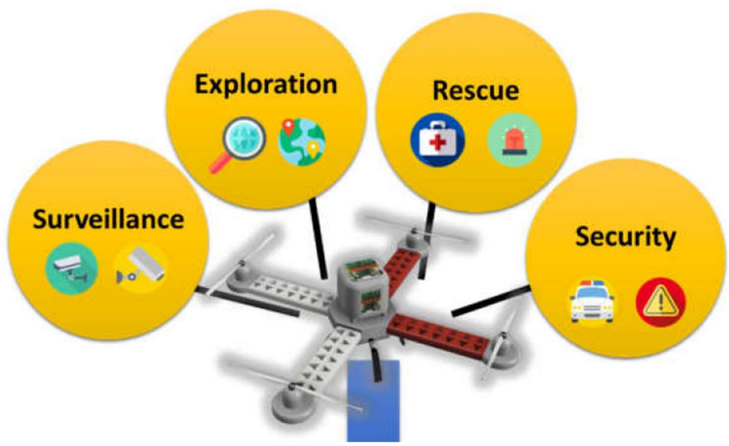

Fig. 13: Use cases of Drones during Disaster

(Source: https://cfdflowengineering.com/working-principle-and-components-of-drone/)

4.2 Specific Use Cases of Drones in Disaster Management Applications

i. **Drone for surveillance and Mapping:**[27]
Drone surveillance is the use of unmanned aerial vehicles (UAVs) to capture still images and video from a distance or at a high altitude to gather information about specific targets, which may be individuals, groups, or the environment. UAVs provide the ideal solution to the problems and limitations faced by other surveillance methods. Drones' small size, ability to fly, and withstand harsh environments allows them to survey objects that may be out of reach and can get a first-person view

[27] https://mydroneprofessional.com/nano-drones/#:~:text=The%20Best%20Nano%20Drone%20with%20a%20Camera&text=The%204DV2%20also%20has%20a,quality%20improve%20in%20coming%20years.

that photographers don't usually get. Drone surveillance presents an easier, faster, and cheaper method of data collection.

Nowadays, drones are equipped with live video cameras, infrared cameras, thermal sensors, and LiDAR are used in large numbers in disaster management. Drone planes can enter narrow and confined spaces, produce minimal noise, and are equipped with night-vision cameras and thermal sensors. For this reason, they provide imagery that the human eye is unable to detect.

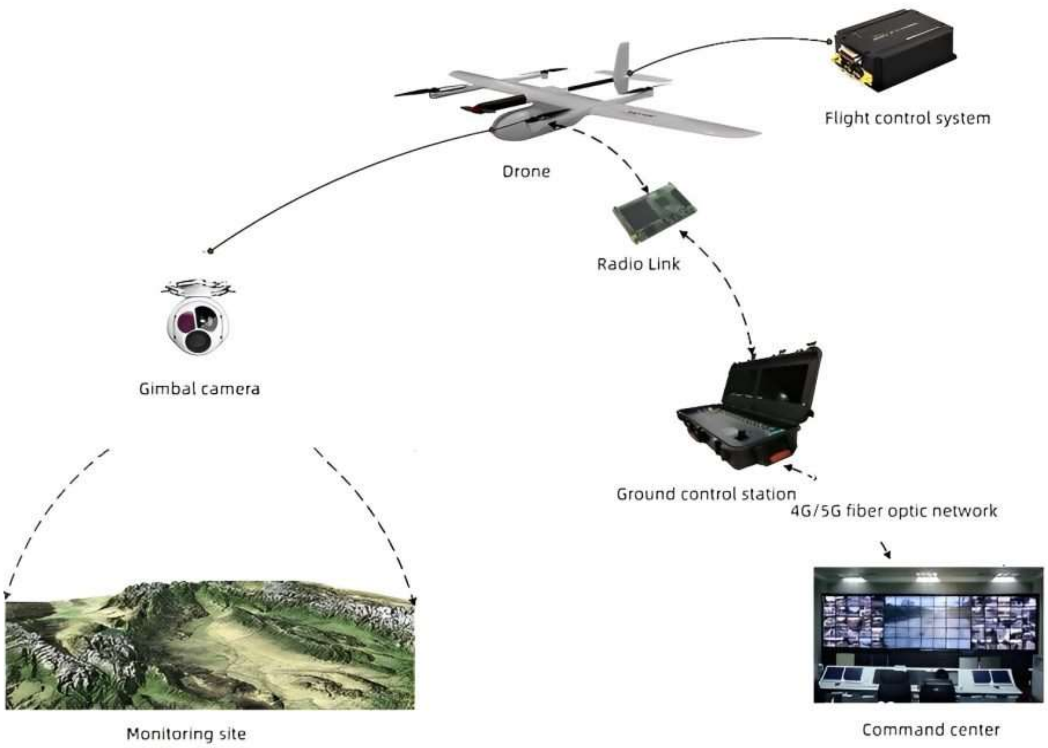

Fig. 14: Surveillance system by a Drone
(Source: https://www.jouav.com/industry/security-surveillance)

