DRONES IN INTERNATIONAL DEVELOPMENT

Innovating the Supply Chain to Reach Patients in Remote Areas

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INTRODUCTION

The USAID Global Health Supply Chain Program-Procurement and Supply Management (USAID GHSC-PSM) project works to ensure an uninterrupted supply of public health commodities. Through procurement and delivery of medicines and in-country technical assistance, the project strengthens health supply chains for HIV/AIDS, malaria, family planning, and maternal, newborn, and child health.

Through the USAID Office of HIV/AIDS, GHSC-PSM received funds to explore the use of drones for HIV/AIDS commodity deliveries to isolated and difficult-to-reach communities and to better understand the potential to improve health outcomes in low resource settings. The resulting activity was designed to focus on rural settings which experience limitations in the existing distribution system and lab sample network. These limitations, coupled with geographic and infrastructure challenges, leave gaps in service provided to patients.

The activity included research into existing drone delivery activities, current drone technology, government regulations, feasibility assessments of numerous countries and scoping visits, public procurement for drone services, and collaborative activity design sessions in the selected country. At the end of this process, USAID GHSC-PSM led a drone intervention to service facilities along Lake Malawi, using unmanned cargo flights to transport medicines, medical equipment, vaccines, diagnostic samples and results, in both directions between the facilities and the district hospital. From the laboratory hospital, samples continued to be moved by Riders4Health to the local capital hospital where laboratory testing is done.

At the time of writing this report, drones for cargo movement in international development have been tested for short periods of time, but rarely implemented consistently for an extended period. This has led to repeated proofs of concept without much added knowledge in the way of operational inputs specific to longer term staffing, drone maintenance, and financial planning such as would be required for replacement parts. The main objectives of this activity included:

-expanding the outer reaches of the formal supply system to previously underserved communities;
-successfully integrating advanced drone technology and capability into an existing supply chain beyond one- to three-week activities (the vast majority of those implemented to date) in order to learn about maintaining an ongoing unmanned aerial delivery system for health;
-demonstrating potential for improved health outcomes with an emphasis on People Living with HIV/AIDS (PLHIV); and
-transparency in documenting and sharing the knowledge gained.

Captured in the Executive Summary are key recommendations for the application of drones in health supply chains. The rest of the document details the steps taken under the GHSC-PSM drone project in Malawi and which are shared here for other organizations and drone implementers to consider as they plan, implement, and assess their own drone activities for health.

EXECUTIVE SUMMARY

Through GHSC-PSM, the USAID Office of HIV/AIDS conducted an eight-month drone activity in Malawi to explore the use of drones for health deliveries to isolated and difficult-to-reach communities.

This activity sought to investigate and better understand the current and future potential for drones to improve health outcomes in low resource settings through the following objectives:

-expanding the outer reaches of the formal supply system to previously underserved communities;

-successfully integrating advanced drone technology and capability into an existing supply chain beyond one- to three-week activities (the vast majority of those implemented to date) in order to learn about maintaining an ongoing unmanned aerial delivery system for health;

-demonstrating potential for improved health outcomes with an emphasis on People Living with HIV/AIDS (PLHIV); and

-transparency in documenting and sharing the knowledge gained.

While the full body of this report details many of the specific steps followed in Malawi, key lessons learned are captured here.

KEY RECOMMENDATIONS FOR SUCCESS

1. PREPARE SAFETY PROTOCOLS AND RESPONSE PROTOCOLS IN THE EVENT OF FLIGHT INCIDENTS.

From the outset, significant efforts must be dedicated to mitigating risks to people or property from incidents involving the drone. The project should plan for and understand built-in redundancies, as the current state of technology results in a high likelihood that a drone operation will experience one or more types of adverse flight incidents. Drone projects can mitigate risk by doing the following:

- Plan flight routes over unpopulated or undeveloped areas wherever possible, even when this results in a longer flight time.
- Ensure maintenance and safety checks are conducted daily, with more thorough inspections at regular intervals.
- Understand legal and regulatory channels for reporting incidents.
- Develop plans to respond quickly and sufficiently to address immediate damage to people or property, including a communication protocol with community members and stakeholders.
- Maintain replacement parts on site, if possible, or have sufficient redundancies in operations to limit disruption to the operation.
- Ensure staff have access to fire extinguishers and emergency medical kits in case of an incident at the takeoff or landing sites.

This is not an exhaustive list of safety measures which can be taken. However, in all cases it is important to have plans in place prior to an incident occurring, and to respond quickly to new safety requirements which might be issued by regulators throughout the course of the activity.

2. IDENTIFY ALL STAKEHOLDERS AND ENGAGE THEM EARLY AND OFTEN.

Stakeholders are critical to the success of a drone operation, both for their input of technical and contextual information, as well as for needed formal and informal approvals. Early stakeholder support will reduce delays and missteps which can result in additional costs. This, in turn, ultimately reduces the length of the activity. Importantly, if a drone activity has never been conducted previously in country, then it may take significant time and effort to identify all relevant parties, which may consist of:

- government ministries and departments (Ministries of health, transportation, and communications)
- NGOs
- community members and leaders (formal and informal)
- military leaders
- local government (formal and informal)
- international organizations
- universities
- private sector
- health workers

Each stakeholder will bring critical insights. Some or all stakeholders may be necessary for navigating drone regulations, importation and import clearance procedures, health supply chain challenges, logistical insights, and for facilitating contacts and introductions. Bringing in the stakeholders early and asking them to refer any additional stakeholders greatly increases the likelihood of obtaining approvals and support through each stage.

3. DETAILED ACTIVITY OBJECTIVES ARE NECESSARY AT THE OUTSET OF THE PROCUREMENT OR SOURCING PROCESS.

Drones come in three main types: multi-rotors, which are more easily maneuverable and can land in small spaces but are typically limited in range; fixed wing, which have impressive ranges but can require expensive infrastructure or other setup, or at the very least, require large unobstructed spaces for takeoff and landing; and, hybrid models, which tend to combine the benefits of the previous two types.

