In collaboration with the Government of Telangana, Apollo Hospitals HealthNet Global and NITI Aayog

WORLD ECONOMIC FORUM

Medicine from the Sky, India: Taking Primary Healthcare to the Masses

INSIGHT REPORT

MARCH 2022

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The drone industry has been widely debated around the world with scores of discussions about the benefits of drones, whether they have reached technological maturity and policy controls. Even today, many potential adopters perceive drones as an unproven business technology, although the success of medical drone deliveries in Rwanda has piqued interest on a global scale, and these projects have been closely observed to learn more about the feasibility of this technology. It is now broadly accepted that drones present a tremendous opportunity to address supply-chain shortcomings in the healthcare sector.

The Medicine from the Sky (MFTS) programme in India's Telangana state pioneered last-mile medical drone deliveries in the developing world and has been instrumental in demonstrating how the drone sector can flourish, given liberal policy reforms. The recently concluded MFTS trials provide evidence of the advantages and potential of the technology, especially when combined with aviation policy changes. They provide a proof of concept not just of the technology but also the approach adopted, and serve as a model for implementation in the developing world.

As was made evident by the COVID-19 pandemic, there is an urgent need for technology that addresses the fundamental limitations of healthcare distribution systems. Urban-grade healthcare infrastructure must be replicated to the greatest extent possible in rural areas, especially in the developing world – where variations in the quality of healthcare are greater and a larger proportion of the population live in rural areas – and drone technology will be a key enabler. However, the real benefits of drone technology will be achieved only when local populations become completely self-sufficient in terms of operating drones and serving their needs.

This report takes a detailed look at the Medicine from the Sky programme whereby, in the first scheme of its kind, vaccines were delivered beyond the visual line of sight (BVLOS) using drones, thus paving the way for numerous other programmes of a similar nature in the region.

Executive summary

In September 2021, after intergovernmental collaboration and detailed policy revisions, the 45-day trial of Medicine from the Sky finally took shape.

The Medicine from the Sky programme in India was commissioned at the India Economic Summit in 2019 under the chairmanship of K. T. Rama Rao, Telangana's Minister for Information Technology, Industries & Commerce, and Municipal Administration & Urban Development (MA&UD), and Jayesh Ranjan, Principal Secretary to Telangana Government, Information Technology, Electronics and Communications (ITE&C) and Industries & Commerce (I&C).

The programme was aimed at using drone technology to extend urban-grade healthcare to the remotest areas and ensure that "nobody is left behind". Since a number of stakeholders had a secondary view of the technology and only a limited perception of its benefits, one of the goals was to measure programming and confidence-building in the ecosystem.

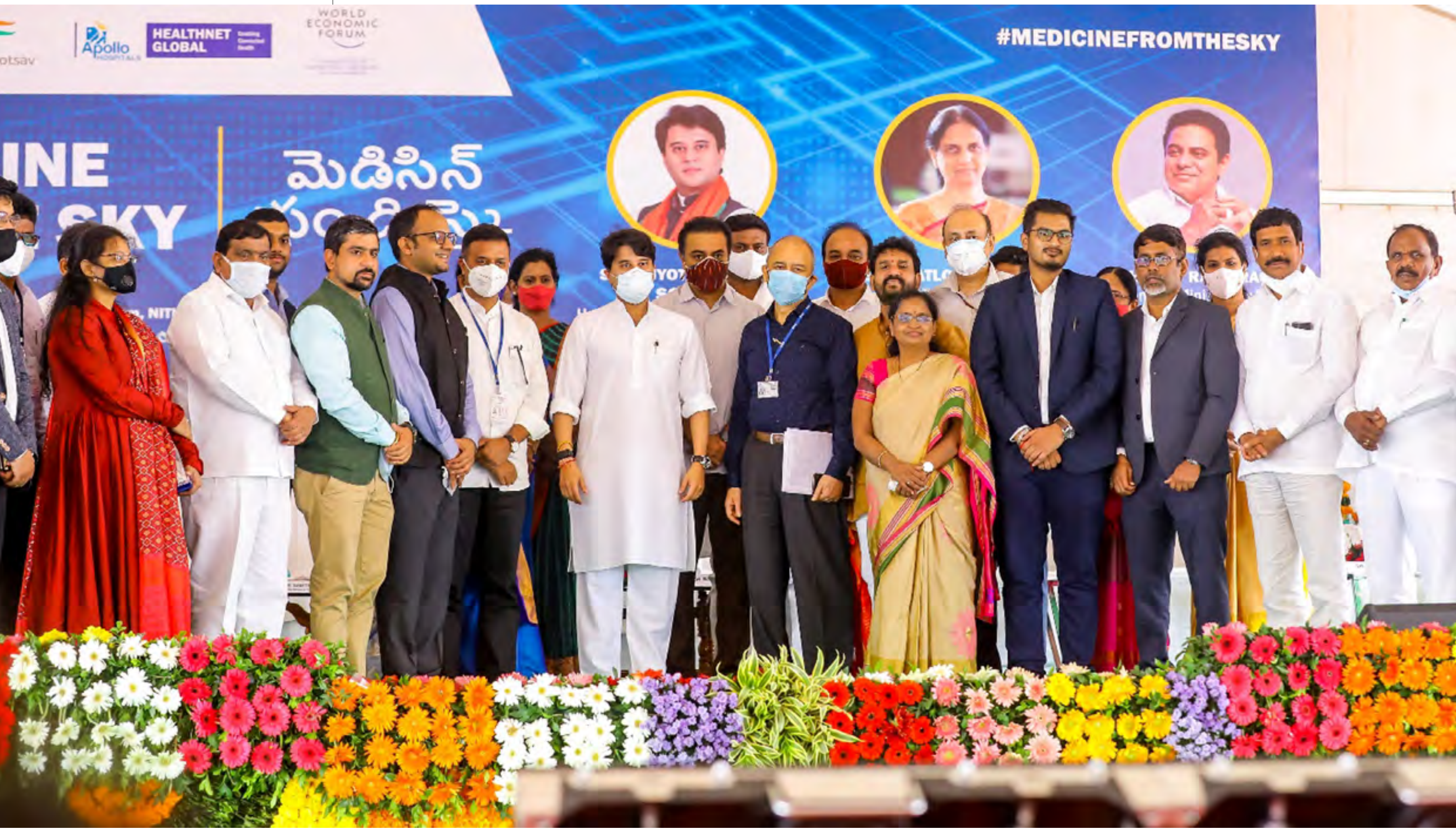
The focus was on three fronts:

1. Technology	Overall maturity of the technology and its capacity to withstand the conditions of the last mile, especially in remote areas
2. Policy	Alignment with policy-makers in articulating the case that drones can be operated safely and securely for social impact
3. Community	Alignment with members of the community, especially beneficiaries (rural citizens), consumers (healthcare workers), implementers, experts and decision-makers, when strategizing for a seamless drone delivery programme

When the programme was initiated, India's low-altitude aviation was governed under the Civil Aviation Requirements for drones under the Aircraft Act of 1934.[1] Over the course of eight community deliberations on the subject, a limited field demonstration of blood delivery was conducted in Hyderabad during the Wings India event in March 2020 in the presence of the Medicine from the Sky (MFTS) community and key decision-makers from the government. Core members of MFTS published an Expression of Interest (EoI) for consortia that would include experts in the field of public healthcare, drone service providers, situational awareness security experts and overall coordinators.

In September 2021, after numerous intergovernmental collaborations involving MFTS core members and policy liberalization under the New Drone Rules 2021,[2] the 45-day MFTS trial finally took shape. During the programme, eight participating drone consortia conducted long-range temperature-controlled vaccine deliveries in rural India. With the successful conclusion of the trials, the greater purpose is to build a framework that can be referred to and easily implemented by other local governments and public health practitioners.

FIGURE 1 | **The Medicine from the Sky programme is inaugurated at Vikarabad, Telangana, by key dignitaries in September 2021**



Introduction

The agenda for the Medicine from the Sky programme was to replicate urban-grade healthcare in rural areas and address unique scenarios that affect local populations.

In mid-2017, when the trial of medical drone deliveries in Rwanda started, there was a clear gap in the blood delivery supply chain. Mortality was a major concern due to failures to deliver blood and blood products as needed and on time. In partnership with the government of Rwanda, drones were able to bridge gaps in the supply chain by ensuring on-demand delivery of blood. Mortality due to issues such as postpartum haemorrhage was significantly minimized using drones in the region. This also set the trend for other countries in sub-Saharan Africa to adopt similar drone-based solutions to address supply-chain issues.

With regard to policy, the World Economic Forum's Centre for the Fourth Industrial Revolution in partnership with the government of Rwanda was able to analyse the situation given the amount of data that was generated by such a large-scale drone programme. This enabled measured decision-making on drone policy using actual data gleaned from (large-scale) macro parameters that had been positively affected by the success of those projects.

As drone policy was still at an early stage globally, several countries did not have set regulations. In India, some states' low-altitude policies were laid out in government-issued circulars, while some had no policies in place at all.

In 2017, India issued an embargo on the use of drones and all drone activities had to go through a paper-based clearance mechanism to operate. When the Medicine from the Sky initiative was conceptualized in India in 2019, the country adopted its initial version of Civil Aviation Requirements for drones, which was comprehensive and highly stakeholder-driven as a result of multiple discussions with industry and civil society.

The three-front approach

Given the vastness of the country, each state in India is subject to hazards and dynamics that are best understood locally. In order to make local populations as self-sufficient as possible, the aim was to address this scenario on three fronts:

– *Data-driven policy recommendations:* Producing information that would help build confidence in policy-making and simplified decisions through data

– *Community sensitization:* Partnering local government and local populations, educating the end consumer by bringing together all stakeholders on a single platform to demonstrate safety aspects and alleviate concerns

– *Technology validation:* Testing the reliability of drones for transporting medical supplies: a) without causing damage and b) while maintaining the required temperature range for the medicine being transported

FIGURE 2 **Community interactions with drone teams on the ground**

1

Calibrating to the local context

Given India's unique challenges in the healthcare supply chain, the goal was to improve the status quo using technology.

The supply-chain conundrum: India's primary healthcare infrastructure is highly expansive to ensure that primary healthcare is accessible to all strata of society in both urban and rural areas. But despite the best efforts, populations across India, especially those dwelling in remote, tribal and/or mountainous areas, face challenges in accessing primary healthcare. One reason for this is that supply chains are riddled with issues such as delayed arrival of medical products, stock-outs, expiry of medicines and delayed arrival of samples for testing. These supply-chain issues are primarily a result of accessibility challenges resulting from geographical factors or the suboptimal road infrastructure.

Telangana scenario: Telangana, the youngest state in India, has always presented itself as a "start-up state". Its willingness to be a pioneer in the adoption of drones was key to making the state a driver of regional agendas for emerging technologies.

In alignment with the state's objectives, the goal for the Medicine from the Sky programme was to replicate urban-grade healthcare in rural areas and address unique scenarios that affect local populations. For example, snakebites are a significant issue in rural Telangana, and therefore timely access to long-tail medicines[3] is critical. Obtaining the anti-venom is time-sensitive, and if treatment is not available within the golden hour (the first hour after the snakebite, when anti-venom treatment will be most effective), the time breach often leads to fatalities.

The MFTS programme wanted to explore locally unique scenarios, such as the above, where drones could ensure timely access to medical supplies and act as a life-saving technology.

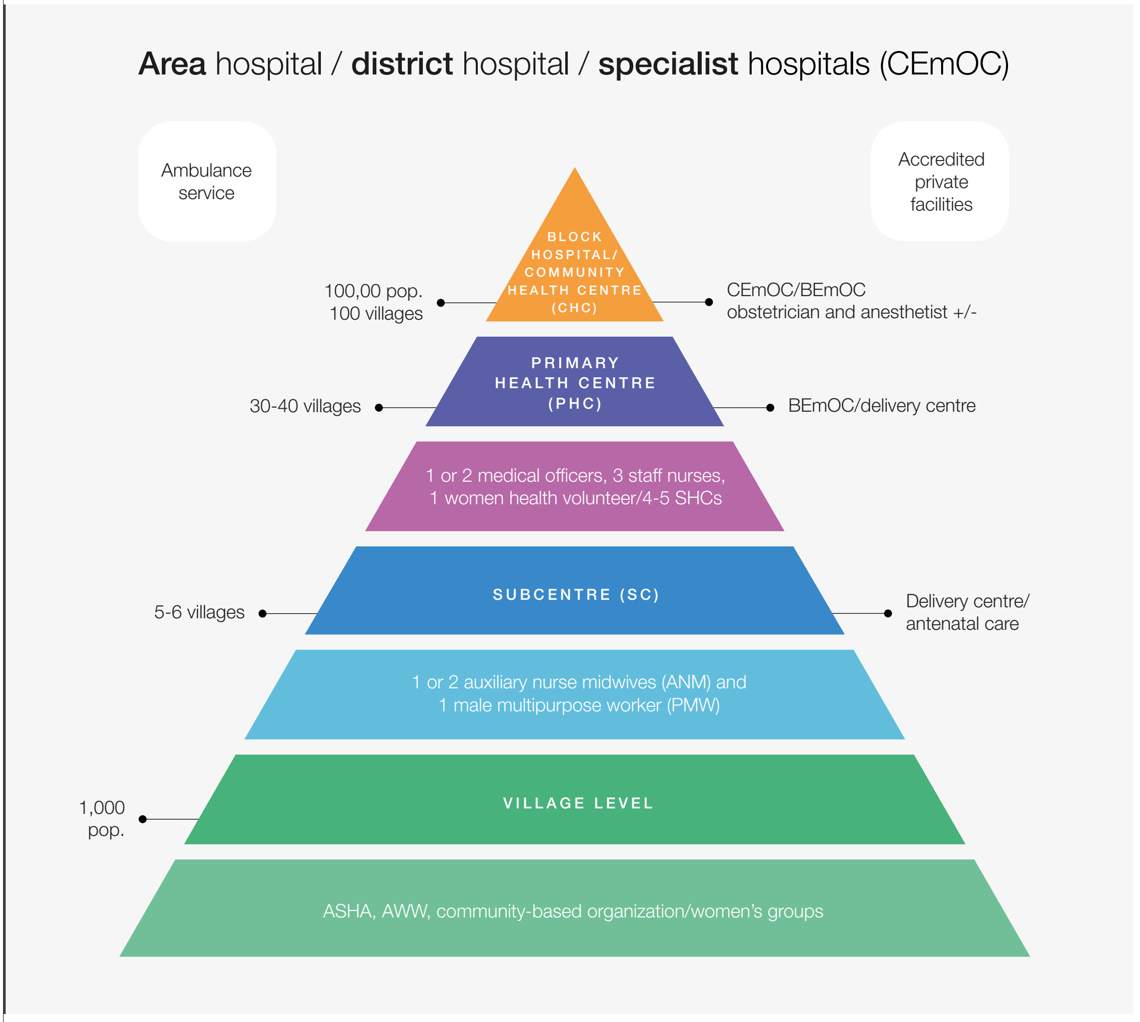
FIGURE 3 **Test delivery of vaccines to ASHA workers on the day of the MFTS launch**

Source: Minister KTR, "Minister KTR Live | Launching of #MedicineFromTheSky Project in Vikarabad", YouTube, 11 September 2021: https://www.youtube.com/watch?v=3mWuYFvPC5E&t=5s

1.1 The Indian context

The Indian public healthcare system can be classified in three categories: primary, secondary and tertiary. For healthcare delivery to happen seamlessly, health centres in each category need to interact as creatively as possible. The accredited social health activists (ASHAs) and community healthcare workers such as Aganwadi rural childcare workers (AWW) at the village level are a crucial cog in the healthcare machinery.