Drones are connected to the control system using datalinks and wireless links and can be equipped with different monitoring tools, including high-resolution cameras, thermal sensors, GPS, and sensors to detect motion. These cameras may include object recognition and tracking technology, and here it is possible to identify individuals remotely from a distance without their knowledge. A drone for surveillance can perform perimeter patrols 30 times faster than a manned patrol, so it provides feedback in a few minutes.[28]

[28] https://www.jouav.com/industry/security-surveillance

Eg., JOUAV CW Series surveillance drones capture 1080P HD video footage and transmit them to the ground station in real time via the dedicated communication link. After receiving the videos, the ground control terminal shares the data with teammates and clients through a 4G/5G router or a network cable.[29]

An effective surveillance system using drone fleets requires seamless integration between reliable hardware and intelligent automation software. Drones deployed for surveillance often require a companion computer (eg. Nvidia Jetson Nano, DJI Manifold 2, Raspberry Pi 3B+/4) with an operating system to enable 'edge intelligence', including AI-powered object detection and autonomous navigation in companion with a system eg., FlytNow that is capable of automating the launch, patrol, and landing cycle of a drone and also enables sharing high-quality video feeds with remote stakeholders, in real-time.[30]

Drones are mounted with an array of sensors that can enhance aerial surveillance capabilities, such as:[31]

- **Wide-angle camera:** These are cameras with a small focal length that has a wider field of view than conventional cameras and can capture a lot more visual data from a single position.

- **Thermal camera:** Also called a thermographic sensor that can convert infrared radiation into visible light. These types of sensors are useful in night-time surveillance since it can detect warm objects in pitch-dark situations.

- **LiDAR:** It stands for Light Detection and Range. It emits pulsating lasers to find the range to an object.

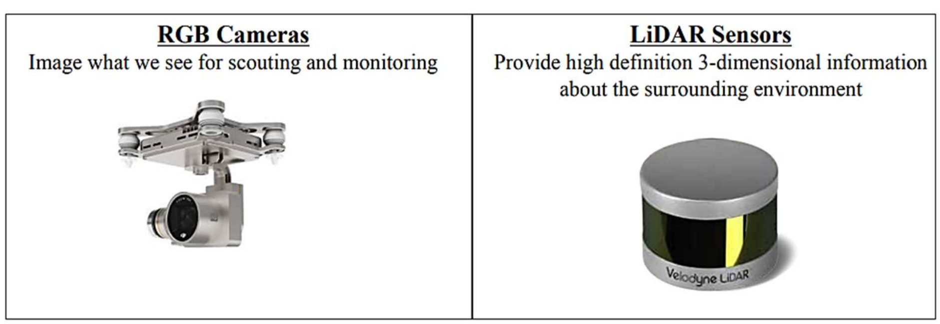

Fig. 15: Sensors for Drone

[29] https://www.jouav.com/industry/security-surveillance
[30] https://www.flytbase.com/blog/drone-surveillance-system
[31] https://www.flytbase.com/blog/drone-surveillance-system

Survey drones generate high-resolution orthomosaics and detailed 3D models of areas where low quality, outdated or even no data, are available. They thus enable high-accuracy cadastral maps to be produced quickly and easily, even in complex or difficult to access environments. Surveyors can also extract features from the images, such as signs, curbs, road markers, fire hydrants and drains. With intensive R&D in drone technology, drones offer a 360-degree view of locations with the help of a 360-degree view camera, which allows rescuers to explore a disaster-affected region in maximum.

Fig. 16: Mapping an area using a Drone
(Source: https://wingtra.com/drone-photogrammetry-vs-lidar/)

Eg: **Project AHEAD –** for Autonomous Humanitarian Emergency Aid Devices

This is an application of artificial intelligence (AI), satellite data links, and unmanned aerial vehicles (UAVs) expands the delivery area for relief and assistance, especially during the highly dangerous "last-mile" leg of humanitarian supply chains. Equipped with 360-degree cameras and LiDAR technology, Project AHEAD vehicles can drive – and even swim – autonomously in harsh environments. A landing pad atop each vehicle enables accompanying drones get a bird's eye view to protect rescue workers potentially exposed to danger during humanitarian aid deliveries.