Given the variability in drone capabilities and limitations, it is difficult to conduct a competitive and successful tendering process without a clear vision of desired outcomes. For instance, what type of launching and landing areas are acceptable in the chosen operating environment? What are the volumes and frequency of identified cargo? What are the acceptable limits of human interaction and engagement with the drone? How much involvement will the service provider be expected to give? Each of these questions and many more should be considered when defining acceptable parameters for sourcing. Intended to build on a clear vision of desired outcomes, the USAID GHSC-PSM Unmanned Aerial Vehicle Procurement Guide includes detailed specifications for inclusion in a

Request for Proposals. It also lists suggested questions and areas for investigation during manufacturer site visits. (See Annex 1)

4. FEW DRONE SERVICE CONTRACTS ARE PUBLICLY AVAILABLE FOR COMPARISON OR USING AS A GUIDE, BUT EXTENSIVE RESEARCH AND INTERVIEWING OF EXPERIENCED DRONE ACTIVITY MANAGERS WILL HELP.

In addition to a potentially lengthy sourcing process, setting up a drone services provider in-country involves importation procedures, demonstrations and approvals, and costs for setting up and scaling. Given the lengthy and expensive nature of this process, it is important to put in place strong, performance-based or outcome-based contracts, as discovering contracting issues and changing providers weeks or months into an activity can waste valuable resources. For the highest level of long-term success, the level of detail in the service contract is crucial. Turning to an experienced drone project implementer for guidance at the outset can save a significant amount of money and other resources, as well as help to ensure continuous services for the healthcare system.

In absence of expertise, the cost of the operation will likely increase, timelines will grow, and likelihood of success decreases, yet few companies have experience contracting for drone services. Currently, the main resources for research are from publicly available documents on drone technology, drone regulations, and drone projects, as well as speaking directly with those who have experience in each of these areas. Relevant information is limited, as well as the number of people with practical experience, though it is expanding.

5. SHARED UNDERSTANDING AND AGREEMENT OVER APPROVAL PROCESSES BETWEEN THE IMPLEMENTER AND ALL IDENTIFIED REGULATORY BODIES WILL PREVENT UNNECESSARY SURPRISES, DELAYS, AND EXPENSES.

Regulatory requirements for drones can differ substantially across a continent, but also between neighboring countries. Some countries may have a formal system of aviation regulations referring explicitly to unmanned aircraft, while others may have fledgling or nonexistent systems. Regardless, regulatory agencies must still be willing to provide a path forward which lays out the requirements to be met to obtain flight approvals.

Of notable importance is the fact that the mere existence of a legal framework which applies to drones does not necessarily mean it is easy to successfully navigate. Proceeding with a drone activity without clearly defined and documented regulatory expectations presents a level of risk since extensive delays can occur which impact the implementation or add significant additional costs. Therefore, the aviation bodies must be able to provide written documentation of their processes, including (but not limited to):

- all steps and requirements for operational approval
- all steps and requirements for individual flight approvals
- all requirements (and limitations) for certifications and licensing
- all instances where government counterparts will need to visit the site of flight operations and indications of associated required logistical support
- schedule of required checks and recertifications (if any)

6. ENSURE THE PRESENCE OF SUFFICIENT TECHNICAL CAPACITY TO IDENTIFY FLIGHT HAZARDS, SPEAK KNOWLEDGEABLY ABOUT AVIATION OPERATIONS CHALLENGES, AND ANSWER QUESTIONS ABOUT THE SPECIFIC MECHANICS OF THE CHOSEN MODEL OF DRONE.

Activity or project managers must lead scoping activities with an emphasis on effectively managing expectations. If, as is likely at the outset, the local population lacks in-depth knowledge of drone capacities and limitations, these gaps in knowledge leave room for exaggerated or unrealistic assumptions, promises, and expectations. If the project management team does not include aviation experience, a licensed pilot should be invited to all technical discussions, as well as trips where take-off and landing areas are evaluated. This individual can be a consultant, but ideally would be a representative from the drone provider. Visits to new potential landing sites, for instance, should be assessed for best inbound and outbound flight paths, which is best determined by an experienced pilot. Technical discussions around communications with Air Traffic Control should be attended by both project management (to ensure appropriate oversight and compliance) and those who will be responsible for day to day flight operations throughout the activity.

7. SEEK EXPERIENCED PARTNERS AND STAKEHOLDERS WHO CAN SHARE LESSONS LEARNED AND LEVERAGE PAST EXPERIENCE TO DEVELOP A ROBUST AND SUCCESSFUL DRONE ACTIVITY.

Building on the prior recommendation, organizations pursuing their first cargo drone activity should not need to reinvent the wheel. Operators who have experience within the chosen country of performance can offer crucial tips on challenges encountered, so that these obstacles may be addressed or planned for appropriately. These challenges may differ from country to country. Experienced operators may be particularly helpful in the realm of regulatory and technical hurdles. For instance, if a certain type of GPS has been deployed with limited success due to signal jamming, this should be known and addressed to the extent possible before importation of the drone equipment. If the country of operations is not a location where you have a project office, then operational information such as availability to locally source tools and other goods needed to successfully maintain the drone fleet will be essential.

8. COMMUNITY SENSITIZATION IS IMPORTANT AT THE BEGINNING OF A DRONE PROJECT BUT MUST BE APPROACHED AS AN ONGOING CAMPAIGN TO CONTINUALLY ENGAGE AND EDUCATE THE BROADER COMMUNITY.

Community sensitization is important to obtaining support for the use of new and unknown technologies. However, it is easy to see this as a time-bound task to check off the list prior or concurrently to the onset of flight operations. In reality, most populations are at least somewhat mobile, and health centers experience turnover like any other place of business. Moreover, it may take several days, weeks, or even months for every member of the community to witness the drone in flight. As a result, new individuals will continuously be exposed to the operations throughout the period of performance.

Community sensitization may therefore be rolled out initially with an increased push for community education and engagement but should also continue through for the duration of the drone activities. This may take place both formally and informally. For instance, ad hoc demonstrations to health workers, police officers, school classes, and other community groups will help to spread information about the activity from the ground up and ensure information is disbursed as widely as possible.

9. TRANSFER OF KNOWLEDGE TO LOCAL STAFF BUILDS A WORKFORCE AND AN ENABLING ENVIRONMENT FOR FUTURE DRONE ACTIVITIES TO THRIVE.

The management, operation, and maintenance of drones will need to be undertaken by local individuals and entities for it to become a sustainable and scalable method of transport. While the transfer of ownership of operations is not occurring at scale presently, this end goal should be kept in sight, and the transfer of knowledge to local entities and individuals should be part of any project. This can be done through the hiring of local staff, as well as making your operation transparent so the surrounding community can learn about the operations and outcomes.