FIGURE 4 **Public health infrastructure in India**



Source: Samiksha Singh, Pat Doyle, Oona Campbell, Manu Mathew and Gudlavalleti Murthy, "Referrals Between Public Sector Health Institutions for Women with Obstetric High Risk, Complications, or Emergencies in India – A Systematic Review", 3 August 2016: PLOS ONE: 11. e0159793. 10.1371/ journal.pone.0159793

Limited infrastructural developments have often led to a disconnect between primary healthcare and higher levels of care. Due to this, patients residing in rural or underdeveloped areas often try to address their health concerns locally, using substandard institutions. Primary health centres are often not well enough equipped to carry out basic procedures. This phenomenon, coupled with lack of availability of medical products and medicines, means that the macro-indicators of development often dip.

FIGURE 5 | State/UT number of subcentres, PHCs and CHCs functioning in India as of 31 March 2018

S. No.	States/UT	Subcentres	PHCs	CHCs
	India	158417	25743	5624
1	Andhra Pradesh	7458	1147	193
2	Arunachal Pradesh	312	143	63
3	Assam	4644	946	172
4	Bihar	9949	1899	150
5	Chhattisgarh	5200	793	169
6	Goa	214	25	4
7	Gujarat	9153	1474	363
8	Haryana	2589	368	113
9	Himachal Pradesh	2084	576	91
10	Jammu & Kashmir	2967	637	84
11	Jharkhand	3848	298	171
12	Karnataka	9443	2359	206
13	Kerala	5380	849	227
14	Madhya Pradesh	11192	1171	309
15	Maharashtra	10638	1823	361
16	Manipur	429	91	23
17	Meghalaya	443	108	28
18	Mizoram	370	57	9
19	Nagaland	396	126	21
20	Odisha	6688	1288	377
21	Punjab	2950	432	151
22	Rajasthan	14405	2078	588
23	Sikkim	147	24	2
24	Tamil Nadu	8712	1421	385
25	Telangana	4744	643	91
26	Tripura	1020	108	22
27	Uttarakhand	1847	257	67
28	Uttar Pradesh	20521	3621	822
29	West Bengal*	10357	913	348
30	A&N Islands	123	22	4
31	Chandigarh	17	0	0
32	D&N Haveli	71	9	2
33	Daman & Diu	26	4	2
34	Delhi	12	5	0
35	Lakshadweep	14	4	3
36	Puducherry	54	24	3

* 11 PHCs situated at Municipal Areas are included

Source: Bulletin on Rural Health Statistics in India, 31 March 2018, Statistics Division, Ministry of Health & Family Welfare

While the problem was clear to see, the priority was also to obtain a detailed assessment of technological capability in the region. It was important to demonstrate the sustained capability of drones in real-time scenarios. Given the state's vibrant start-up ecosystem and its desire to use Fourth Industrial Revolution technologies for social impact, Telangana was an ideal candidate for an exploratory programme on drone-based medical deliveries. In Telangana, it was possible to commission a multistakeholder community to take part in the programme due to the state's public health infrastructure and the intent of the state's leadership to integrate innovative technology to optimize healthcare. The state also had ongoing initiatives in telehealth. Partnering with Apollo Hospitals HealthNet Global as a clinical representative in the programme significantly helped in identifying immediate questions and circumstances during the programme and in enabling vaccine and medicine availability, as well as monitoring the adherence of clinical protocols throughout the project. On a social level, the Telangana population is open to and well-disposed to the use of technology. The local district government made it clear they would welcome the use of drones to support local planning and delivery.

The district of Vikarabad was commissioned due to its unique location. While largely rural, it was less than two hours by car from Hyderabad, the state's capital. The success of this programme would lie in the increased uptake of drones in the region. While the learnings would be demonstrated to local government, state government and the local population, discussion of "whether to adopt or not" would be deliberated in Telangana, with the programme providing a proof of concept in the immediate vicinity. Hence, demonstration and adoption would set a trend in the region and send out a positive message on the engagement of drones for medical deliveries.

1.2 Need of the hour

FIGURE 6 **Drone delivery use cases**

Blood stock
- Decrease maternal mortality
- Decrease infant mortality
- Decrease mortality from trauma

Vaccine stock
- Improve immunization rates
- Reduce population prevalence of diseases

Long-tail medic
- Reduce mortality caused by snakebites or rabies
- Improve treatment of cases that require second- and third-line antibiotics
- Provide “urban” standard of care to rural patients

Diagnostic specimens
- Improve turnaround time for some tests
- Improve integrity and security of diagnostic specimens

Source: World Economic Forum, “Medicine from the Sky”, 2019: https://www3.weforum.org/docs/WEF_Medicine_from_the_Sky.pdf

Scoping exercise: When the programme was formally initiated at the India economic summit in New Delhi in 2019, the core agenda was to include delivery of blood, medicines, vaccines and organs. The timely delivery of these items was of vital importance during the golden hour. It was around this time that human organ deliveries were first trialled in Maryland, US, with the delivery of a human kidney by drone.

Intangible factors: India has a well-established green corridor[4] when it comes to urban transport by road. The Medicine from the Sky team deliberated at length on some of the intangibles of organ delivery by road: issues such as pressure on local law enforcement, traffic congestion and the limitations of road transport due to the very short window of transporting organs. Blood supplies fall under a similar category, as the need for specific blood types and the availability of the same type in blood banks could be a cause for concern.

Impact of the COVID-19 pandemic: Owing to the COVID-19 pandemic, the decision to test vaccines was established. Approval for vaccine deliveries was formalized in mid-2020 after the first wave of COVID-19 in India. The Indian healthcare system also witnessed a heavy burden during the second wave of COVID-19 from April to May 2021.

Blood delivery demonstration: In March 2020, a brief feasibility check was conducted in a highly controlled environment for blood delivery using drones within the visual line of sight. This delivery was carried out with due approval from India’s aviation regulators in the presence of key government officials, paramedics and doctors, who oversaw the evaluation.[5] However, the decision to stress-test drones for vaccine deliveries was made largely in order to increase preparedness for pandemic situations such as COVID-19.

FIGURE 7a | **The Joint Secretary for Civil Aviation inspects a drone prior to a field study**

Source: Libin Chacko Kurian, "Hepicopter to Deliver Covid Vaccines in Telangana after MoCA, DGCA Nod", ITLN, April 2020: https://www.itln.in/hepicopter-to-deliver-covid-vaccines-in-telangana-after-moca-dgca-nod-aviation

FIGURE 7b | **Drone carrying blood post-landing during a feasibility check in March 2020 at Begumpet Airport**

1.3 Approach to assessing feasibility

Airspace demarcation: An airspace territory of 16 corridors was earmarked in the district of Vikarabad. This included public and primary health centres and local district hospitals. To address the problem at hand, the Medicine from the Sky team was able to create a blueprint for a small-scale, low-altitude air freight system. It was the multistakeholder approach that would help take the programme to the next level of ratification. With Indian think tank NITI Aayog partnering with the World Economic Forum, Telangana local government and Apollo Hospitals HealthNet Global, the core team brought together the leading experts in the ecosystem to determine the ideal model in practice.

Inviting bids for the pilot: In March 2020, in partnership with Telangana local government, organizations were invited to submit expressions of interest and their bids for the delivery of medical products using drones. Start-ups involved in this process, which shared their experiences and insights, were instrumental in refining the scope of the experiment. Furthermore, to ensure the total safety and security of the programme, a coordination process with India's airports authority, the directorate general and Ministry of Civil Aviation helped develop protocols in collaboration with the relevant air traffic controllers. After analysing every aspect of safety and security and even producing virtual renditions of drone fly-throughs, a foolproof plan was developed for the roll-out.

FIGURE 8 **Non-negotiable points during the drone programme**

Medical
- Reliability of the drone
- Payload temperature
- Shock-free landings

Airspace
- Safety of airspace/ground
- Security
- Scalability – management of traffic

Technology
- Mean time between failures
- Repeatability
- Consistency

Source: World Economic Forum

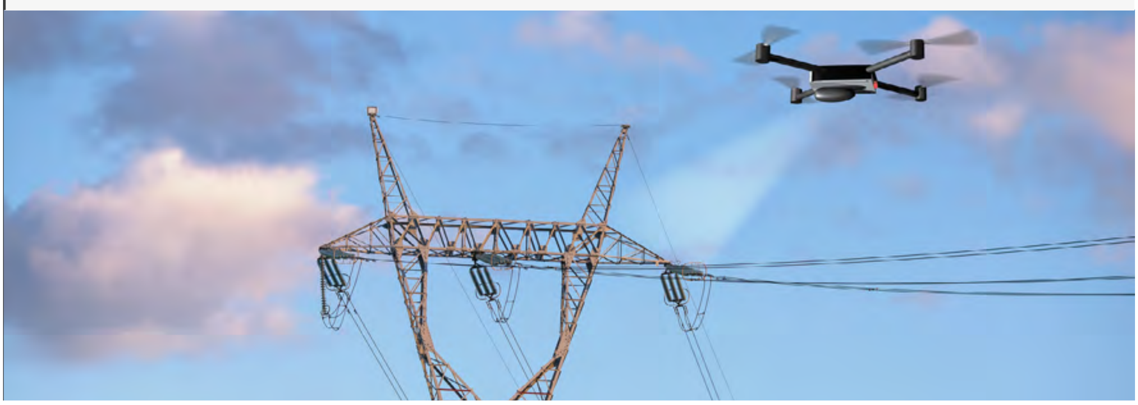
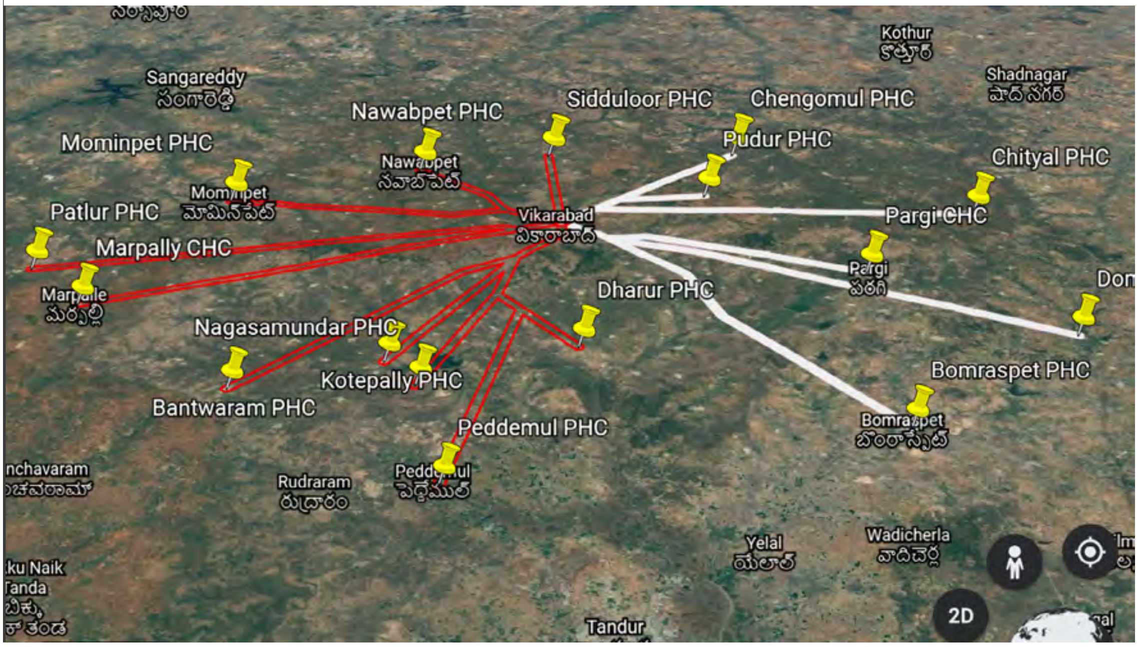


FIGURE 9 | Corridors earmarked in Vikarabad district for the 45-day drone programme



1.4 The impact of disruptive technologies

Labour and markets: Creating new markets, upskilling the labour force and disrupting the traditional status quo can lead to economic development, increased well-being (both health and economic) and improved amenities. It is generally accepted that innovative technology, even if it leads to a loss of employment, will positively affect society.