Edge-enabled drones are unmanned aerial vehicles (UAVs) that have compute installed on the device. They can be equipped with a range of sensors, such as LIDAR and infrared sensors, capturing data that can be a valuable tool in ensuring public safety by providing better situational awareness and critical data to emergency responders. They can provide aerial perspective of the area and transfer real-time images and video footage to teams on ground, allowing them to locate and rescue individuals more efficiently and safely.[32]

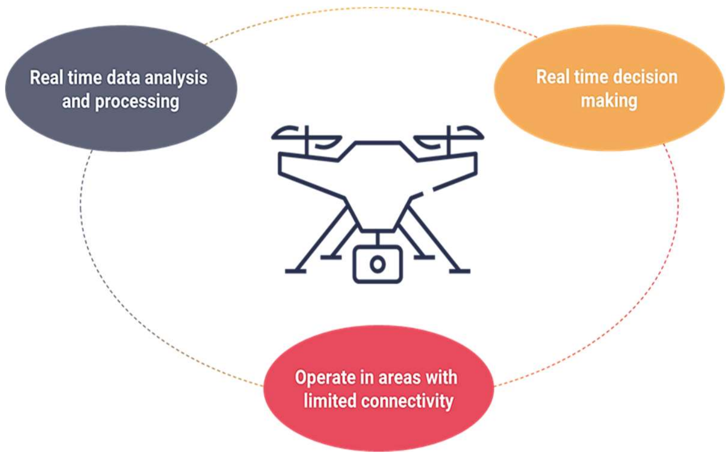

Fig. 17: Drones providing real time data

(Source: https://stlpartners.com/articles/edge-computing/edge-computing-drones-edge-uav-industry-transformation/)

Eg: **DEEP** damage assessment

After Cyclone Idai hit Mozambique in 2019, WFP's rapid disaster mapping operation deployed drones for the first time, allowing damage assessments in days rather than weeks. In just three days, locals were trained to use 10 different drone systems to capture more than 17,000 high-resolution images to inform relief operations. A digital engine for emergency photo analysis (DEEP) also made its debut there, using high-resolution images from satellites and drones to identify damaged buildings with 85 per cent accuracy within hours, lowering field operation costs.

The system appeared again in Colombia and the Philippines, as well as after the August 2020 port explosion in Beirut, Lebanon.[33]

ii. **Drones for delivering Urgent supplies**

UAVs can deliver emergency supplies encompassing first aid, fast-acting medicines, small tools for help such as ropes, flashlights. Moreover, drones can also provide food supplies and energy inducing supplies through quadcopters and drones. For many conditions, drone technology may make it easier and safer to provide this home-based care. Drones can carry out these duties much more quickly than

[32] https://stlpartners.com/articles/edge-computing/edge-computing-drones-edge-uav-industry-transformation/

[33] https://www.itu.int/hub/2022/04/mars-rover-to-aid-ai-satellites-uavs-humanitarian-action/

traditional routes, as well as having the additional advantage of keeping additional personnel away from potentially dangerous areas.

In May 2020, with the world in the grip of the global COVID-19 pandemic, SOARIZON was involved in a ground-breaking medical drone delivery trial in the Scottish Highlands. Trailing the delivery of PPE supplies and COVID test kits, it was proved that delivery time could be reduced from up to six hours by road and ferry, to just 15 minutes by drone.[34]

Indian Council of Medical Research, through its 'i-Drone' project, delivered essential medical supplies to remote parts of the Northeast. A total of 17,275 units of medical supplies were delivered through drones, covering 735 kilometres in 12 hours.[35]

Recently, during July 2023, heavy rainfall was encountered by the northern and eastern part of India including Himachal Pradesh, West Bengal, Sikkim, Arunachal Pradesh, Assam, and Meghalaya with a red alert being issued for Uttarakhand. Garuda Aerospace, which is a Tamil Nadu based UAV solutions company, deployed its logistics and delivery drones in Assam as well as Himachal Pradesh, playing a major role in supporting NDRF rescue efforts and in supply of essential supplements. Two drones with teams of four pilots each were deployed in Himachal Pradesh, which apart from delivering essentials, helped in assessing the weather conditions, movement of floodwaters and identifying areas that are at risk of flooding, thus, ensuring safe operations.

iii. **Drones for communication infrastructure**

During a disaster, maintaining communication is one of the most important aspect for smooth and effective Search and Rescue operations. The ability of rescuers to maintain contact with incident command (IC) and each other is a critical component of search and rescue (SAR) operations. When rescuers lose radio communication with operation leaders, the effectiveness of operations may be substantially affected. When communication loss occurs during a SAR event, it has a significant impact on the ability of rescue personnel to request additional resources, deliver medical aid, relay details relative to victim status, or call for an emergency evacuation. This often occurs owing to the limitations of standard communications equipment in difficult terrain or when victims are beyond line-of-sight, such as in canyons or mountains.