The transfer of knowledge to the broader community is separate from (and in addition to) the need to train health workers. The training of health workers is likely done with the goal of ensuring safe interactions with the drones and ensuring sufficient support at health facilities to eliminate the need for additional staff. Health staff becoming comfortable and fluent in the operation of drones is critical to the daily operation, and something which will enhance their support for the integration of drones into their daily work. It is unavoidable that the introduction of drones will require flexible adaptation on the part of the health care workers. At a minimum, these individuals will need to adjust how they communicate and document the ordering and delivery of health commodities, diagnostic samples, and test results. They will also need to be available to assist with the preparing, sending, and receiving of goods. Written communications protocols and job aids—developed with the input of local healthcare workers—will help to align stakeholder expectations and prepare them for effectively carrying out their new or amended duties.

10. PLAN FOR INFORMATION CAPTURE AND SHARING WHEREVER POSSIBLE.

Currently, the body of available knowledge regarding drones for cargo delivery is not substantial in breadth or depth. This is a result of few drone operations taking place, limited lessons learned, and a lack of recommendations being documented and disseminated. Without information and experiences to reference, implementers are not able to build off previous operations or lessons learned, and the ability to save time, money, and resources, as well as mitigate risk is reduced. Beyond the impact to implementers, the lack of information sharing stunts the adoption of drones by donors, governments, businesses, and others who influence resources and approvals for future operations.

Documented quantitative and qualitative insights, both during and after the operation, as well as allowing visitors to observe, is particularly important for a solution which is in its infancy. Success stories are beneficial for capturing improvements in efficiency and quality of healthcare in ways that other data cannot. Additionally, videos and images of the operation help bring to life something that is only conceptual to many. For these reasons and others, drone operations should strive to be transparent and forthright in its communications.

11. EFFECTIVELY LEVERAGE ASSETS TO EXPAND THE DELIVERY SYSTEM AND IMPROVE DELIVERY EFFICIENCY.

Integrating drones into health supply chains creates a conduit to previously underserved health facilities, allowing improved access to resources and reducing the challenges faced by health facilities due to terrain, budget, and personnel limitations. Therefore, once the conduit is set up by way of the drone, medical needs at the facilities should not be limited to a specific health area. Utilizing the drone for multiple health needs, across many health facilities, and potentially for uses beyond medical cargo will improve the cost benefit ratio.

Consider also that a significant portion of the costs to operate drones are fixed, and therefore the value of the drone increases as more customers are served. This can be achieved by increasing the size of the drone fleet, sourcing drones with the widest possible range to reach a higher number of facilities, or by identifying multiple hubs of operation. The hub is the location from which the drone pilots operate, and where the drone is stored and maintained. The chosen hub location may be a Central Medical Store, regional hospital, district hospital, or other secure location which holds product stock. With drones requiring only a light infrastructural footprint, this location can essentially be mobile.

In this arrangement, the hub of operations is relocated to where the need is highest in any given week, while the facilities served (which may be health centers, dispensaries, community hospitals, etc.) are those facilities with a need for services which are within range of the hub of operations. An example scenario is shown below:

Week	Hub of Operations	Facilities Served
1	District Hospital	a, b, c, d, e, f
2	Regional Hospital	g, h, i, j
3	District Hospital	a, b, c, d, e, f
4	Local/Community Hospital	k, l, m, n

This expands the reach of the drone to new areas which would otherwise be out of range without doubling or tripling the resources needed to have multiple hubs operating in parallel, and is effective because remote facilities typically serve a limited number of patients. Aside from emergency needs, weekly service is typically sufficient to meet their medical delivery needs.

Importantly, facility staff may not be able to identify all possible use cases until they have seen the drone operations perform successfully over time. As staff gain familiarity and confidence with the distribution channel, new recommendations for uses are likely to surface, and the best configuration for operations may evolve.

12. DRONES ARE AN EFFECTIVE TOOL FOR OVERCOMING SURFACE BARRIERS AND SYSTEM LIMITATIONS.

Drones are well-suited to overcoming unique challenges where traditional forms of transportation and distribution prove too slow or too unreliable to be effective. Emergency medicine deliveries, supplementary distributions in between routine drops, accessing remote locations, and overcoming roadblocks are a few examples of where this tool may prove most effective.

A complete understanding of existing systemic issues and root causes of distribution challenges will inform the type of solutions which will provide a successful outcome. Often this analysis points to a combination of issues within the supply chain that are best addressed through a combination of policy interventions.

SECTION I: PLANNING

Photo Credit: USAID GHSC-PSM

ACTIVITY OVERVIEW AND OBJECTIVES

For patients in areas that are hard to reach with traditional transport methods, access to medicines, a diagnostic sample collection network, and timely receipt of test results save lives and improve health outcomes. To improve transit times and ensure patients living with HIV receive faster and more reliable health services including more effective treatment, USAID GHSC-PSM launched an innovative approach to improve last-mile delivery in Malawi, using unmanned aerial vehicles (UAVs), or drones, for ongoing, bi-directional delivery of medicines, samples, and test results.

Using drones as a tool within health supply chains allows for overcoming logistics challenges faced in many parts of the world, including:

- Lack of infrastructure or poorly maintained infrastructure (e.g. roads, bridges)
- Infrequent and inconsistent deliveries which are outside the timeframe which support adequate health service delivery
- Geographic barriers (e.g. mountains, lakes) that make it difficult to complete deliveries
- Roadblocks due to civil unrest, natural disaster, or normal seasonal obstacles (e.g. rainy season)

USAID GHSC-PSM's groundbreaking drone activity began flights in June 2019 and made regular deliveries and collections for six health facilities (see Milestones). The drones had vertical takeoff and landing (VTOL) capabilities and landed at each facility, allowing for cargo deliveries in two directions. This enables the drone to deliver medicines and test results, as well as collect laboratory samples for delivery to the lab. The drone achieved faster and more reliable delivery of patient diagnostic samples and results, including for viral load, early infant diagnosis (EID) and tuberculosis (TB). With faster results, HIV-positive patients begin antiretroviral treatment sooner, which increases the efficacy of the treatment regimen, and in other cases helps doctors confirm whether the treatment is working. Availability of test results is essential to identifying local prevalence rates and can trigger prevention activities to reduce the spread of infection among these remote, underserved populations.

Prior to implementation of the drone activity, the round-trip transportation of lab samples and results regularly took up to eight weeks or longer, delaying diagnosis and treatment. Even then, close to half of the sample test results never made it back because either the samples or the results were lost in transport.