Perceptions: *The Future of Jobs* report published by the World Economic Forum in 2016, forecast a positive outlook for employment in India owing to rapid modernization through technology. Transportation and logistics emerged alongside education and training as growing areas in terms of employment.[6]

In the 1960s, there were concerns about the labour-saving aspects of technology. The automation of routine tasks through technological innovation was viewed as a threat to the continued need for a fully employed workforce. However, these viewpoints were largely exaggerated. Advances in artificial intelligence (AI) and autonomous vehicles have undoubtedly affected the service-sector workforce. Most advanced economies significantly depend upon service-sector employment, and most jobs that have been created are in the service sector rather than in manufacturing.[7]

Disruption of the status quo: Individuals with limited experience can operate drones and refine apps with the aid of short-term training programmes. Drones can provide very high levels of detail, efficiency and decision-making systems when it comes to determining routes, calculating slopes and developing elevation models, among others,[8] presenting an ideal opportunity for drone-based medical deliveries.

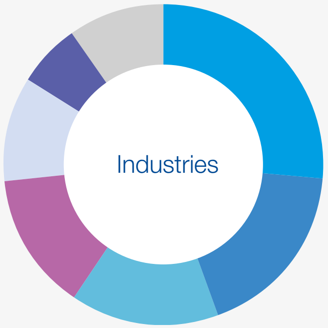
BOX 1 | The mainstreaming of drones in healthcare

– **Use-case validation:** With regards to patient care, there is an irrefutable need to use drones – to deliver medicines in the golden hour after a snakebite, for example, to provide critical care for patient monitoring and to distribute life-saving equipment such as defibrillators or aspirin tablets

– **Trust building:** Often, drone technology finds itself at the centre of a media hype cycle. To tackle this, measures need to be taken to establish trust and set expectations for the consumer. Hence, entities that choose to adopt drones may do so in a measured manner.

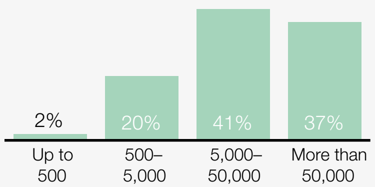
Country profile
India

Sample overview



- Information and Communication Technology...27%
- Mobility...18%
- Energy...15%
- Basic and Infrastructure...14%
- Professional Services...11%
- Consumer...6%
- Others...10%

Number of employees



Workforce disruption

Main industries

Industry	Employment outlook, 2015–2020	CURRENT: Local share of recruitment, specialists	CURRENT: Ease of recruitment, overall	2020: Local share of recruitment, specialists	2020: Ease of recruitment, overall
Information and Communication Technology	stable –0.38%	51–75%	neutral	51–75%	neutral
Mobility	growth 1.15%	76–100%	neutral	76–100%	neutral
Energy	growth 1.36%	76–100%	hard	76–100%	harder
Basic and Infrastructure	growth 3.13%	76–100%	hard	51–75%	harder
Professional Services	strong growth 5.00%	51–75%	easy	26–50%	harder
Consumer	strong growth 5.00%	76–100%	hard	51–75%	neutral

Ease of recruitment

Occupation types	CURRENT: Country/region	CURRENT: Sample average	2020: Country/region	2020: Sample average
Mass employment Database and network professionals	neutral	hard	neutral	neutral
Strategic/specialist Software and applications developers and analysts	hard	hard	harder	harder
New and emerging Data analysts	–	–	hard	hard

Employment outlook by main job family
Current workforce (thousands)

Current workforce (thousands)	Outlook	Job family
–	Growing	Architecture and Engineering
–	Declining	Arts, Design, Entertainment, Sports and Media
–	Stable	Business and Financial Operations
–	N/A	Community, Social and Protective Services
–	Growing	Computer and Mathematical
–	N/A	Construction and Extraction
–	Growing	Education and Training
–	N/A	Farming, Fishing and Forestry
–	N/A	Healthcare Practitioners
–	N/A	Hospitality and Food Related
–	Growing	Installation and Maintenance
–	N/A	Life, Physical and Social Sciences
–	N/A	Legal
–	Growing	Management
–	Declining	Manufacturing and Production
–	Declining	Office and Administrative
–	N/A	Personal Care and Service
–	Stable	Sales and Related
–	Growing	Transportation and Logistics

N/A · Growing · Declining · Stable

Source: World Economic Forum, The Future of Jobs, https://www3.weforum.org/docs/WEF_Future_of_Jobs.pdf

1.5 Recommendations for long-term medical drone delivery planning

Strategic planning: Smaller organizations form a significant proportion of India's drone sector. Over the years, 180 start-ups in the ecosystem have raised $27 million.[9] Despite the enthusiasm of a youth-centred industry contributing positively to a host of sectors, many SMEs have suffered high failure rates, performance issues and inconsistent availability of work. To gain the edge over incumbent systems, strategic planning is of paramount importance.[10] In comparison with a show-up-and-demonstrate approach, medical drone programmes need precision planning that involves detailed assessments prior to deployment. This is largely to manage expectations and build the procuring agency's confidence. The Medicine from the Sky programme followed a gradual approach, starting from a field study in 2020 through to exemptions from unmanned aerial system (UAS) regulations. On commencement of the programme on 11 September 2021, the initial missions were payload-free and within-line-of-site operations for the first two days prior to gradually increasing the lift-off weight and distance to near-full capacity.

FIGURE 11 **Indicative phased planning**

Phase I (1.5 –2 months)

Detailed ground-level assessment

- Conduct a detailed study of the health system in the state
- Invoke the industry core group and curate a case for medical drone operations in the state
- Develop an implementation plan
- Map out all possible stakeholders in the equation

Phase II (3–4 months)

Limited operations with experienced players

- Decisions: delivery of vaccines, pharma products, blood components to hospitals and district sites
- Limited route network, integrate with medical supply chain, facilitate steady service in live conditions
- Airspace: exemptions/ procedural clearances/ intimations where needed to ensure deconfliction from critical areas

Phase III (6 months +)

Scaling up of the delivery network

Develop a case for permanent, replicable, sustainable drone operations in affected districts across the state with a foolproof business model

Source: World Economic Forum

FIGURE 12 **Drone loaded with vaccines prepares to take off from a hub location and land at a healthcare facility in Vikarabad**

2 Piloting drone programmes in a federal republic

The decision equilibrium is a function of a comprehensive needs assessment, central compliance and local requirements.

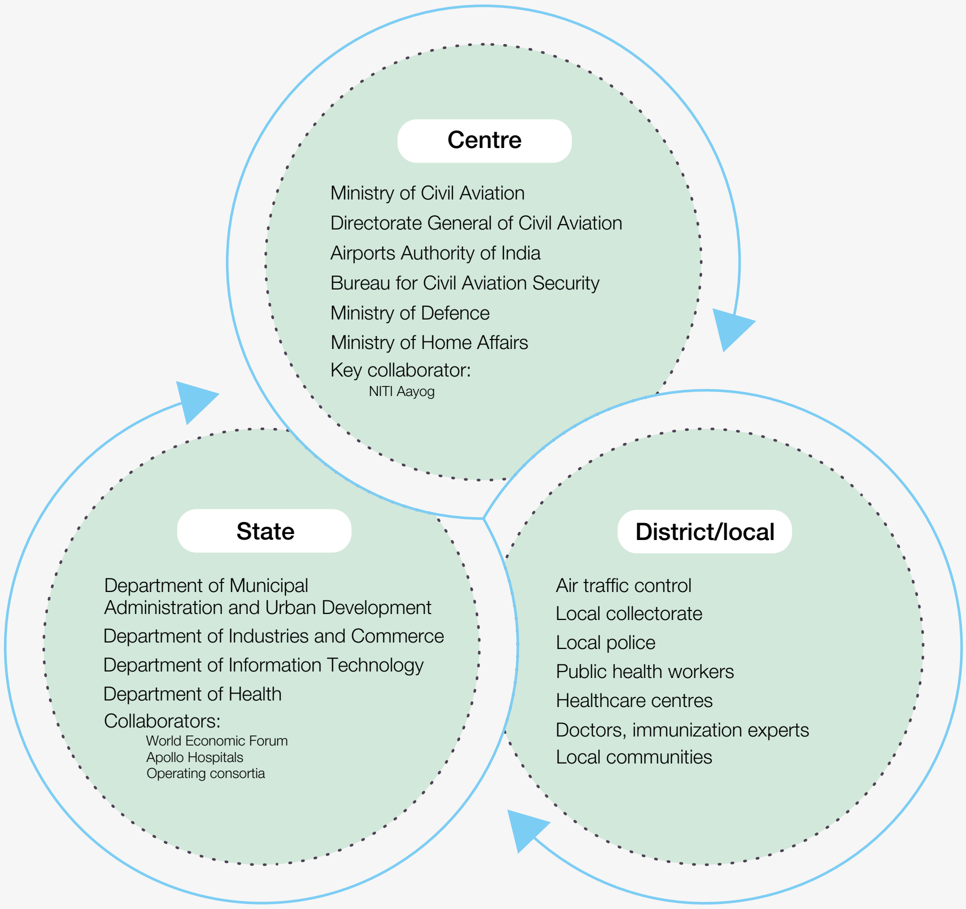
BOX 2

Cooperative federalism in India through drones

The UAS sector has repeatedly demonstrated how a collaborative and coordinated approach between decision-makers and stakeholders can positively affect those at the bottom of the pyramid – the strata of society that does not have access to basic healthcare. India presents a classic opportunity to build a replicable model of federalism that is cooperative, creative, constructive and competitive; a sandbox where states compete not just with each other but also with the federal government.[11]

FIGURE 13

Map of stakeholders



Source: World Economic Forum

2.1 Negotiating regulatory scenarios

Regulatory challenges regarding UAS have been a global issue for a large part of the decade prior to the launch of the MFTS programme in 2021. There have been discussions about securing the lower-altitude skies for drone activity to ensure that there are no conflicts between crewed and uncrewed aircraft. The Indian MFTS programme involved detailed discussions between government, industry, civil society and academia. While there was a blanket ban on drones in 2014, the pursuit of a rationalization of drone regulations started to take shape in 2018. India's first Civil Aviation Requirements were introduced in December 2018, culminating in the liberalization of the drone economy in August 2021 with the release of the new Drone Rules 2021. Part of the complexity was attributed to the distributed nature of the subject. While drones and aviation come under the jurisdiction of the federal government, healthcare is largely a subject of the state government, hence presenting a classic case for cooperative federalism. NITI Aayog adopted a cooperative federalism philosophy in order to iron out drone regulatory issues to address medical supply-chain challenges, with the Medicine from the Sky project at the forefront of its push for change.

FIGURE 14 | Industry-government virtual round table on drones hosted by NITI Aayog, Telangana local government, Apollo Hospitals and the World Economic Forum

Efforts were made to ensure that all drones used in the experiment were as failsafe as possible and in compliance with the law. The testing and regulatory validation process was taken very seriously: there were more than 1,000 pages of standard operating procedures (SOPs) that comprehensively detailed the infrastructure, technology and local scenario; thus, process was key to the success of the programme. Arguably, healthcare and aviation are two of the most highly regulated sectors globally – and this programme was a combination of both. Hence, being able to safely experiment with the delivery of vaccines through aerial freight required a very delicate balance that the programme had to maintain from its inception.

Being at the forefront of leveraging emerging technologies, Telangana has always acted as a testbed for innovative solutions to support scaling across the nation. The COVID-19 pandemic has highlighted that healthcare supply chains can be further strengthened, and drones offer a robust value proposition, especially when it comes to remote areas and emergencies. Medicine from the Sky is the first-of-its-kind initiative in the country to generate insights that shall benefit the entire ecosystem. The enthusiasm and support by all the partners is deeply appreciated.

K.T. Rama Rao, Telangana's Minister for Information Technology, Industries & Commerce, and Municipal Administration & Urban Development (MA&UD)

Drone use provides the opportunity to support our traditional approaches to healthcare delivery, especially in under-served or remote regions of the country. Our healthcare sector could potentially witness large-scale deliveries of long-tail medicines, vaccines, blood and vital organs throughout the country across terrains with drones in action. As clinical partners in the Medicine from the Sky initiative, Apollo Hospital's HealthNet Global will be responsible for enabling vaccine and medicine availability and properly monitoring the adherence of clinical protocols throughout the project.