[34] https://botsanddrones.in/drone-applications-%26-uses/f/how-drones-are-helping-in-emergency-response

[35] https://economictimes.indiatimes.com/small-biz/sme-sector/is-drone-delivery-the-future-of-logistics/articleshow/95347079.cms?utm_source=contentofinterest&utm_medium=text&utm_campaign=cppst

To maintain the safety of mobilized SAR personnel and victims, reliable communication during live SAR operations is critical in cases involving medical or traumatic circumstances and in the implementation of large-scale search operations.

This highlights the need for rescuers and SAR operators to maintain a reliable channel of communication. The consequences of communication issues can be made worse in more urgent circumstances where large-scale search operations require constant communication and coordination between multiple search teams. Drones can help in resolving this problem by establishing or recovering communication channels temporarily.

The typical communication equipment library of regional SAR teams consists of 5-8 W dual-band 2-way radio. UAV communications systems typically operate on frequencies of 2.4 GHz and 5.8 GHz. They work by using one frequency to control the aerial vehicle from the ground via a remote pilot while the other frequency is used to beam data or relay First-Person View (FPV) video. By utilizing high-quality, reliable communications links, UAVs are able to relay aerial visuals and data to those on the ground with ease, while still remaining in flight.

There are various methods for establishing robust communication links via drones, especially for Beyond Visual Line-of-Sight (BVLOS) operations. Drone and UAVs (unmanned aerial vehicles) utilize a variety of communication methods in order to create a data link between the vehicle and ground control station (GCS), and sometimes between multiple aircraft (swarm technology). This sort of connection uses well-known and standardized communication protocols like Bluetooth and Wi-Fi. UAV communication systems may be used for command and control (C2), to broadcast telemetry data, and to send video and data from sensors and payloads back to the control station.

- **Radio Frequency:** The most common method of drone communications uses radio – RF (radio frequency) signals in bands such as HF (high frequency) and UHF (ultra-high frequency). RF datalinks may be analogue or digital, and provide greater range than Wi-Fi but are still limited to line-of-sight (LOS). Range will depend on the size of the antenna and the power of the transmitter in the UAV communications system, as well as frequency, with lower frequencies providing longer ranges but lower data rates. Billions of devices around the world communicate via wireless radio frequency waves. Device transmitters and receivers communicate along with a distinct frequency. Many drones use this unlicensed method of communication. Specific RF signatures mean that even in a busy city environment, drone communication peaks are distinct enough to be a reliable technology. The technology is tried and is largely safe. However, on the other hand the technology is fragile and signals can be intentionally or unintentionally hijacked through signal jammers. The signal has a limited range and must be operated within the line of sight.

- **Single or multi sim LTE/4G:** Licensed and regulated cellular networks offer LTE modules and 4G network services. This can be used for drone communication as they provide wide coverage and uniform quality. LTE / 4G connections allow faster and higher volume data transfers than previous generations of network services. Further, these services offer a good range over large distances, provided the area is covered by enough cell towers. This means that remote territories are under-serviced. The downside of this is that, long-range flight options are limited due to typical wireless connectivity being insufficient. LTE/4G offers failover mechanisms in the form of backup connections, but the failover is not bonding.

- **5G:** 5G offers data speeds that are hundreds of times faster than 4G. It is perfectly suited for high-resource tasks like transmitting real-time high definition footage during unmanned autonomous or semi-autonomous vehicle use. It has improved latency and data speeds than previous generations. For drones to make effective use of a 5G network, the coverage must be comprehensive. Any reliance on a single 5G communication link is disadvantageous, especially with low coverage which will hinder operations in rural terrain. Antennas are needed everywhere for it to operate smoothly.

- **Satellite:** Since, satellite technology offers global always-on communication and control, it can be a reliable method for drone communication. The coverage provided is very wide, and uptime being consistently high. The advent of satellite-provided high-speed internet for rural areas — such as the service provided by Low Earth Orbit (LEO) or Medium Earth Orbit (MEO) satellite constellations can prove to be of benefit to a great extent for drone communication. This allows any drone to be summoned back to its original station if it wandered beyond the line of control. However, this technology is currently mainly used in large military-style UAVs that fly over large distances and heights. Commercial drones don't have a viable solution yet that incorporates satellite communications.