During the period of June 2019 through February 2020, the USAID GHSC-PSM drones flew 19,750 km during 428 flights, carrying medicines, medical supplies, lab samples and test results to and from eight different locations. **For HIV Viral Load and Early Infant Diagnosis test results alone, the drones carried results for 225 patients, delivering diagnosis and treatment up to eight weeks earlier than in the past.**

Drone Activity Milestones

August 2018:
First scoping trip; government and stakeholder engagement.

November 2018:
Second scoping trip including stakeholder coordination, and site and feasibility assessments.

June 2019:
Training began for 5 Malawian safety pilots. Drone demonstrations for Department of Civil Aviation (DCA), including first in-country flights. Approval given by DCA for beyond visual line-of-sight flights

July 2019:
Launched first sustained bi-directional medical cargo flights between health facilities in Nkhata Bay and Likoma Island,

August 2019:
Launched sustained, bi-directional medical cargo flights to Chizumulu Island; for the first time, these are managed by trained health facility staff rather than a flight team.

November 2019:
Added four additional health facilities located in villages along the shore of Lake Malawi.

December 2019:
Conducted the first successful nighttime flight to demonstrate capacity to respond to emergency medical needs at any time.

February 2020:
Marked the conclusion of the pilot with a successful record of 428 flights for delivery and collection.

The USAID GHSC-PSM drone activity in Malawi was a pioneering activity, designed around the following objectives:

- **Integration of drones into the existing supply chain and distribution channels** rather than operating as a parallel supply chain or storing products outside of regular storage facilities. This builds a stronger case for assimilation of drones into public health supply chains.

- **Collection and sharing of information from sustained use of drones over several months**. Advancing beyond previous bi-directional drone pilot programs that offered limited numbers of test flights, data from ongoing, regular use helps stakeholders assess the operational and health impact, as well as costs and benefits of integrating bi-directional use of drones into supply chains.

- **Expanded potential for using drones for public health programs** through training of local health facility staff to use and receive drones for health commodity transportation. As demonstrated on Chizumulu Island (see milestones), and later across all serviced facilities, health facility staff were trained to handle communications procedures, security of the landing area, loading/unloading of cargo, and basic drone operations. Bi-directional use of drones has been shown to be a viable option in remote locations where only health facility staff are available to handle the drones.

- **Establishment of appropriate channels and process streams** for communications between stakeholders to request health deliveries, confirm quantities of medicines available, and convey arrival times to ensure that a health professional can safely receive the delivered goods. This is particularly important in the case of laboratory samples, where specific handling procedures may be required. Local pharmacy and laboratory staff contributed to the development of the new process streams to ensure staff receive all the needed and relevant information.

- **Advanced transparent and timely information sharing** for local and global actors interested in developing sustainable drone programs to improve regular and emergency distribution of health supplies.

- **Enhanced local capacity** by hiring and training local staff to be part of the flight operations team. In the case of Malawi, most staff involved in carrying out flight operations on both sending and receiving sides were Malawian. Expatriate expertise was brought into the country only where high-level project management or aviation regulations required it. This helps build a cohort of drone professionals and adds to the capacity of the country to carry out future work with drones more self-sufficiently.

The value of a drone intervention cannot be based on cost alone since drones make deliveries achievable where they were not otherwise possible. Drones can reach customers with a speed and consistency which produces improved health outcomes.

Drones will not resolve all challenges facing a supply chain. They are best suited to overcoming unique challenges where other forms of transportation and distribution prove impossible, unreliable, or too risky to be effective. They will be one tool amongst others, albeit one with exciting new capabilities.

This activity contributes to the limited body of knowledge on cargo drones, providing lessons learned from a sustained application and allowing the drone community to learn about the health impacts, costs, and operational considerations. Through USAID GHSC-PSM, drones have proven to be a valuable innovation that can save lives when deployed strategically in the existing HIV/AIDS and broader health supply chain.

SELECTING THE RIGHT DRONE

To choose the best drone for your needs, it is helpful to have activity objectives determined prior to initiating the procurement process, as this will influence the type of drone(s) utilized. Multi-rotor or quadcopter drones, for example, are well-suited for urban areas due to their limited range and payload. Fixed wing drones (those that are most similar in appearance to manned aircraft) can exhibit impressive payload and range, but often need additional infrastructure or large, unobstructed areas of ground for taking off and landing. These may be well-suited to deliveries in one direction, where the drone is not required to land at the target site but drops the payload by parachute or lowering device. Hybrid drones with VTOL capacity can take off and land in small spaces such as next to a health facility and have a similar payload and range to fixed-wing drones. They are capable of performing deliveries in two directions but use significant amounts of power to take off and land, and therefore may be unable to stop at multiple facilities in a single delivery route which are not close together, unless a power source is available at the target site.

For all drones, the question of electric versus fuel power is critical, as remote locations may lack access to fuel or high-quality fuel, which can cause significant delays or damage to the drone engines. Deliveries using battery-powered drones must either be able to access a power source at the target facility for recharging, or they must make deliveries and collections with enough remaining battery power to safely return to the hub of operations. The USAID GHSC-PSM Unmanned Aerial Vehicle procurement guide includes detailed specifications for inclusion in a Request for Proposals, as well as suggested questions and areas for investigation during manufacturer site visits. This can be found in Annex 1.

INITIAL INVESTIGATIONS AND SCOPING VISITS

Depending on your level of knowledge of drone applications, you may wish to begin planning by first conducting an analysis of existing drone activities for the movement of cargo. For example, GHSC-PSM began research with the aim of understanding the range of possible use cases and locations where cargo drone activities had already occurred, available technologies, regulatory frameworks, and individuals or organizations to contact for more information. USAID GHSC-PSM first conducted this analysis in late 2017 and early 2018. The data gathered from this exercise led the GHSC-PSM project to carry out scoping visits in Zambia, Lesotho, Rwanda, and Malawi.

The purpose of conducting these scoping visits was to assess feasibility and readiness for a drone activity for health product distributions. USAID GHSC-PSM looked to countries which were of strategic interest to the USAID Office of HIV/AIDS, had an active ground presence in the form of a field office, an interested group of stakeholders and supportive regulators, and where a compelling use case existed in line with the identified activity goals. The four countries listed above were each assessed for regulatory challenges, as well as level of stakeholder support within the Ministry of Health, the country's aviation regulatory body, and stakeholders within the public health community.