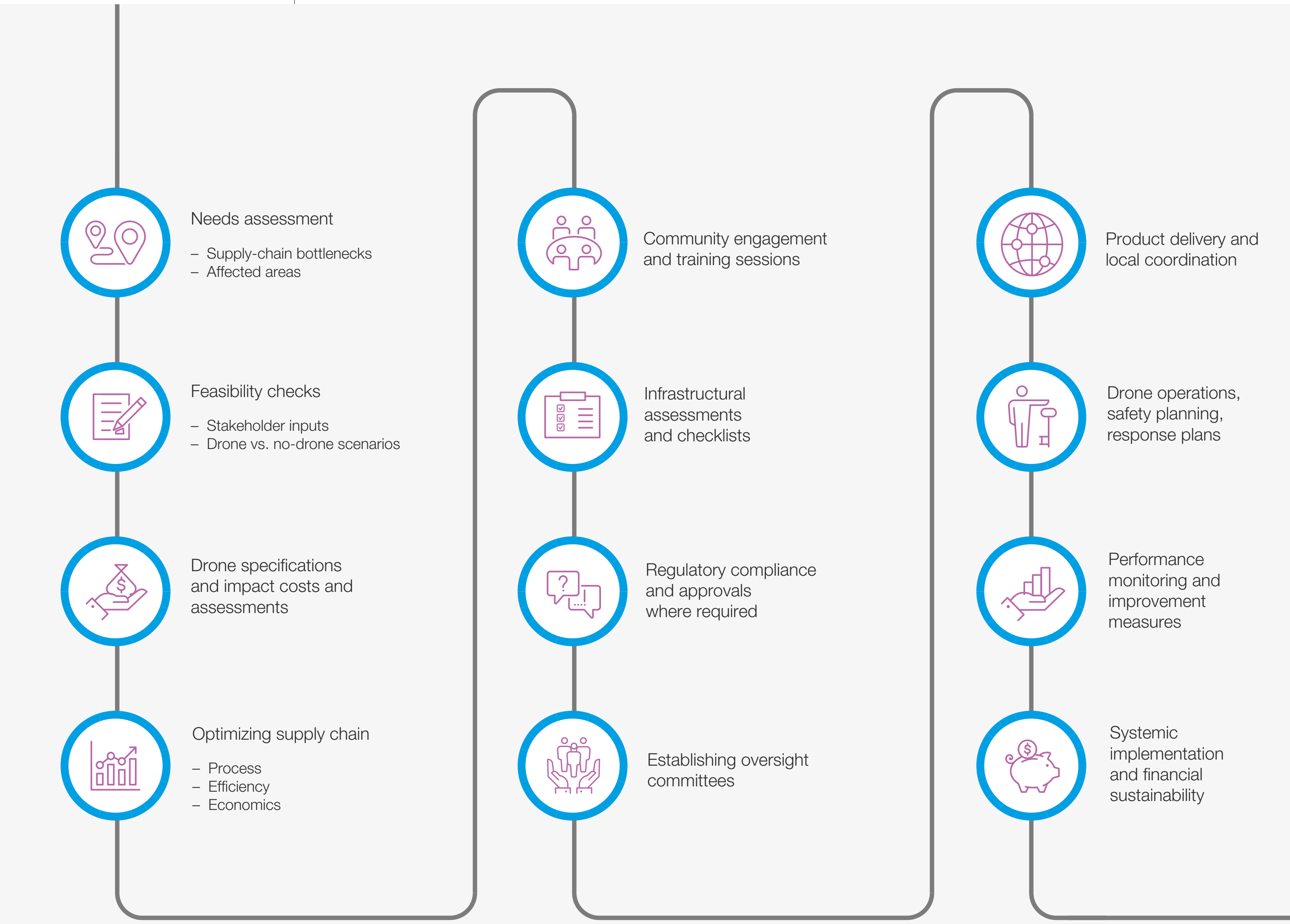
Sangita Reddy, Joint Managing Director, Apollo Hospitals Group

2.2 The drone decision

When agencies – governmental, non-governmental, public or private – consider the use of UASs to address healthcare issues, a comprehensive needs assessment is required coupled with a positive outlook on the technology. It is crucial to weigh up the differences between drone and no-drone scenarios while also accounting for intangible factors. A few key points that need to be addressed are as follows:[12]

1. Where are drones needed?
2. What are the site locations?
3. Which assets and infrastructure are required, and what is the budget?
4. What products will the drone carry?
5. What will trigger a drone flight and how often will drones fly?
6. What are the operational and regulatory protocols?
7. What reporting mechanism (for logging mission details) will be used?
8. How will communities be engaged?
9. How will success be measured?
10. How will the system sustain drone programmes?

FIGURE 15 **Indicative steps to including drones in a health supply chain**



Source: UPDWG, "Designing Medical Drone Delivery Systems: Day 2", YouTube, 20 November 2021, https://www.youtube.com/watch?v=Rya6o6ac6d4

In an Industry Core Group meeting convened by the World Economic Forum, NITI Aayog, Public Health Foundation of India (PHFI) and the Government of Telangana in August 2021, a few key issues emerged:

1. Areas of need can be dynamically identified through simulation exercises for take-off and landing.

2. Real-time data combined with geospatial intelligence can help provide important insights, especially for missions beyond the visual range.

3. The quality of technology affects the unit economics significantly – a poor-quality drone may result in higher overheads.

4. Lack of historic data or benchmarks can lead to arbitrary pricing, which may further affect the economics of a drone mission. The insurance premium borne by the drone operator should not make the end costs unreasonable (e.g. a drone assigned three deliveries a month signed on an INR 500,000/$7,000 insurance scheme does not make economic sense).

5. The requirement for measured drone intervention is evident, but a collaborative effort is needed to overcome logistical constraints.

2.3 Securing the skies and the area of operations

Risks and mitigation methods: Inspired by the Specific Operations Risk Assessment (SORA) guidelines created by the Joint Authorities on Rulemaking on Unmanned Systems (JARUS),[13] the programme focused on three key categories of potential harm: 1) injuries to third parties on the ground; 2) injuries to third parties in the air; and 3) damage to critical infrastructure.[14] These were the key non-negotiable points before proceeding with operations. The most significant factor involved complete deconfliction with any manned aviation activity. Every participating consortium submitted a detailed concept of operations that outlined the organizational hierarchy of each participating entity, the qualifications of the air crew and ground staff, the concept of operations – detailing the modus operandi, weather checks, aircraft flight procedures during every mission, and emergency and communication protocols with the nearest air traffic controller.

Validation by regulators: The above-mentioned risk and mitigation methods were presented through a formal "hazard identification and risk mitigation" exercise with key representatives from central government and regulatory bodies. In order to quantify the air and ground risks involved, the consortium presented a digitally simulated fly-through, which helped arrive at a Specific Assurance and Integrity Levels (SAIL) score of "II". On a scale of VI, the score indicates a low risk in case of impact.[15] Further, considering that the 16-corridor airspace earmarked for this effort was relatively thinly populated and deconflicted from manned airspace given the flight cap of 400 feet (120 m) above ground level, operations were cleared for action.

2.4 Planning for contingencies

Well before operations commenced, drone teams visited Vikarabad district and travelled the routes on the ground to learn more about how best to optimize output while maintaining the highest levels of safety. For every corridor, emergency landing sites were established in case of connectivity issues or other contingencies. The table below provides a list of scenarios in case of contingencies and actions to mitigate risks in the future. Further, it was important to measure flight altitudes and air routes, bearing in mind the presence of high-tension cables, towers, power lines and uneven terrain.

Some examples are:

– Loss of propulsion
– Aircraft battery failure
– Ground control station failure
– GPS failure
– Public encroachment
– Rogue remotely piloted aircraft (RPA)
– Battery fire while UAS grounded
– Fire (UAS in flight)
– Fire (GCS or transmitter)

2.5 Communication protocols with local and central agencies

In order to secure low-altitude airspace during uncontrolled drone operations, UAS Traffic Management (UTM) systems play a key role. A developed UTM system defines roles and responsibilities, data-exchange protocols and software functions to enable the management of low-altitude drone activity. Multiple drone operations within the same airspace and beyond the visual line of sight can be safely managed through UTM systems.[16] In simple terms, it is important to know exactly where the drone is in the airspace at every point during every mission.

The EoI floated by the Government of Telangana mandated the presence of a UTM service provider for every entity that submitted its bid for the programme.[17] However, communication with the local air traffic control took an analogue approach during the programme. This involved keeping the local ATC abreast of all drone activity through a daily debrief while operating in the air corridor.

1. SOP ATC Coordination Requirements

 1.1. **[FILING FLIGHT PLAN]** Remote pilot to file flight plan (including planned geofence, route waypoints, altitudes, plan start-and-end time) as per ICAO format and send to ATC Shamshabad on email _____.

 Note 1: *ATC Shamshabad recommended manually emailing the filled ICAO format FPL initially to avoid any technical issues and then switch to UTM filing/emailing capability if applicable.*

 1.2. Filing of Flight Plan (FPL) by remote pilot in Step 1.1 must be done at least 24 hours prior to operation date to ensure in-time FIC and ADC clearance and issue of FIC# and ADC#.

 1.3. **[OBTAIN FIC NUMBER]** UTM coordinator/representative to request FIC# for the FPL on telephone number __________ and communicate back to remote pilot in command before start of flight.

 1.4. **[OBTAIN ADC NUMBER]** UTM coordinator/representative to request ADC# for the FPL on telephone number _________ and communicate back to remote pilot in command before start of flight.

 1.5. **[IN-FLIGHT COORDINATION]** UTM coordinator/representative and remote pilot to communicate over pre-identified means of communication (telephone/in-app messaging etc.) before commencement of flight.

 1.6. UTM coordinator/representative and remote pilot to communicate on end of flight.

 1.7. UTM coordinator/representative and/or ATC-designated POC [point of contact] to monitor ongoing flight operation on UTM ATC dashboard as provided by UTM provider.

 1.8. **[FLIGHT PLAN DEVIATIONS]** UTM coordinator/representative and remote pilot to communicate over pre-identified means of communication (telephone/in-app messaging etc.) in the event of deviation required from filed flight plan or changes to ongoing operation due to changes in weather, local emergencies or ATC requirements.

 1.9. UTM Coordinator/representative and/or ATC designated POC should communicate if any emergencies to RPAS [remotely piloted aircraft system] flying to ATC.

 1.10. **[END OF DAY DEBRIEF]** UTM coordinator/representative to debrief end-of-day flight to ATC if needed.

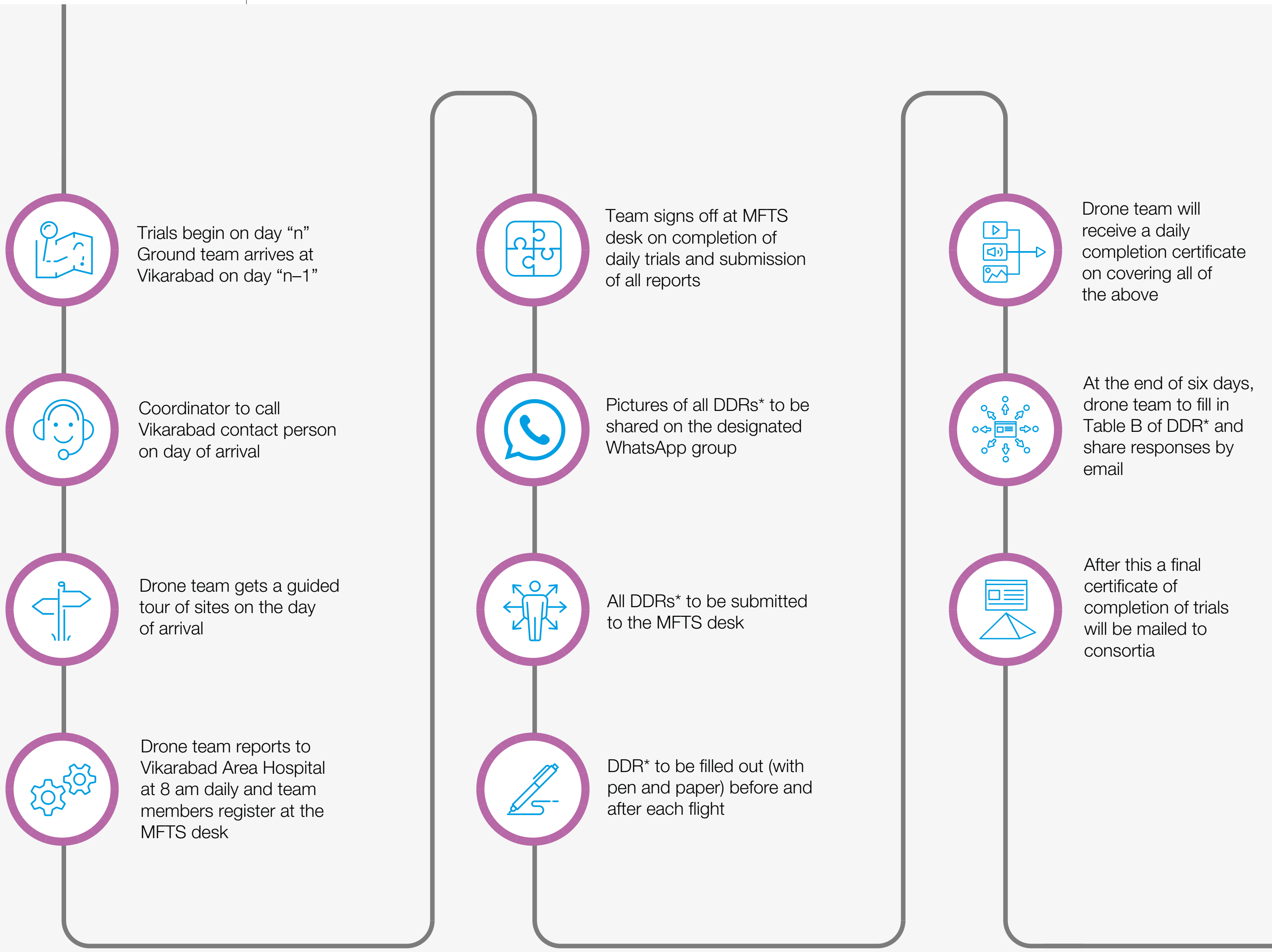
2. Steps 1.1 to 1.8 to be followed for each planned flight.

2.6 Play-out of the drone programme

Setting stage: Drone companies were invited to participate in these experimental trials. In total, eight consortia were shortlisted. Test sites were identified, both take-off and landing, in coordination with the relevant district administrations. Necessary approvals were obtained from the Ministry of Civil Aviation (MoCA)/Directorate General of Civil Aviation (DGCA) to conduct a trial of drones in Vikarabad district in the state of Andhra Pradesh. Vaccines and other medical stock-keeping units (SKUs) for trials were stored at a cold-chain equipment at the take-off location. Orientation and training were given to paramedics on drone operations and cold-chain handling. Mock drills began for the distribution of vaccines, medicines and diagnostic samples. A questionnaire was developed and validated by all of the partners to capture vital statistics related to medical and operational aspects during the drone trial. All data related to medical and operational aspects were captured.

The Medicine from the Sky guide: Prior to mobilizing drones at the participating location, all consortia were provided with a brief guideline document that outlined details of local logistics, boarding recommendations, operational contact details, and emergency and COVID-19 protocols. Furthermore, the document provided protocols on data capture and submission to the Medicine from the Sky operations put in place for the trial.