The single points of failure in our communications infrastructure can be addressed by deploying aerial assets provisioning reliable communication capabilities. These resources can be used over long distances, while providing persistent overhead surveillance services and geospatial data. To guarantee reliable communication, it's imperative to provide seamless airborne communication nodes that can mitigate some of the vulnerabilities of our global infrastructure. An electric aircraft capable of recharging itself in flight enables nonstop communications to provide true beyond-line-of-sight communications in difficult radio-frequency environments. Additionally, access to wireless capabilities such as 4G/LTE and 5G is extremely critical during times of emergencies. This allows authorities to coordinate emergency services when needed and allows the general public to continue to communicate with each other.

Eg., One solution being proposed by Kraus Hamdani Aerospace is the K1000ULE, a large, long-endurance aircraft that harness the power of nature to fuel themselves while providing critical infrastructure on a widespread basis. These aircraft do not rely on depletable energy sources, don't need to be positioned in space, and require no ground terminals to safeguard communications globally. Further, they are capable of providing a resilient inter-vendor, mesh-based communications infrastructure that provides over-the-horizon networks that are self-aware and can cover large areas beyond line-of-sight. These on-the-move capabilities offer secure IP-based information exchange and bridge radio networks that were not previously interoperable.

AERIAL BASE STATIONS

Drones can provide airborne communication in a variety of cases, including as Aerial Base Stations (ABSs) for ground users, relays to link isolated nodes, and mobile users in wireless networks.

Using UAV as a base station is standardized by third Generation Partnership Project (3GPP) and Google Loon-enabled emergency LTE services. A reliable communication between the UAV and its controlling unit or the application server is essential. The ubiquity of cellular networks and their infrastructure make them a perfect candidate to provide such continuous connectivity. Initially, efforts to connect UAVs via 3GPP networks were made in Release 15 of LTE, when a study to identify potential enhancements for aerial UEs was conducted, several of which were subsequently specified during the work item (WI) phase, completed in 2018.[36] Since 4G and 5G cellular networks are being widely deployed, the Release 17 of 3GPP focusses on use of radio communications solutions for large scale and cost-efficient UAV-enabled services. It mentions mechanisms for identification and tracking of UAVs. It further mentions about authentication and flight path authorization as well as revoking authorization of UAV via proper USS/UTM. Methods for UAV location retrieval and monitoring its presence and reporting are also part of the Release 17 document.

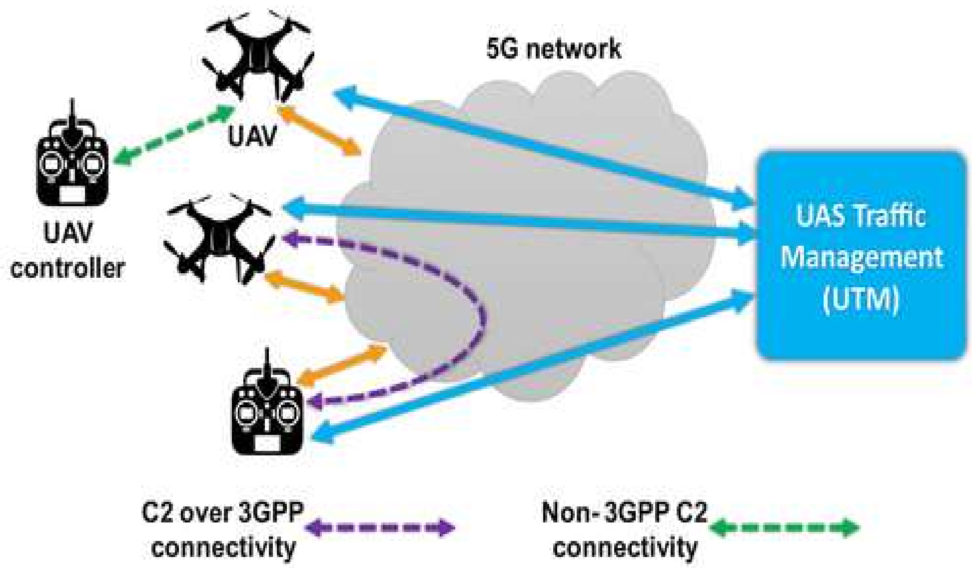

Fig. 18: UAS Traffic Management (UTM)
(Source: https://onlinelibrary.wiley.com/doi/epdf/10.1002/ett.4721)

With the arrival of Release 18 UAVs are set to fly into the 5G-Advanced technology that will provide support for UAV to UAV-C direct communication using PC5, Broadcast Remote Identification (BRID), Detect and Avoid (DAA) etc.