Using the above criteria, Malawi was tentatively selected for implementation of the activity. A second scoping visit was then required to gather additional information from potential sites and confirm approval processes with regulators. The outcomes of this second trip included:

- Mapping of processes for regulatory approvals from each approving body
- Identification of central, district, and local stakeholders, both formal and informal
- Establishment of essential relationships and feedback from service delivery points
- Gathering of critical operational information

This trip included interviews with stakeholders who had successfully navigated the approvals process for flying drones in Malawi. A good deal of needed information—including detailed guidance for operating within the Malawi Drone Corridor, assistance in liaising with the Malawi Department of Civil Aviation (DCA), and cooperation for importation of equipment—came from UNICEF. UNICEF is responsible for assisting DCA in running the Humanitarian Drone Corridor, established in Kasungu, Malawi, and therefore was the go-to source for the first stage of operations in Malawi, which includes importation of drones and related equipment, successful completion of safety and operational demonstrations for DCA, and obtaining approvals to operate anywhere outside of the DCA and UNICEF-managed corridor.

Following the experience of conducting scoping trips in four countries, and a second, more in-depth information gathering trip to Malawi, USAID GHSC-PSM developed a guide to assessing feasibility and readiness for drones. The guide provides detailed information on questions to be answered at the activity design stage and is applicable to all drone interventions in development, not only those which are related to health supply chains. This document can be used prior to selecting a place of performance for a drone activity, or to help prepare for an activity with a specific place of performance in mind. In the case of the latter scenario, the assessment of feasibility and readiness may reveal additional support activities which must occur prior to the startup of flight operations or may expose risks to be considered during the planning phase.

VALIDATION OF USE CASES

USAID through the GHSC-PSM project set out to conduct this activity to move beyond testing drone technology. The activity's objectives, as stated previously, included:

- Demonstrating integration of health deliveries and sample collections into the existing health distribution system, rather than operating in parallel to or separately from the existing supply chain.
- Determining health benefits of utilizing drones
- Understanding the costs and operational consideration for the application of drones

To ensure the objective of integration was achieved, the next stage in planning and preparing for the drone activity included conducting site visits to the individual health facilities or health surveillance assistant (HSA) outposts.

This stage in the planning process could proceed concurrently to initial scoping visits if time and budget allows, and if a specific region or area of operation has been selected. At a minimum, visits to these sites need to be made prior to finalization of the activity design in order to get valuable feedback, buy-in, and information from the facility directors or in-charge personnel, as well as to communicate intended plans with the healthcare staff who may be involved with the drone activity day to day.

Target sites were first identified by the Ministry of Health. Each potential site of operation (including the identified hub of operations and all target delivery/collection sites within feasible range) was visited with an aim to achieve the following objectives:

- Determination of sites to participate in the activity, based on needs and interest
- Confirmation through root cause analysis that identified needs are based, at least in part, on transportation challenges (rather than supply or forecasting challenges, for instance)
- Assessment of availability of resources (e.g. safe storage space for equipment, working space for the hub of operations, willingness, and availability of personnel to assist)
- Identification of local political and civil leaders, both formal and informal
- Gathering of critical operational information (e.g. potential lodging for staff, availability of supplies for purchase, identification of seasonal impacts to accessibility, etc.)

Additionally, each potential takeoff and landing site was visited and assessed from a technical perspective to assess flight route considerations such as visibility, obstructions, and hazards; safety and crowd control; workspaces and storage locations for safekeeping of equipment; and availability of power and connectivity.

The results of the site visits confirmed that infrequent last-mile delivery of tests and unreliable return of sample results caused patients to be turned away at facilities on certain days. This was especially the case in small communities on Lake Malawi that depend on water transport, such as Ruarwe and Khondowe. In these remote villages, patients would sometimes walk long distances to give a sample, only to find that the facility could not properly store the sample or that the sample would expire before the next planned sample collection.

In another example, lab samples on Likoma Island were only collected every Friday prior to the start of the drone activity. If a patient went to a clinic for testing on a Monday, they would likely be turned down and told to return, reducing the odds that the sample would be collected at all. Additionally, some collected samples were stored for several days or weeks before being loaded onto a ferry or private boat. Sometimes, these samples expired, and the patients would need to be re-tested. This situation resulted in both patient and health worker dissatisfaction, which has shown direct correlation to a reduction in compliance with treatment regimens and general health, as well as the level of health service delivery.[1]

The site visits also revealed locations where cellular connectivity was unreliable or unavailable, enabling early notification to the drone service providers that a communications solution with the drone must be non-reliant on cellular networks to complete deliveries to these locations. With all of this information and more, USAID GHSC-PSM was ready to move into the design finalization stage and begin work toward drone operations approvals.

ACTIVITY DESIGN

An understanding of the existing distribution system is critical to successfully integrate into the health supply chain. In Malawi, the health supply chain is significantly funded through international donors. For example, the USAID GHSC-PSM project provides funding and procurement of medicines in the areas of HIV, malaria, and family planning, filling in gaps in coverages from other donors. This supply chain covers more than 650 public health facilities, from central-level hospitals down to small public health clinics.

The Central Medical Stores Trust (CMST) distributes health commodities to the Regional Medical Stores through three administrative areas, and ultimately down to central and district hospitals and health centers. Smaller health centers are typically government-run, but occasionally are funded by organizations such as the Christian Health Association of Malawi (CHAM) and other NGOs. In some cases, small health facilities collect supplies directly from district pharmacies or health centers.

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[1] Schneider, J., Kaplan, S.H., Greenfield, S. et al. Better physician-patient relationships are associated with higher reported adherence to antiretroviral therapy in patients with HIV infection. J GEN INTERN MED 19, 1096–1103 (2004). https://doi.org/10.1111/j.1525-1497.2004.30418.x

Central

- Health product procurement is largely donor-funded
- Central Medical Stores Trust distributes commodities to the regional level

Regional Medical Stores are located in three administrative areas of Malawi

- Receipt and storage of product destined for the districts

District

- District hospitals and health facilities distribute product to the sub-district level, or SDPs may collect supplies directly from the district facilities

Sub-District

- Service Delivery Points (SDPs) include Health Surveillance Assistants (HSAs) and Dispensaries
- Includes non-government funded SDPs (e.g. the Likoma Island Hospital is funded by CHAM)

Because forecasting of needed medicines is inherently imperfect, it is difficult to consistently make accurate estimates of the quantities of medicines and products needed at each facility. Under- or over-estimating quantities needed can cause shortages (or stockouts, in the most severe cases), while overstocking medicines often results in expiry and waste. The addition of drones introduces a limited form of "just in time" delivery which can correct for under- or overstocked products by delivering needed supplies between regular distributions, or by collecting and redistributing products where it is needed.