FIGURE 16 **Workflow for drone teams on data submission**



* DDR = drone demonstration report

Source: World Economic Forum

Training: The SOPs, along with training decks, were shared with the participating organizations. Virtual training was conducted a week before the trials started, followed by several sessions of on-the-ground training for the drone companies as well as for the paramedics and other staff involved in the trials. The training included knowledge-sharing of cold-chain management before, during and after every drone flight and on COVID-19 prevention practices to be followed during trials.

FIGURE 17a | **Local health workers being educated about the programme**

FIGURE 17b | **Cold boxes being loaded with medicines prior to a drone journey**

FIGURE 17c | **Vaccine-loaded payload box being mounted on a drone for a BVLOS flight**

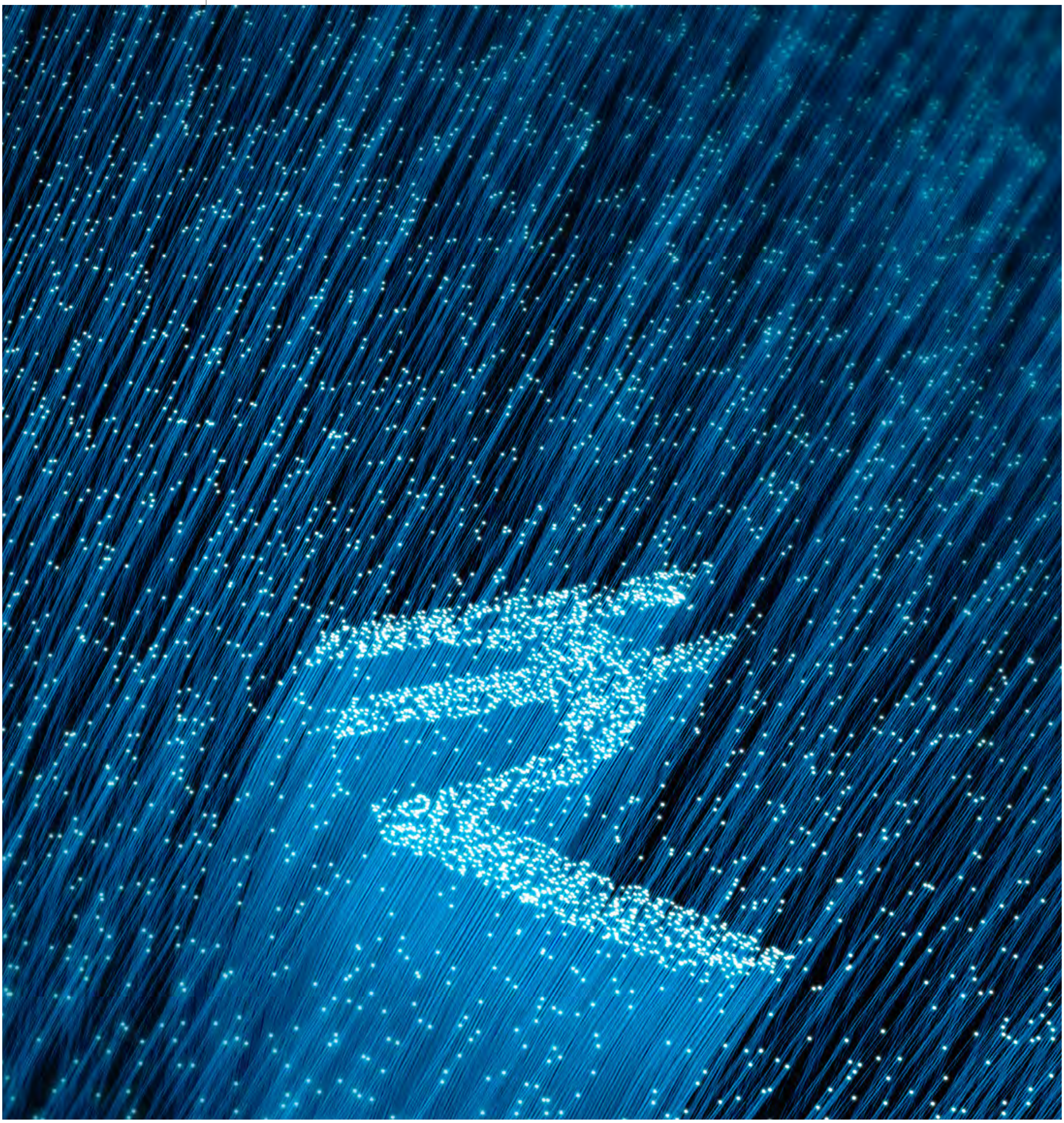
FIGURE 17d | **Medicine from the Sky operations desk being set up**

Setting up a Medicine from the Sky operations desk: An MFTS desk was set up at the take-off location. This was equipped with all cold-chain equipment, boxes, vaccines and other medical SKUs for trials. The desk served the following activities:

- Reporting of teams arriving at Vikarabad
- Providing guidance on hotel accommodation/ other local guidance, etc.
- Daily screening of drone teams for temperature checks and other risk assessment for COVID-19
- Provision of payload boxes, vaccines, coolants and other medical SKUs required for trials
- Provision of masks, gloves and other safety-related equipment
- Help desk for any medical/cold chain-related queries
- Post-trial handover of cold-chain and sample vaccines
- Submission of filled-in drone demonstration reports (DDRs) at the end of the day

3 Learnings and outcomes

Learning is earning – for better outcomes, measuring every possible aspect of the exercise is paramount.



3.1 Drone demonstration report

Conclusions from the Medicine from the Sky programme were recorded using the drone demonstration report. An abridged version was first used during a field study conducted in a limited experiment by Wings India 2020,[18] where the transportation of blood samples was tested using a drone. Given the complexity of the pilot programme in Vikarabad, the purpose of the drone demonstration report was to obtain context-specific data samples to understand the feasibility, safety and success rate of medical drone missions. The drone demonstration report also acts as a pre-take-off and post-landing checklist for drone operations, mission planners and medical staff present on the ground. The outline of the report is shown in Appendix 1. The final data samples were a result of all participating entities updating the form with data at the point of origin and the point of landing.

3.2 Findings

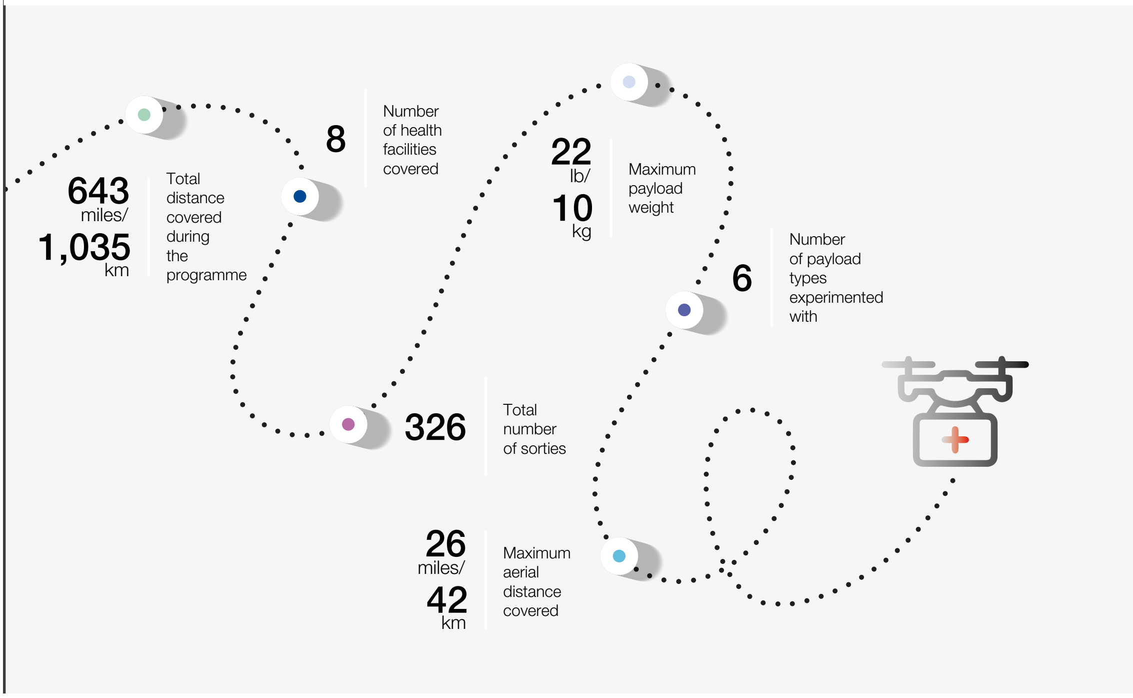
In the index value of development formulated by the state government, Vikarabad falls into the "average development" category among districts in Telangana.[19] With 18 administrative units or *mandals*,[20] Vikarabad is a relatively new district in the state, having been commissioned in 2016. Drone connectivity emerged as a highly impactful method of medical transit between health facilities given the distances and requirements on the ground.

In an intensive pilot programme in a live scenario that lasted 45 days in total, payload-capable UASs covered a total aerial distance of more than 373 miles (600 km), delivering a range of medical products, including COVID-19 vaccines, regular vaccines, COVID-19 samples, medicine and blood. In a test predominantly focused on vaccines, drones and their payloads were stress-tested in different weather conditions – sunny, cloudy and rainy, with humidity levels ranging from 58 to 99%. In total, eight air corridors were activated within the 16-corridor window endorsed by the regulatory agencies. Seven different multirotor drones were introduced into the equation. On average, the drones used in the beyond-visual-line-of-sight (BVLOS) exercise flew at a height of 300 feet (90 m) carrying an average weight of 2.3 kg, which included payload boxes, supplies and coolants at an average temperature of 5°C.

3.3 Direct benefits

FIGURE 18

Medicine from the Sky pilot – highlights



Source: Data gleaned from drone demonstration reports submitted by consortia after every flight

Eight medical facilities acting as spokes were directly connected to a hub with a cold-chain facility for medical deliveries in Vikarabad, resulting in a functional networked aerial system over the 45-day period. Six of these eight medical facilities were primary health centres (PHCs) connected to 40 subcentres (SCs) covering a population of more than 300,000. Some 326 sorties were successfully completed. The programme provided training for the planned expansion of the drone network in the district that could further be extrapolated to the "middle mile" as well as other districts of a similar nature. In 2018–2019, when VillageReach, a healthcare provider with the goal of reaching under-served populations, carried out a phased approach to integrating drones into the immunization supply chain in the Democratic Republic of the Congo, the local government commissioned an intergovernmental agency that would act as a one-stop mechanism to procedurally facilitate drone missions. This, combined with local surveys and community education programmes,[21] would lead to an effective case for fully fledged commercial operations. Keeping a focus on the Vikarabad scenario, future plans include building a roster of flights over a planned time frame for medical freight delivery. In terms of mission timing, the total "drone time", which would include assembly, mounting, dismounting and flight time, was significantly faster than land-based journeys of the same distance using conventional means.

Mission averages

- Average time taken to assemble base station from scratch – 6.5 minutes
- Average time taken to mark checklist and deploy drones – 2.5 minutes
- Average time taken to mount payload on drone – 1.5 minutes
- Average flight journey from A to B – 8.5 minutes
- Average flight distance from A to B – 2.2 miles (3.5 km) (BVLOS only)

3.4 Infrastructural improvisations

Having successfully maintained cold-chain temperatures over long ranges, vaccines, samples and medicines were found to maintain their consistency from their point of origin and during the flight. Of the eight activated health facilities in the areas (eight PHCs and two SCs), the new area hospital that was identified as the take-off location for trials was not equipped with a cold-chain facility. This was enabled by Apollo Hospitals. The cold-chain facility would set a precedent for more remote areas. The possibility of drones delivering temperature-controlled items to remote areas on demand could reduce capital expenditure at local facilities. In a pandemic, vaccines would have to be well stocked and continuously maintained in a limited temperature range. This could potentially reduce stock-outs in remote areas. In addition:

- The health facilities would require fixed drone landing pads and charging points built as infrastructure requirements
- Multi-stop drone ports would be required en route to distant medical facilities
- A maintenance-cum-storage facility for drones in the vicinity would also be important for regular and smooth operations

3.5 Incidents

In total, three incidents were recorded during the entire drone programme. The details are as follows:

1. A drone carrying a dummy load experienced a rough landing within 15 feet (4.5 m) of the ground.

2. Two instances of drones carrying vaccines experienced a telemetry issue, resulting in a communication loss for approximately 20 minutes. The connection was soon restored, with the drone ultimately landing at the correct destination. In the second case, the drone landed at an emergency site.