With 5G and mmWave communications UAVs have gained great importance as Mobile Base Stations (MBSs) especially when terrestrial base stations becomes out of service or for places that become temporarily crowded. Recent developments in Massive MIMO transmission with millimeter-wave beamforming also enables high data rates and enables simultaneous transmission to multiple ground users.[37]

[36] https://www.3gpp.org/technologies/nr-uav
[37] https://www.itu.int/dms_pub/itu-s/opb/jnl/S-JNL-VOL3.ISSUE2-2022-A35-PDF-E.pdf

Regarding next-generation mmWave communications, drone-enabled flying base stations find great applicability in establishing short-term line-of-sight (LOS) links among radio antennas and UEs. Thus, the coverage and capacity of wireless networks can be effectively enhanced, whilst next-generation communications can be supported in a more effective manner, especially in dense cells. Additionally, MIMO-based techniques have the potential to formulate an entirely new and dynamically reconfigurable enhanced cellular network, capable of providing never-seen-before high capacity services. A great example of on-demand terrestrial network coverage and capacity enhancements is the establishment of high-throughput links in first-response and emergency scenarios, in which the existing infrastructure is either damaged or inadequate; in this case, aerial base stations can be used to alleviate the load on the terrestrial cellular grid, or provide broadband connectivity where no infrastructure was available in the first place. The below figure showcases a possible application of on-demand terrestrial network coverage enhancement in the case of a wildfire. In this scenario, the line-of-sight between the radio antenna and the corresponding UEs associated with the end user in need (firefighter) is blocked. Temporarily deploying a drone BS helps alleviate this issue by introducing a new path, thereby establishing a temporary yet direct and reliable link between the end user and cellular infrastructure.[38]

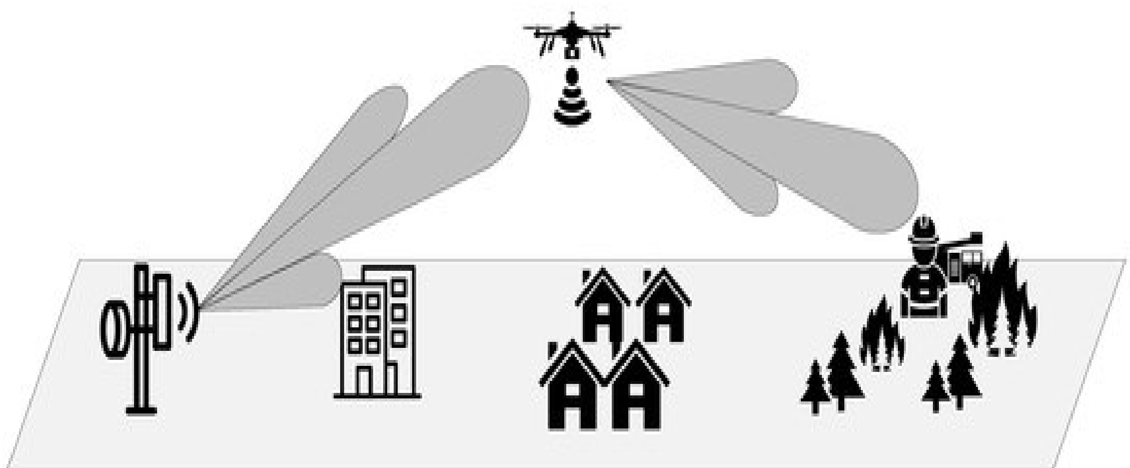

Fig. 19: Drones for Communication Infrastructure
(Source: https://www.mdpi.com/2504-446X/6/2/39)

Another method for restoration of communication channel, can be to use drones with attached repeater system. Radios are the primary mode of communication used in SAR operations. When radios fail to allow adequate communication, cell phones are often used as a replacement.

[38] https://www.mdpi.com/2504-446X/6/2/39

However, if cell phone reception is not available, as is the case in most wilderness settings, the options for restoring communication between IC and SAR teams become limited to devices that communicate via satellite or radio repeaters. A simplex repeater uses a single radio frequency to transmit and receive communication, requiring the transmitting user to complete an entire communication before it is relayed to the receiving user. Owing to non-simultaneous transmission and receiving, it requires a delay after transmission for the repeat.