As noted previously, smaller facilities sometimes collect medicines directly from district health centers in between scheduled shipments. As a result, small, resource-limited facilities may be forced to develop their own transportation solutions. For example, the assessment team conducting site visits observed HSAs and other health workers leaving their worksites for days at a time. If they had to wait for the weekly ferry, a dispensary or health outpost was sometimes left without trained health staff for several days. Moreover, the health staff often made these trips at their own expense, paying for the ferry, lodging, food, and other expenses out of their own pockets.

The activity management team concluded that drones had high potential to reach underserved communities, deliver emergency commodities between regular distributions, enable more frequent sample collections for patient diagnosis, and save resources at remote facilities.

With these indications that drones could improve health outcomes at the sub-district level, USAID GHSC-PSM designed the drone delivery and collection activity to link district facilities and smaller, last-mile SDPs, specifically selecting facilities which were not adequately serviced by motorbikes or any other form of distribution.

Combining the information gained during the earliest stages of investigation into existing drone delivery activities, the scoping visits, and the site-level assessments, USAID GHSC-PSM staff created an activity design aimed at ensuring the following factors:

(1) medical professionals, rather than an outside labor force, participate in and complete the majority of the required work;

(2) no new infrastructure or infrastructure projects are required;

(3) no parallel supply chain is established and products continue to be kept in existing storage facilities;

(4) the introduction of drones does not introduce new requirements or obstacles for the transportation and distribution network.

The resulting activity design was structured in a phased approach, briefly described below, and detailed more thoroughly in later sections of this report.

Phase 1:

USAID GHSC-PSM selected Likoma Island to receive deliveries and return samples for processing during Activity Phase 1. The Nkhata Bay District Hospital was identified as the most effective base of operations. This location—in addition to being within comfortable range of both Usisya and Likoma Island—serves as the district's center for dispatch of commodities to local health facilities and HSAs, as well as a collection point for laboratory samples. The Nkhata Bay District Hospital also provided a locked workspace for storage of the drones and equipment and experiences consistent power supply for recharging the drone batteries. The northern site of Usisya was chosen as a battery recharging point, as well as a jumping off point for reaching the district-identified priority sites of Ruarwe and Khondowe.

As this was the first time in Malawi that bidirectional health deliveries had been made outside of the drone corridor, a slow and incremental approach to drone flights was enacted in order to ensure safety. To further mitigate risk, the activity was designed to test flights extensively by conducting short test flights followed by increasingly longer test flights until the delivery/collection facility on the island was reached. The flight routes were also planned to operate primarily over water, and to avoid populated areas when flying over land, rather than to fly in a direct line for the entire route.

Prior to the drone activity, the Likoma Island hospital of St. Peters collected lab samples each Friday and held until a health worker could carry the samples via the weekly ferry between the island and the mainland district hospital in Nkhata Bay. Prior to and during the implementation period, the ferry was broken and therefore unusable for health deliveries for several weeks. Phase I connected the Nkhata Bay and Likoma Island District hospitals with daily deliveries and collections.

Phase 2:

Phase 2 introduced a second delivery and collection site on Chizumulu Island, which is a neighboring island to Likoma in Lake Malawi. Before the option to use drones, lab samples from Chizumulu were often held for several days or a week until delivery to Likoma Island could be made. This means that long sample turnaround times were even longer for the smaller island facility on Chizumulu. Phase 2 incorporated new flights between the two islands and trained local health personnel capacity to receive and reload the drone independently after receiving appropriate training. This represented one of the first times that deliveries and collections were made without the presence of licensed drone pilots, who monitored and controlled the operations remotely from the Nkhata Bay District Hospital. The achievement demonstrated the scalability of a bidirectional health delivery network and proved that local workers and community members alone can safely operate the system outside the hub of operations.

Phase 3:

Phases I and 2 were used to ensure a progressive and iterative rollout of the drone activity. This increased safety by allowing for incorporation of lessons learned and improved efficiency and safety of flight operations. In addition to the two island health facilities, phase 3 added deliveries to and collections from four fishing villages along the edges of Lake Malawi (i.e. Toto, Mtawa, Ruarwe, and Khondowe, not including the hub of operations in Nkhata Bay or the stopover point in Usisya primarily serviced by motorcycle). These fishing villages are not accessible by truck or motorbike—even during the dry season—and must be accessed by chartered boat, a time-consuming and expensive mode of transport. With the inclusion of drones in last mile distribution, daily deliveries and collections to the additional facilities were possible.

Further details on flight operations can be found below in Section 2, which focuses on Implementation.

CONTRACTING WITH DRONE SERVICE PROVIDERS

As with other forms of health product distributions, government-owned supply chains should evaluate their core competencies and ideally outsource responsibilities which fall outside of those competencies. In subcontracting with multiple drone manufacturers during this activity, USAID GHSC-PSM learned useful lessons in the execution and management of such contracts.

The project management team determined that any contract for drone services would serve the following primary purposes:

1. Assign responsibilities to the subcontractor while maintaining ownership of those responsibilities which are of the highest strategic importance to the procuring organization
2. Create formal and informal mechanisms for communication and reporting between stakeholders, and assign roles for communications
3. Ensure the highest level of service to the government, health facilities, and community members experiencing the benefits of health deliveries by drone

To achieve these aims, the team worked to develop a contract with clearly defined roles and responsibilities. Stakeholder management, strategic planning, performance measurement, and communications activities were largely kept within the project management team (with expert input), while day to day safety of flight operations and training of local staff was designated to the drone services provider.

The team also strived to define financial responsibilities for costs which are not direct or immediate—such as insurance and replacement parts. However, it was later found that the contract could have benefited from more explicit statements of unanticipated costs, despite the firm fixed price nature of the contract. One contract management area which was difficult to reach consensus on between USAID GHSC-PSM and the first of two selected drone service providers was performance monitoring mechanisms. Some service providers may be reluctant to agree to a specific number of flights, given that certain environmental factors are beyond their control. If a price per flight or kilometer is offered as part of the service provider's business model, this is less of a threat to cost efficiency. However, many providers offer flat rates or fees for a drone delivery network up to a certain fleet size or number of delivery and collection sites. The activity found that this operational model requires a minimum standard of flight performance, such as number of flights completed or percent of cargo delivery and collection requests fulfilled.