3. A drone carrying vaccines could not complete a BVLOS mission and returned to the point of origin.

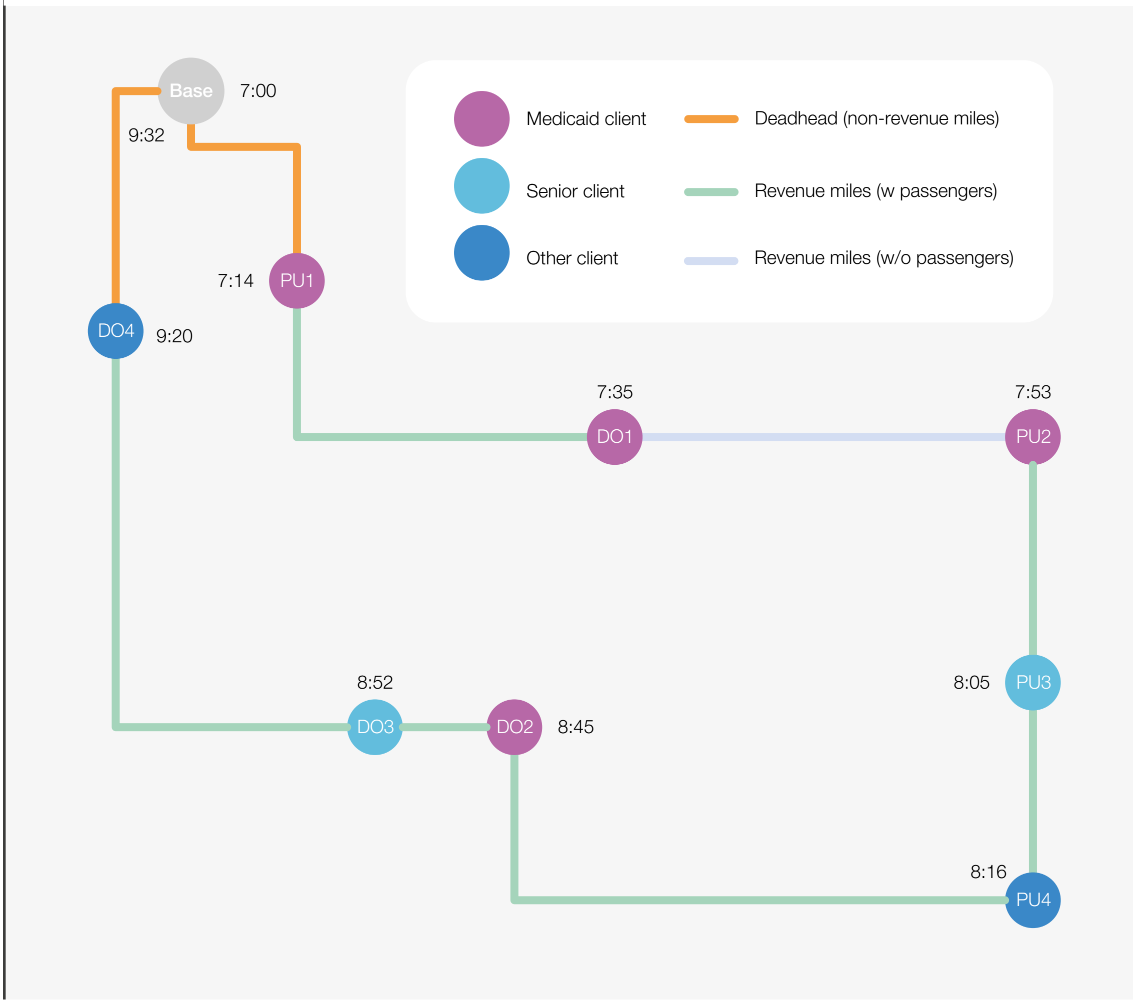
All recorded incidents were classified as VLOS incidents with no noticeable threat to the surrounding population or establishments. No damage to the medical products in transit was noted.

3.6 Cost parameters and comparative economics

No-drone scenario: In a no-drone scenario, a diesel van was used to transport vaccines from the district vaccine store to the PHCs across the district. The van took roughly three to four days to cover the entire district for a month's stock, covering approximately seven primacy health centres in a day. The operations were a combination of middle- and last-mile logistics.

By these means, 22 health facilities were covered in a span of three to four days for vaccine stock-ups. Over and above the base ambulatory costs, the expenses involved fuel, three to four attendants and logistic handling expenses. Furthermore, subcentres located at the last mile in areas unreachable by van or car were reached on foot or using two-wheeled vehicles (such as motorbikes or bicycles).

FIGURE 19 **Demand-response routing on road**

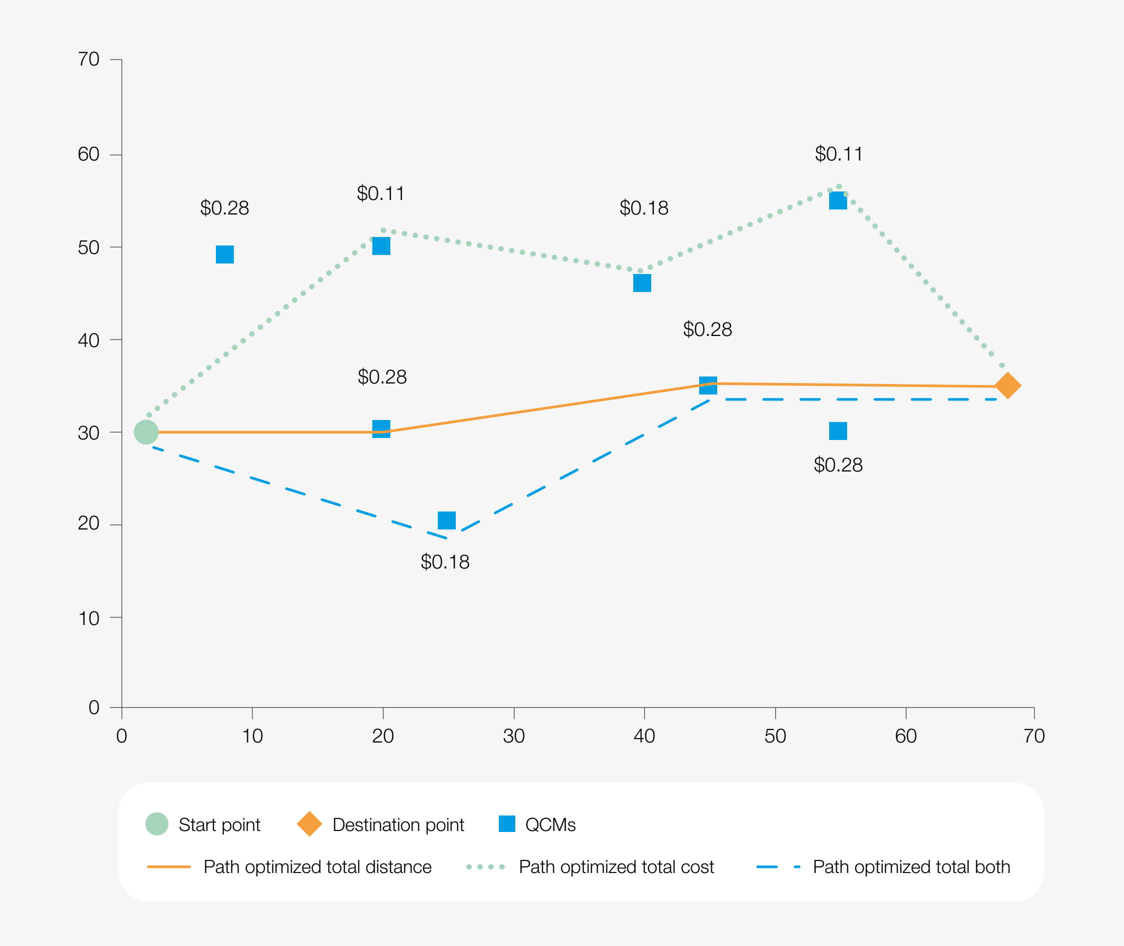


Source: Richard Garrity, "Cost Allocation Technology for Non-Emergency Medical Transportation", RLS & Associates, Dayton, OH, June 2020: https://transit.dot.gov/sites/fta.dot.gov/files/2021-04/Cost-Allocation-Technology-for-Non-Emergency-Medical-Transportation-Final-Report.pdf

Problem modelling: When configuring a drone network, it is important to define trajectories based on minimizing distance, costs of charging and wear-and-tear while ensuring drone flights remain within their permitted flight paths. In triangulation with the air traffic controller to ensure deconfliction with non-drone or third-party activity, a drone network should have the following components: a traffic control centre that is under the supervision of a programme management desk (e.g. the Medicine from the Sky desk), battery charging stations, emergency landing spots and base stations with the necessary infrastructure.[22]

FIGURE 20

Three different scenarios for a single drone in a drone network



Source: Hussein Al-kabi and Sayyed Majid Mazinani, "DNCS: New UAV Navigation with Considering the No-Fly Zone and Efficient Selection of the Charging Station", Ain Shams Engineering Journal, 12 (4), 2021: https://reader.elsevier.com/reader/sd/pii/S2090447921001386?token=5C7CE1244F2663B27BE31066E64F69417EF523DA7B94C7CB2E08E3D0355AF850FAD8DA8555A272186C32EFBC85598532&originRegion=eu-west-1&originCreation=20220207082258

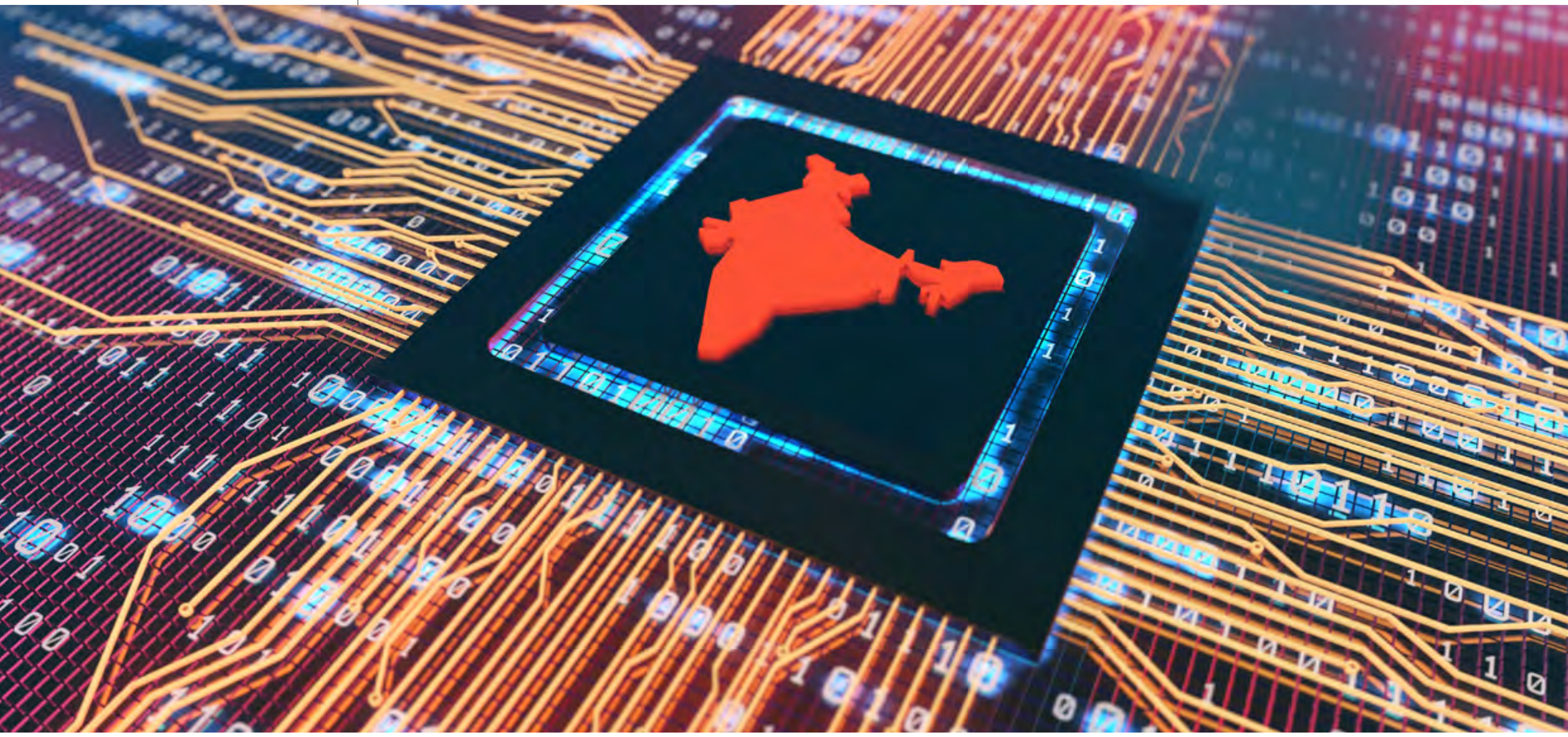
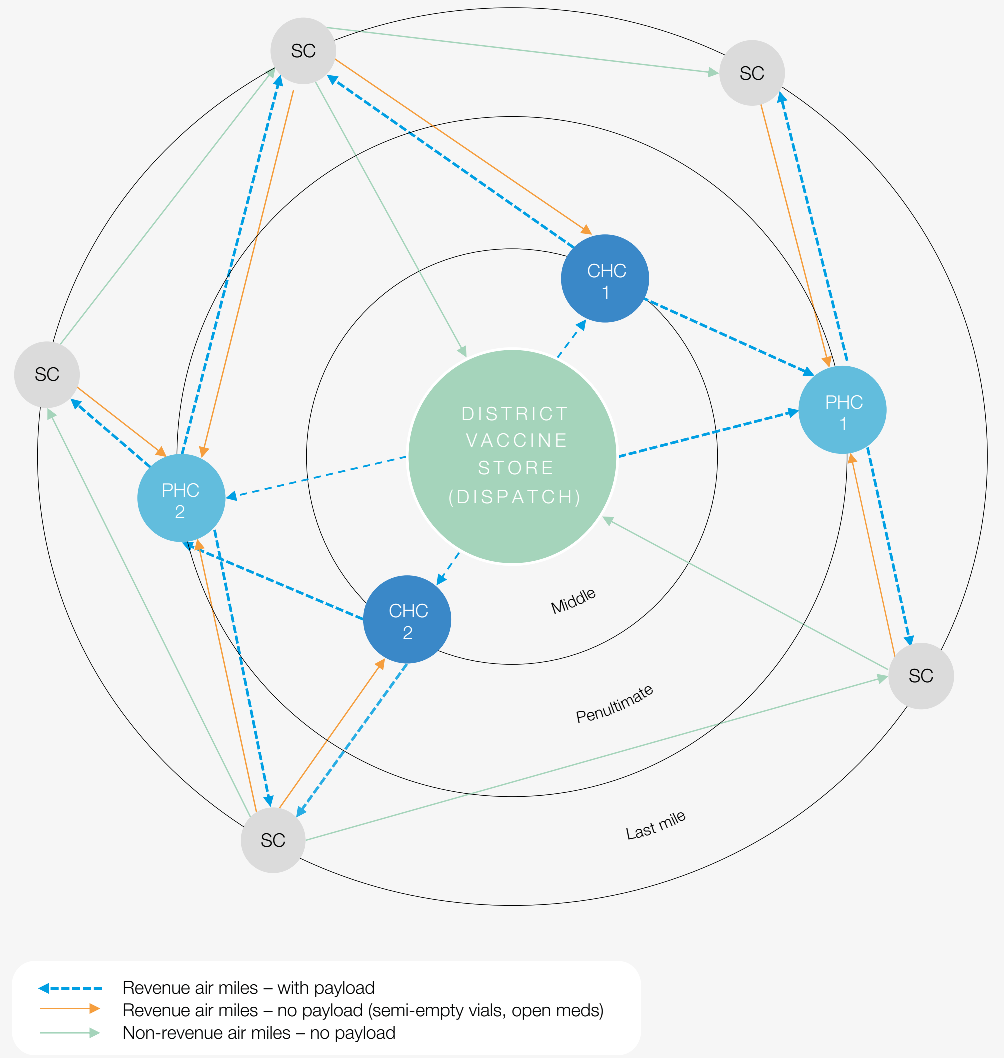