CASE STUDY: As per a study conducted in Southern Utah, it was tested whether communication could be restored at disaster stricken sites using a drone equipped with a lightweight simplex repeater system. For a location to be included in the investigation, several criteria had to be met: The site must have been the location of a live rescue event in the last 3 years, radio communication between rescuers and IC must have been lost or compromised during the operation without reestablishment of communication at the location or in the immediate surrounding area of the victim, attempts were made to re-establish communication but failed, the cause of the communication loss must have been likely due to terrain characteristics, and global positioning system coordinates of IC and victim were recorded. 20 such sites were identified including terrains like slot canyons, vertical cliffs, steep mountains, and wide deserts.

Implementation: Communication between an Incident Command (IC) and "rescuer" was held using a BaoFeng BFF8HP 5 W 2-way radio, as well as the experimental configuration of a Mavic 2 aerial drone with a tether-mounted Surecom SR-112 controller-repeater system. Once loss of communication between team members was confirmed, often after rescuer entry into a canyon or movement beyond a ridge or hill, IC deployed the drone-repeater system configuration. The drone was piloted 122 m directly, or nearly directly, above IC in the attempt to restore communication. Once communication was restored, it was assessed every 2 min for the duration of the personnel deployment from the point of loss of communication to the location of the victim and back to IC. A single drone battery charge enables 18 min of continuous drone use. To allow for the continual service of the drone, a battery bank consisting of 3 standard Mavic 2 drone batteries and a mobile charging station were used throughout the experiment. Global positioning system coordinates and communication status were recorded.

Result: After the deployment of the drone-repeater system configuration, radio communication was restored to baseline in all 10 locations and allowed for the simulated IC and search team to exchange dialogue with minimal, if any, static or interruption. Across all 10 scenarios, the time elapsed from communication loss to restoration was *6.5±1.1 (4.4–9.9) min*. In every case, after reestablishment of communication, IC and the rescuer maintained contact throughout the remainder of the simulated operation. In 4 of the 10 locations, the drone-repeater system was unable to restore radio communication after being flown directly above IC. In these cases, the drone was piloted horizontally in the direction of the rescuer, and clear communication was subsequently achieved. The maximum horizontal distance necessary for the drone to travel to re-establish communication was *115 m*.

Limitations: The longest distance between IC and the deployed SAR team was 8.9 km, and communication was restored with a single SAR team in each case. In instances where SAR operations cover large distances and multiple teams, it is possible that additional or more powerful equipment would be needed to restore communication. More strategic placement of the drone and pilot might also be considered (ie, between IC and the victim). Here, drone pilots need to keep the drone in their line-of-sight. If a waiver is obtained, or if the pilot is operating in an area where these laws do not apply, it is possible that communication could be restored in more complicated or restrictive terrain.

However, variables such as the drone's free-space propagation behaviour at high altitudes and its exposure to antenna side lobes can contribute to radio environment alterations. These differences may render existing mobility models and techniques as inefficient for connected drone applications. Therefore, drone connections may experience significant issues due to limited power, packet loss, high network congestion, and/or high movement speeds. More issues, such as frequent handovers, may emerge due to erroneous transmissions from limited coverage areas in drone networks. Therefore, drone networks require more efficient mobility and handover techniques to continuously maintain stable and reliable connection. More advanced mobility techniques and system reconfiguration are essential, in addition to an alternative framework to handle data transmission.

5.0 DISASTER SPECIFIC USE CASES

Apart from the general use cases of drones as mentioned in the earlier section, specific uses of drones can be identified for specific disaster situations also. ITU has published a Report titled "HSTP-DIS-UAV Use cases and scenarios for Disaster Information Service using Unmanned Aerial Vehicles"[39], which describes use cases of drones and its scenarios for various representative disaster situations (here, natural disasters). Such use cases are described in detail below:

5.1 For drought

i. The risk for an agricultural drought can be predicted from water level measurement of river
ii. Near farmland with UAV-mounted visible light camera.
iii. The risk for an agricultural drought can be detected from measurements of soil moisture and
iv. Vegetative state by a UAV-mounted hyperspectral or multi-spectral camera.
v. An UAV equipped with a temperature-humidity sensor can detect differences of the atmospheric state.
vi. An on-board computer system of a UAV analyses sensor data and detects droughts in this scenario.
vii. This scenario requires considerable on-board computing power and battery capacity.

5.2 For earthquake:

i. Risk for earthquake can be estimated from measurements of the land surface temperature by a UAV carrying a multispectral camera.
ii. Damages to man-made structures and topological changes by earthquakes can be detected by
iii. An UAV with a visible light camera.
iv. Computer vision technologies can be used for automatic detection of earthquake.
v. The on-board computer system acquires overlapping aerial images of the regions and analyses
vi. Sensor data.
vii. If an earthquake is detected, the sensor data and related information is sent to an earthquake incident command center via wireless communication.