USAID GHSC-PSM also clearly defined data collection requirements for each flight, including time of take-off, time of landing, vehicle ID, and flight plan ID. The full list of data collection requirements can be found in Annex 2. A sample scope of work for the drone service provider is provided in Annex 5.

SECTION II: IMPLEMENTATION

Photo Credit: UNICEF Malawi

FLIGHT OPERATIONS APPROVALS

USAID GHSC-PSM shared the completed activity design document with stakeholders for feedback before it was finalized and held a stakeholder meeting in Lilongwe at the beginning of April 2019. Stakeholders from both central and local levels were invited, including the District Health Officers from the Nkhata Bay and Likoma Island districts, the Christian Health Association of Malawi (CHAM)-who manage the hospital on Likoma island- the Ministry of Health, the Department of Civil Aviation, UNICEF, and others. During this meeting, the activity design was thoroughly reviewed and discussed, and the Ministry of Health granted approval for the activity to proceed.

This approval provided the green light to proceed with importation of drones and equipment, and to begin preparations for a demonstration of flight operations in the Kasungu Humanitarian Drone Corridor of Malawi. The demonstration needed to mirror intended operations as closely as possible. Operators must demonstrate the drone could perform as described, as well as prove a high level of safety and coordination with other aviation bodies (such as Air Traffic Control) in order to receive Remotely Piloted Aircraft Operator Certificate (ROC). The ROC is not necessary for operations inside the geographic boundaries of the drone corridor, which was established for the purpose of allowing companies to safely test and demonstrate their product and procedures in a controlled airspace. The ROC is required, however, for any operations outside of the corridor.

GHSC-PSM spent one and a half weeks inside the corridor conducting tests and preparing for the official demonstration—time which was spent testing communications and mechanical troubleshooting. The Kasungu Airport—a largely unused airstrip representing the most commonly used part of the corridor—was set up as the drone base of operations, while a small facility and Health Surveillance Assistant (HSA) located in Lifupa, Malawi, more than 40 kilometers away, was designated as the recipient site. For the demonstration, the drones carried antimalarial medicines and returned with dummy cargo to the base of operations.

At the same time as preparations for the flight demonstrations were taking place, the USAID GHSC-PSM team worked with health facilities in the Nkhata Bay and Likoma Island districts to establish appropriate drone ordering and communications protocols.

Once the ROC was issued by DCA, the project moved to immediate deployment to the Nkhata Bay District for setting up operations and preparing for the formal launch of project deliveries by drone. USAID GHSC-PSM also used this demonstration to fulfill requirements for approvals to deliver dangerous goods (including TB samples) and to perform night flights with Air Traffic Control approvals.

More recently, the government has also added the stipulation of ethics controls via appraisal by an Ethics Review Board for drone activities relating to the delivery or collection of health commodities. The requirement for ethics approvals will vary from country to country and should be confirmed during the initial investigations and scoping visit.

COMMUNITY SENSITIZATION

Following earlier visits to the district level during the feasibility assessment, a team returned to Nkhata Bay and Likoma districts to present the final version of the design plan, hear from local leaders, and sensitize the local community. Community sensitization was led locally, by representatives from the Ministry of Information and Communications Technology (MoICT). After identifying popular local gathering places, such as markets and community centers, activities for sensitization included Town Halls for Q&A, short videos of drones flying, radio ads, and dramatizations acting out what to expect when the first drone arrives. GHSC-PSM coordinated with MoICT to provide responses to anticipated questions in advance of these events, as well to review popularly asked questions and ensure the sensitization team was equipped to respond completely and accurately.

However, while drone operations tend to attract a smaller crowd of observers over time, turnover in health center staff along with normal community mobility means that new individuals will continuously be exposed to the operations. Community sensitization may therefore be rolled out initially with an increased push for community education and engagement but should continue through both formal and informal channels for the duration of the drone activities. GHSC-PSM's drone activity continued this work throughout the period of performance through ad hoc demonstrations to health workers, police officers, and groups of visiting school children. These groups were given the opportunity to see the operations up close, ask detailed questions about the activity and the drone itself, and could then spread this knowledge to other members of the community.

START-UP

Several start-up activities took place throughout the previously described stages of preparations, as well as throughout the approvals processes described below. For example, USAID GHSC-PSM worked with the drone service provider to import tools and supplies for conducting basic maintenance on the drones. Where possible, items were sourced in Malawi.

GHSC-PSM also undertook a hiring process to find available individuals in Malawi with aviation experience, exposure to drones in some capacity, or related skills. Through newspaper advertisements and word of mouth referrals, the project identified and hired five Malawian staff members who were to work closely alongside the drone pilot to learn as much as possible about the operations. Three of these five were former interns at UNICEF Malawi who had limited experience using drones for mapping applications. The other two were referred to GHSC-PSM from DCA where they were serving as interns, and both had degrees relevant to aviation. These staff members learned critical flight operations processes and safety procedures and carried them out until responsibilities could be transferred to local health facility staff members in phase 3 of the activity The aim of educating this local cohort of Malawian youth, as well as the health facility staff members, was to transfer knowledge of drone operations and management. The activity was thereby able to both empower a cohort of drone-educated providers within Malawi as well as demonstrate the capacity to scale operations using local expertise and experience.

Prior to beginning flight operations, the activity needed to create a way for health facility needs and dispatches to be communicated, as well as the distributing facilities to confirm receipt of requests and medicines available. It also was a means for flight staff to notify health staff of shipments that needed to be collected from the landing site, and when flights would be departing. This needed to be created since no other cargo drone activity had done this before, and there was no existing solution available, therefore GHSC-PSM drafted a communications protocol using agreed-upon WhatsApp message structures for SDPs to request medicines or a pickup of lab samples, confirm a safe and clear landing area before arrival of the drone, and communicate when the return flight is initiated. Pharmacy and laboratory technicians from both the Nkhata Bay District Hospital and the Likoma Island Hospital provided input to the message format, including what information they needed in order to dispatch or receive medicines and samples.