FIGURE 21 | Demand routing along air corridors



Source: World Economic Forum

TABLE 1 | Dispatch characteristics of a drone delivery mission

Sortie	ETD	Action	Drone code	Route	ETA	Distance
1	9.00 am	Dispatch from base	RX-123	DMS – CHC	9.20 am	9.3 miles (15 km)
2	9.35 am	Drop package	RX-123	CHC – PHC 1	9.51 am	7.5 miles (12 km)
3	10.13 am	Drop package	RX-123	PHC 1 – PHC 2	10.39 am	13.7 miles (22 km)
4	11.01 am	Open vials pickup	RX-123	PHC 2 – CHC	11.26 am	11.2 miles (18 km)
5	11.42 am	Load vials	RX-123	CHC – DMS	12.01 am	9.3 miles (15 km)
6	12.16 am	Drop package	MX-781	DMS – SC 1	12.41 am	19.3 miles (31 km)
7	12.47 am	Drop package	MX-782	SC 1 – SC 2	1.05 pm	11.2 miles (18 km)
8	1.19 pm	Call for pickup of open vials	MX-783	SC 2 – SC 3	1.37 pm	10.6 miles (17 km)
9	1.48 pm	Return to base	MX-784	SC 3 – DMS	2.26 pm	18.6 miles (30 km)

Source: Richard Garrity, "Cost Allocation Technology for Non-Emergency Medical Transportation", RLS & Associates, Dayton, OH, June 2020: https://transit.dot.gov/sites/fta.dot.gov/files/2021-04/Cost-Allocation-Technology-for-Non-Emergency-Medical-Transportation-Final-Report.pdf

Performance – road vs. air: Cost allocation models are often developed under the common theme that demand response logistic costs are a function of two key factors – time and distance. Trips by road that consume more time and/or cover more distance incur higher operating and maintenance costs for the transport sponsor/service provider. Time and distance are an accepted measure of performance.[23] In the case of drones, however, two other key factors come into play: route density and drop size. These factors kick in specifically in last- and penultimate-mile missions. Several deliveries over a short time frame or distance will ensure a lower cost per delivery, while several packages to a specific location would mean lower per-drop costs.[24] This presents a pressing need for drones capable of reverse logistics. In the case of light and valuable payloads that are time-sensitive – for instance, the dispatch of a live-saving drug or a 7 lb (3.2 kg) defibrillator – cost may not be at the forefront of the decision-making process.

As per first-hand inputs provided by participating consortia as shown in Table B in Appendix 2, the line items denote the cost components noted on the drone demonstration report for a seven-day pilot programme. Note that there are specific costs to the pilot programme at Vikarabad (such as travel and logistics). Many of these cost components may not feature in the costing once drones are permanently deployed and fully operated by locally trained staff.

On average, under the given weather conditions (monsoon), approximately 96 miles (154 km) (BVLOS) was covered cumulatively by each team on a weekly basis. This would relate exclusively to the drone service cost components for the pilot programme alone as the consortia had to travel from different states. However, in a well-established local drone delivery network, costs relating to travel, accommodation, drone logistics etc. might not be considered necessary in case of permanent deployment.

Note: The drones used for the Vikarabad experiment were multicopters falling into the "small" category of drones. Costs may vary when higher payload-capable drones operate over longer distances for extended periods of time.

An overview of operations of Vikarabad's existing vaccine distribution system as obtained from the District Vaccine Store, Vikarabad (2022)

- Total no. of PHCs – 22
- Total no. of subcentres – 156
- Type of vehicle (vaccine van) used – Bolero Van
- No. of vehicles deployed – 1
- Total manpower required – 3 (one driver, one helper/attender, one district vaccine logistics manager)
- Avg. weight delivered/PHC – ~77–88 lbs (35–40 kg) (including syringes, diluents and a wide variety of routine vaccines/packaging, etc.)
- Total distance covered – 373 miles (600 km)
- No. of days for delivery – 3–4 days for supplying one month's stock of vaccines to all PHCs across the district
- No. of vaccine variants supplied – ~15–17 each in 40–50 vials per PHC

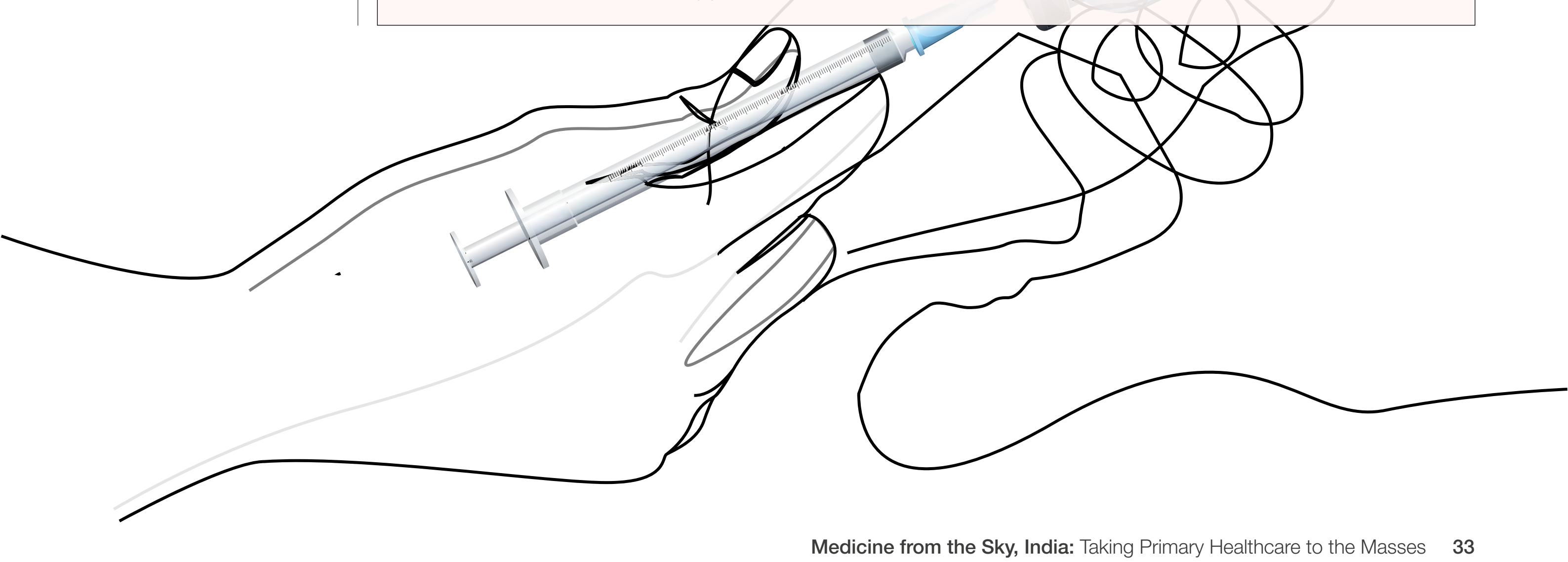


TABLE 2 | Indicative status of cost allocations on permanent deployment

Serial no.	Cost allocation	Status when drones permanently deployed	Comments
1	Round trip/flights or train costs to area of operations	Null and void	Applicable during a pilot programme where foreign resources are brought in
2	Hardware logistics	One-time cost	Will change to one-time procurement/lease or maintenance and repair when deployed permanently
3	Accommodation	Null and void	Local resources will take over
4	Local transport	Pro rata cost	Will be limited once air corridors are activated and will be needed in case of urgent demand or when new routes are to be established
5	Local SIM cards with data	Periodic cost	Data top-ups and recharges pro rata
6	Power generator	Operational expense	As per unit consumption at the ground station. May be factored into the budget of the health facility
7	Food	Null and void	
8	Visas	Null and void	
9	Resource travel insurance	Null and void	
10	Operational insurance	Periodic cost	Annual premium on equipment and/or third-party liability
11	Ground-level paraphernalia – tents, tables	One-time cost	The operations desk will be a convergence point for all drone/logistics-related activity
12	Medicine from the Sky desk	Graduation into a permanent drone desk	Office supplies, book-keeping and coordination of logistics
13	Training and education	One-time cost	Will be handled locally once handed over to local healthcare workers
14	Local resourcing	Permanent recruitment or contracting	

3.7 Considerations for designing a drone programme

TABLE 3 **Planning a medical drone programme**

Serial no.	Parameter	Requirement
1	Landing infrastructure	Designated take-off and landing zones measuring 10 ft x 10 ft were demarcated for the pilot programme. For full-scale commercial deliveries, a levelled, hardened surface would be ideal for take-off and landing. Facility to house a temporary maintenance, repair and operation (MRO) shed would be useful for ground teams.
2	When the mission is extrapolated to a 93 mile (150 km) air corridor	The ideal drone type for such a use case would be hybrid vertical take-off and landing (VTOL) crafts or fixed-wing drones. An extended corridor would require provisions for navigational markers and autonomous flight-capable drones. A higher flight ceiling might help conduct operations swiftly and seamlessly. Further drones conducting such missions must have a much higher payload capability.
3	Incidentals that require greater planning during a medical drone mission	What gets measured gets improved. For this, data points are key at every juncture of the drone mission. If critical medical requirements are high during the rainy season, drones will have to be technologically iterated to handle rough weather, especially in hilly areas. Administrative incidentals would include boarding and lodging costs for ground teams, drones, a vehicle and equipment storage area, network connectivity, local transportation and base station requirements such as charging points and laptop stations.
4	Community engagement	The Vikarabad drone programme witnessed large crowds at the point of operations. Locals were curious about the role of Fourth Industrial Revolution technologies being implemented in the region. Over and above general information about the technology benefits, it is important to instil a sense of ownership in drone projects, especially in rural areas. This can happen if rural youth feel included from the point of initiation. This further leads to a sense of responsibility and promise offered by local governments to young people in terms of stimulation of the local economy through jobs and fortification of the primary healthcare infrastructure.
5	Defining a last mile and the basics of scale	The final point of healthcare requirements in a rural settlement may be served through relatively well-established hubs in the area. While drones are often associated with the last mile, the middle mile of healthcare also offers significant potential – medical transit between two hubs or even on a well-established campus. Furthermore, different drone types with varying payload capabilities need to be considered in the equation. Every last mile must be served by a drone hub. Every take-off and landing point serves as an information touchpoint that may potentially raise demand for infrastructural and multipurpose developments.

Source: Data gleaned from drone demonstration reports submitted by consortia after every flight

Conclusion

Drones are a long-term investment that act as a gateway to increasing the quality of primary healthcare in rural areas.

- No drone programme is a single-entity solution. In an ecosystem with several moving parts, it is important to take small steps and measured decisions when implementing drones.
- Setting expectations with end consumers is also vital to the uptake of this technology. Since drones frequently appear on the front pages of newspapers and online publications, it is important to communicate and articulate their use as lucidly as possible.
- Drones are a force multiplier for existing infrastructure. Even in the case of medical deliveries, drones will power up the intermodal supply chain alongside vans, ambulances and motorbikes. Drones will act as one of the many means to deliver healthcare on the last mile.
- Drone solutions do not apply only to the last mile but also have immense potential in the middle mile. Regulations, technology advancements and awareness must go hand-in-hand. Any lag between these three levers may lead to skewed decision-making on a wider scale.

In November 2021, the Government of India revised its policy on public procurement.[25] In accordance with this change, the process is now more quality-oriented, and the selection method based on the least expensive option (colloquially known as "L1") will not necessarily be the one used. While favouring the lowest-cost service provider may be acceptable for routine services, drones and drone-related solutions are not a routine service. Procuring drone services for medical deliveries requires knowledge-based insights into local scenarios. Limited dry runs offer an opportunity for real-time experiments, backed up by a quality centre procurement mechanism that is fed into by data from the preliminary phases. Drone original equipment manufacturers (OEMs) and service providers who deal with the details of public policy and operations are generally in a better position to ascertain local scenarios. The possibility of a no-drone scenario should also not be ruled out if the local situation does not permit drone delivery. The expansion of the drone programme is a multistakeholder subject. When discussing its implementation, nobody should be left behind.