5.3 For flood:

i. The risk for a flood can be estimated from topographic measurement data of flooded areas and

[39] https://www.itu.int/dms_pub/itu-t/opb/tut/T-TUT-DIS-2018-UAV-PDF-E.pdf

ii. Cross sections of a river by a UAV carrying a LIDAR sensor.
iii. The risk for an overflowing river can be estimated from measurements of soil moisture and vegetative state by a UAV carrying a multi-spectral camera.
iv. A UAV equipped with a visible light camera can detect changes of the surface of an overflowing river in daylight.
v. Computer vision technologies can be used for automatic detection of floods.

5.4 **For landslides:**

i. The risk for landslides can be estimated from measurements of displacement rate as well as changes in the surface topography by a UAV carrying a LIDAR sensor.
ii. The risk for landslides can be estimated from measurements of soil moisture and vegetative state by a UAV carrying a multi-spectral camera.
iii. A UAV equipped with a visible light camera can detect changes of the surface topography in daylight.
iv. A UAV with an infrared thermographic camera can be utilized for detection of landslides at night.
v. Computer vision technologies can be used for automatic detection of landslides.

5.5 **For fire:**

i. The risk for wildland fires can be estimated from measurements of soil moisture and vegetative state by a UAV carrying a hyperspectral camera.
ii. A UAV equipped with a visible light camera can detect flames and smokes in daylight.
iii. A UAV with a thermographic camera can be utilized for detection of fire and remaining fire.
iv. An on-board computer system of a UAV analyses sensor data and detects fire in this scenario. This scenario requires considerable on-board computing power and battery capacity. The on-board computer system acquires and analyses sensor data. If fire is detected, the sensor data and related information is sent to a fire incident command centre via wireless communication.

6.0 CHALLENGES OF USING DRONES

Apart from the numerous advantages of using drones, there are also multiple challenges that need to be addressed. With the rapid growth of the drone industry and expansion of drone applications, limitations of existing solutions for point-to-point communication and control between a drone and its controller have become increasingly obvious. Drones are highly sensor-dependent gadgets [28]. As a result, they rely on sensor readings to function effectively. However, because these sensors handle sensitive data, a malevolent operator could use them to jeopardize the flight operation.

There are several other major problems that the drone industry is currently faced with:

i. Limited operation range, i.e., most drones can only fly within the visual line-of-sight (LOS) distances of the controllers
ii. Limited bandwidth that cannot guarantee real-time high definition (HD) image/video transmission
iii. Inaccurate tracking, i.e., existing positioning based on global navigation satellite system (GNSS) may not be reliable due to potential spoofing and jamming
iv. Limited operation time due to battery constraints

Further, unregulated use of drones could pose a threat on the security front as well. They are battery-powered, and hence relatively quiet. Therefore, detecting drones is difficult. They can be manually controlled or programmed to fly low giving the defender very little warning time. Also, detection by normal civil and military radars is difficult as their radar cross-section is very small; their small size makes visual acquisition problematic too. When a drone makes an approach at night or drones are used in a swarm to saturate defenses, quick response can be difficult.

7.0 CONCLUSION & FUTURE WORK

Despite the several challenges, the potential benefits of using drones for various applications far outweigh its drawbacks, making it a worthwhile investment for the future.

As connectivity improves and automation increases, we can expect to see drones at the edge, completing autonomous missions, and uploading data directly to the cloud, bringing substantial business benefit to Telcos and other enterprises.

Drones make it possible to perform remote engineering and network-planning tasks, automate tower inspections, and enhance the measurement of wireless coverage and performance.

With 5G telecom services having been rolled out in India in October 2022, 5G-enabled ecosystem for drones will create opportunities for a more efficient and relatively inexpensive methods for particularly in disaster management, rescue and relief operations. They will enable new use cases leveraging 5G connectivity.

In conclusion, drones have the potential to complement existing disaster management efforts and technologies, providing valuable information, enhancing response efforts, and ultimately saving lives.

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- NR Support for UAVs
- Optimal Beamforming and Deployment of Millimeter-Wave Drone Base Stations
- Drones in B5G/6G Networks as Flying Base Stations
- UAV Communication Systems enable extended range control and streaming of data and video
- Drone Communication: Top Methods for UAV Connectivity
- Garuda Drones Help NDRF Deliver Supplies
- Is drone delivery the future of logistics?
- UAV & Drone Communications
- Drones : Challenges