Goals for 2030

1. Drones in the intermodal logistics system – 3.1 million miles (5 million km) of aerial distances for medical and humanitarian missions
2. Empanelled UAV operators, UAVs that reach 80% of all remote healthcare facilities in all Indian states
3. Ensuring that all remote health facilities are certified as drone capable, with the necessary infrastructure
4. Some 4.7% of those of working age are motor vehicle drivers. The region (South Asia/BIMSTEC[26]/Middle East) to have at least 1 million drone pilots by 2030
5. Replication of the India model of implementation and roll-out in SAARC, MENA and ASEAN countries[27]

Appendices

Appendix 1

TABLE A **Data points**

Sr #	Data point
1	Name of the consortium
2	Date of flight
3	Time of flight
4	Flight type
5	# Of the flight day (Î±): (write as Day1, Day2 etc.)
6	# Of the flight in day (Î²): (if second flight of day, enter 2)
7	Name of take-off location: (enter name of hospital/area) e.g. New Area Hospital VKB
8	Take-off location – Latitude (e.g. 17.336430)
9	Take-off location – Longitude (e.g. 77.904845)
10	Name of landing location: (enter name of hospital/area) e.g. Siddulur
11	Landing location – Latitude: (e.g. 17.336430)
12	Landing location – Longitude: (e.g. 77.904850)
13	Aerial distance: (in km between locations) e.g. 6.7
14	Model name/specifications
15	DAN (drone acknowledgement number)
16	Drone category and class
17	Drone payload capacity: (mention capacity in kg) e.g. 5
18	Endurance: (mention time in mins) e.g. 90
19	Drone max. speed (in km/h)
20	Note the drone battery voltage (in volts)
21	Type of payload box
22	Payload contents
23	Pilot name
24	Co-pilot name
25	Accountable manager name

26	Check if the appropriate coolant is used in the payload box (at point A)
27	Check the type of coolant used in payload box
28	Note total weight of coolants being inserted in payload box: (mention weight in kg) e.g. 0.75
29	Note the number of coolants used in payload box: (mention the no. of coolants) e.g. 0, 1, 2, 3...
30	Check quantity of items inserted in payload box (e.g. vaccines: no. of vaccine vials/PF syringes, ampules etc./ no. of diagnostic samples/no. of medicine strips/bottles etc.)
31	Check weight of vaccines/diagnostic samples/medicines, etc: (mention weight in kg) e.g. 1.9
32	Check total weight of payload box (including vaccines/diagnostic samples/blood units/medicines/ coolants etc.)
33	Check the volume of the vaccine/diagnostic samples/blood packets/medicine packages: mention total volume (Lx BXH in cm) of medical packages, e.g. 1010 cc)
34	Check labelling on the package
35	Check and verify details with dispatch note, details of the batch number, expiry date etc. on vaccine vial/ or any other medical payload content
36	Check for any breakage/damage/leakage/discoloration of any medical payload content being transported
37	For freeze-sensitive medical payload contents, check the frozen ice packs/coolants are not placed in direct contact with the contents
38	Check the data logger is placed and activated in the medical payload compartment
39	Check the condition of packaging of payload and its content
40	Note temperature readings in °C (temperature inside box using IR thermometer gun) e.g. 6
41	Note atmospheric/outside temperature in °C (as seen in temperature meter or weather forecast app) e.g. 34
42	Note the atmospheric humidity in % (as seen in the humidity meter or weather forecast app) e.g. 79
43	Note the atmospheric pressure in mm HG (as seen in weather forecast app) e.g. 760
44	Note the wind speed and its direction e.g. 6 km/h SW
45	How are the weather conditions at point A?
46	Time taken to assemble base station from scratch (in minutes/seconds) e.g. for 5 min 30 sec write as 5.30
47	Time taken to mark checklists and deploy drone (in minutes/seconds) e.g. for 4 min 22 sec, write as 4.22
48	Time taken to pack payload contents and mount on drone (in minutes/seconds), e.g. for 2 min 55 sec, write as 2.55
49	Note temperature readings in °C (temperature inside box using IR thermometer gun) e.g. 7.5
50	Note the time of drone landing
51	Verify payload content as per dispatch note (check and verify the quantity batch number, expiry date, weight)
52	Check for any breakage/damage/leakage/discoloration of medical payload content
53	Verify the temperature maintained during the transit using the data logger (check if temp is within 2 to 8 range

54	Upload the temperature log file
55	Note atmospheric/outside temperature in °C (as seen in temperature and humidity meter or weather forecast app)
56	Note the atmospheric humidity in % (as seen in the humidity meter or weather forecast app) e.g. 83
57	Note the atmospheric pressure in mm HG (as seen in weather forecast app) e.g. 710
58	How are the weather conditions at point B?
59	Check the condition of packaging
60	State of medical payload content on landing
61	Total aerial distance actually travelled (in km) e.g. 9.8
62	Time taken for drone journey from A to B (in mins) e.g. 30
63	Note the speed of drone (in km/h)
64	Note the drone battery voltage (in volts)
65	Note the altitude (height) the drone is flying (in ft)
66	Time taken to dismount payload and remove contents (in minutes/seconds) e.g. for 5 min 30 sec, write as 5.30
67	Impact of the drone journey on the payload
68	What to expect if the journey was extrapolated to 62 miles (100 km)
69	Were there any incidents, crashes, close shaves, lost connections, any other issues during the sortie? Please elaborate
70	In case of any incidents, crashes, close shaves, lost connections, any other issues during the sortie. Please upload incident number
71	Note the flight log reference number
72	Healthcare rating
73	Drone expert rating
74	Regulator rating
75	Anything else you could comment on

Appendix 2

TABLE B Qualitative inputs

Question #	Query
1	Total flight hours (BVLOS only)
2	What are your views on the take-off and landing infrastructure? If this were a live environment, how would you model a drone port of the area hospital?
3	If you were to iterate this initiative to an inter-district exercise over a distance of 93 miles (150 km), how different would your approach be?
4	As a consortium, how did you experientially benefit from this exercise?
5	Were the available conditions sufficient to max out the capability of your systems on ground?
6	What are your expectations from a subsequent iteration of this exercise?
7	If your consortium had to price services for the seven-day trials, what would the approximate amount be and what would some of the key cost components be?
8	What are your views on a procedural shortening of the regulatory process for last-mile medical and emergency services?
9	We initiated the documentation process in February and flew drones in July (six months). How would you broadly shape a one-touch system that can bring this down to 15 days?
10	How would you scale up this initiative to other parts of India and which national-level schemes would Medicine from the Sky fit into (healthcare)?
11	Was this the first time you conducted a long-range drone experiment? What were some of the hits and misses?
12	How important is alignment with local governments?
13	Did you interact with locals or allay the fears of locals on the initiative? How important is this aspect and how would you describe it?
14	What according to you in the most essential item to be carried on a drone?
15	What qualifies as a “last mile” in your view? Where in India (or Asia) do you see this becoming a natural order of logistics in healthcare?
16	What are your views on the ATC communication protocols for this exercise and what would be a suggested plug-and-play?
17	Please mention any miscellaneous comments that you would like to cover

Appendix 3

TABLE C **Provisional costs for Malawi RPA activities**

Item	Price ($)	Comments
Round-trip flights from the US, Europe and Asia to Malawi	1,500–2,000	Price per person
Hardware logistics	Depends on weight, distance, carrier, etc.	If RPA components travel as cargo, freight forwarders are used for handling all components of the logistics. There are 2–3 cargo flights per week to Lilongwe
Accommodation	Average of 65–75 per night	Lilongwe is more expensive than Kasungu, but the majority of time will be spent in Kasungu. Prices in Lilongwe are frequently above $100 per night
Local transport	60–70	Per day including driver, fuel, mileage, insurance
Local SIM card with data	20–30	Includes 10–15 GB of data
Fuel	1.20 per litre	Price fluctuate depending on the market
Power generator	300–500	Price depends on the size and power; however, a generator can be hired as well
Food	15–20	Per person, per day in Kasungu (Lilongwe prices are considerably higher)
Visa	75	Price per person for a single-entry tourist visa (available only with cash at the airport; Category 2)
Vaccines	400–800	Depending on existing vaccine coverage. Yellow fever vaccination is obligatory to enter Malawi
Malaria prophylaxis	70	Per 12 pills (1 pill per day)
International travel insurance	Depending on country/ scope	Advisable to have medical emergency evacuation coverage
Folding table (for ground station)	100	Arrange with local contacts in advance to identify and select source options that are affordable and convenient for you
Tent (for ground station)	120	Arrange with local contacts in advance to identify and select source options that are affordable and convenient for you

Source: The Department of Civil Aviation, MACRA, VillageReach, GIZ and UNICEF: "Malawi Remotely Piloted Aircraft (RPA) Toolkit", December 2019: https://www.updwg.org/wp-content/uploads/2019/12/Malawi-RPA-Toolkit-2019_Dec.-Final.pdf

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Endnotes

1. Ikigai Law, "A Comparison of the Draft Unmanned Aircraft System Rules, 2020 and the Civil Aviation Requirements on Remotely Piloted Aircraft System, 2018", 27 June 2020.
2. Press Information Bureau, "Ministry of Civil Aviation Notifies Liberalised Drone Rules, 2021", 26 August 2021: https://pib.gov.in/PressReleseDetailm.aspx?PRID=1749154.
3. Chris Anderson popularized the idea of the long-tail problem in a 2004 WIRED article entitled "The Long Tail".
4. A green corridor is a route that is cleared out for an ambulance carrying harvested organs to ensure delivery to the destination in the shortest time possible.
5. World Economic Forum, "Medicine from the Sky", Wings India 2020, Hyderabad, 2020.
6. World Economic Forum, "Future of Jobs Report", 2015: https://www3.weforum.org/docs/WEF_Future_of_Jobs.pdf.
7. Danny Leipziger and Victoria Dodev, "Disruptive Technologies and Their Implications for Economic Policy: Some Preliminary Observations", Institute for International Economic Policy Working Paper Series Elliott School of International Affairs, George Washington University, June 2016: https://www2.gwu.edu/~iiep/assets/docs/papers/2016WP/LeipzigerDodevIIEPWP2016-13.pdf.
8. SenseFly, "Survey Drone vs. Scanning Total Station: A Gravel Pit Comparison", 29 August 2018: https://www.sensefly.com/blog/survey-drone-vs-scanning-total-station/.
9. Chetan Thathoo, "Govt Plans to Make India a Drone Hub By 2030, Notifies Drone Certification Scheme", Inc42, 27 January 2022: https://inc42.com/buzz/govt-notifies-drone-certification-scheme-plans-to-make-india-a-drone-hub-by-2030/.
10. Calvin Wang, Elizabeth Walker and Janice Redmond, "Explaining the Lack of Strategic Planning in SMEs: The Importance of Owner Motivation", ECU Publications, 2011: https://www.researchgate.net/publication/49277688_Explaining_the_Lack_of_Strategic_Planning_in_SMEs_The_Importance_of_Owner_Motivation.
11. Anna Roy and Vignesh Santhanam, "Drones in India: A Model for Cooperative Federalism?", World Economic Forum, 15 July 2021: https://www.weforum.org/agenda/2021/07/drones-in-india-a-model-for-cooperative-federalism/.
12. UPDWG, "Designing Medical Drone Delivery Systems: Day 2", YouTube, 20 November 2021, https://www.youtube.com/watch?v=Rya6o6ac6d4.
13. JARUS, "JARUS Guidelines on Specific Operations Risk Assessment (SORA), 30 January 2019: http://jarus-rpas.org/sites/jarus-rpas.org/files/jar_doc_06_jarus_sora_v2.0.pdf.
14. The Hindu, "Trials of 'Medicine from Sky' Project Likely This Month-End", The Hindu, 13 June 2021: https://www.thehindu.com/news/cities/Hyderabad/trials-of-medicine-from-sky-project-likely-this-month-end/article34804786.ece.
15. Ibid.
16. ITE&C Department, Government of Telangana, "Medicine from the Sky Drone-Based Medical Delivery", 14 March 2020: https://it.telangana.gov.in/wp-content/uploads/2020/03/EoI-Medicine-from-the-Sky-Telangana.pdf.
17. Ibid.
18. Express News Service, "Yes, Drones Can Deliver Med Supplies Too", The New Indian Express, 15 March 2020: https://www.newindianexpress.com/states/telangana/2020/mar/15/yes-drones-can-deliver-med-supplies-too-2116938.html.
19. Deccan Chronicle, "More Backward Districts in Telangana Now", 29 November 2016: https://www.deccanchronicle.com/nation/current-affairs/291116/more-backward-districts-in-telangana-now.html.
20. DistrictsInfo, "Vikarabad District | List of Mandals in Vikarabad District": https://www.districtsinfo.com/2016/12/vikarabad-district-list-of-mandals.html.
21. Village Reach, "Drones for Health in the Democratic Republic of Congo", October 2020: https://www.villagereach.org/work/drones-for-health/uav-drc/.
22. Hussein Al-kabi and Sayyed Majid Mazinani, "DNCS: New UAV Navigation with Considering the No-Fly Zone and Efficient Selection of the Charging Station", Ain Shams Engineering Journal, 12 (4), 2021: https://reader.elsevier.com/reader/sd/pii/S2090447921001386?token=5C7CE1244F2663B27BE31066E64F69417EF523DA7B94C7CB2E08E3D0355AF850FAD8DA8555A272186C32EFBC85598532&originRegion=eu-west-1&originCreation=20220207082258.
23. Richard Garrity, "Cost Allocation Technology for Non-Emergency Medical Transportation", RLS & Associates, Dayton, OH, June 2020: https://transit.dot.gov/sites/fta.dot.gov/files/2021-04/Cost-Allocation-Technology-for-Non-Emergency-Medical-Transportation-Final-Report.pdf.
24. Dan Wang, "The Economics of Drone Delivery", IEEE Spectrum, 5 January 2016: https://spectrum.ieee.org/the-economics-of-drone-delivery.

25. Das Gupta, Moushumi, “Lowest Cost or ‘L1’ No Longer the Only Way to Select Bidders – Why Modi Govt Revised Policy”, The Print, 9 November 2021: https://theprint.in/theprint-essential/lowest-cost-or-l1-no-longer-the-only-way-to-select-bidders-why-modi-govt-revised-policy/762738/.

26. BIMSTEC is the Bay of Bengal Initiative for Multi-Sectoral Technical and Economic Cooperation, covering seven South Asian and Southeast Asian nations.

27. SAARC is the South Asian Association for Regional Cooperation; MENA is the Middle East and North Africa; ASEAN is the Association of Southeast Asian Nations.

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