PHASE 1: JUNE-JULY 2019

As mentioned in the Activity Design section above, the Malawi drone activity was rolled out in phases, each incorporating lessons learned from the previous phase as well as reaching additional target sites. The activity began with flights between the District Hospital, located in Nkhata Bay, and St. Peter's Hospital located on Likoma Island (see Figure 1 map).

Success! With the equipment delivered by drone, Likoma Island lab technicians prepared control tests for HIV self-test kits which had been sitting unused for several months. Once the control tests were performed, these kits were delivered to Chizumulu Island, where they were distributed to community members.

The Nkhata Bay Hospital served as the base of operations due to its function within the region in holding and distributing inventory to local facilities, as well as serving as a collection point for diagnostic samples. The hospital is also within range of many of the target facilities and experiences consistent power for recharging batteries. A pilot certified with a Remote Pilot's License (RPL) was stationed at the Nkhata Bay Hospital and was responsible for maintaining and safely storing the drones in a locked space each night after operations concluded. The RPA license holder also oversaw safety procedures before, during, and after each flight.

On the other end, the Likoma Island Hospital, managed by the Christian Health Association of Malawi (CHAM), was required to have support personnel with a valid radio operator's license due to the nearby island airport. In the final phase of our activity, the local airline servicing Likoma suspended its flight activity to the island. However, the regulatory requirement for personnel with a radio operator's license continued to pose an operational challenge which limited the ability to transfer all responsibilities on the island to local staff.

A special WhatsApp group was also established at the outset of the activity which enabled the drone operators to communicate regularly with the Department of Civil Aviation, Air Traffic Control, and in-country commercial and recreational pilots to request approvals for flights, receive updates on incoming and outbound manned aircraft, and monitor radio communications for relevant information.

To ensure transfer of knowledge, the local Malawians hired to support the activity worked alongside the RPL and radio license holders—staff from the subcontracted drone provider—to learn flight operations. Over time, these individuals learned to safely and accurately complete pre and post flight checklists, assemble and disassemble the drone, and to monitor in-flight data, all under the supervision of the RPL holder. This work, begun in phase 1 of the activity and continuing for several months, contributed to a capable young cohort of Malawians with drone operations and project management experience.

Photo Credit: USAID GHSC-PSM

USAID GHSC-PSM ensured that local staff were thoroughly trained in flight operations and tested for comprehension and performance. Initially, they were trained on basics such as maintaining flight logs and weather systems tracking. Following a comfortable introductory period in which all staff demonstrated competency of this foundational knowledge, they were next trained on remote safety procedures and ground station communication. Staff trained on the ground station learned how to effectively communicate between takeoff and landing sites, proper communication channels with DCA, and how to properly track the drone on its flight path.

Simultaneously, staff were trained in manual flight on training drones (low-cost off the shelf), beginning with small Styrofoam and plastic drones that they could fly on the weekends without concern for harm to people or property. The staff were also introduced to flying commercially available hobby drones, such as the DJI Mavic.

Finally, the local staff who showed advanced proficiency and understanding received hands-on training of flying the drone, as well as learning how to plot flight routes and scout landing zones for future use. Out of this cohort, one staff member gained enough knowledge and capacity to begin operating the drone independently during takeoff and landing procedures, made possible by the highly iterative training that allowed him to slowly build manual flight skills. This was the first locally trained pilot in Malawi to have the ability to fly a commercial drone under supervision of the RPA holder.

Manual training using off-the-shelf drones was a critical part of staff instruction. In the case of one local staff member, progressive training complemented his degree in aerospace engineering and ultimately built capacity to manually control the commercial craft while under an RPA holder's supervision. In all cases, staff were granted the opportunity to make connections between the cargo flights they supported each day and the aviation mechanics and physics behind them. Depending on project design and setup, this may not be a requirement for local staff members but is nonetheless a rewarding part of a holistic learning experience.

By the end of this phase, the local staff were well-trained and ready to continue their study of drones for application in Malawi. Most of these individuals moved forth to attend a program at the new African Drone and Data Academy, an institution sponsored by UNICEF.

PHASE 2: AUGUST-OCTOBER 2019

Following weeks of successful daily or twice-daily round trip flights between Nkhata Bay and Likoma, the activity transitioned to the second phase of implementation. Throughout phase 1 of the activity, trained operators had been stationed at both ends of the flight to assume manual control should anything unexpected happen during the takeoff or landing procedures, such as an animal or person entering the cleared landing area. However, this setup limited the potential scalability of the system, as trained operators stationed in every landing site would exponentially increase the cost of the system.

To demonstrate the possibility of operating without an extended network of expatriate drone operators, the activity focused on including flights to Chizumulu Island without placing any extensively trained operators at the landing site. Several preparatory steps made this setup possible, including first sending a drone pilot to the island to identify a secure location suitable for landing the drone.

At the same time, the District Health Officer was charged with identifying responsible community members to work with. When the drone pilot visited Chizumulu Island to identify a landing site, they were also tasked with training community members to clear the landing zone, unload the drone cargo, reload the drone, perform a visual check for damage to the drone, and to communicate with the remote drone pilot via WhatsApp when ready for return flight. One of the two staff trained was not a health facility worker, but rather a respected community member who interacted with the health facility frequently. Including both this worker and the HSA in operations was critical to ensure operations could continue in the absence of either individual.

PHASE 3: NOVEMBER 2019-FEBRUARY 2020

Activities in phases 1 and 2 progressed slowly, with an iterative expansion of activities that allowed for incremental testing of each new flight route. As the activity entered its third and final phase, GHSC-PSM contracted with a second drone services provider. The search process for this vendor emphasized the need for a faster startup period and enhanced potential for scalability. The operational model under the new service provider emphasized reliance on health facility staff and began by identifying community members at each node of operations—usually but not always HSAs—and training them to communicate with the remote operator stationed at the base of operations in Nkhata Bay via WhatsApp. As with Chizumulu Island, these individuals' responsibilities included maintaining a clear landing area, unloading medical deliveries from the drone, and reloading it with patient samples when available, and communicating with a remotely stationed drone pilot. Additionally, these community members were able to initiate launch of the drone for return flight through a simple interface and push of a button. In addition, select facility staff (or trusted community members) such as the ones located in Usisya and on Likoma Island were trained in procedures for safely recharging and replacing drone batteries.

With the new operational setup, activity was also able to quickly increase the number of supported sites from two to seven, more than tripling the size of the drone-serviced network. Certified drone operators (with RPL licensing) were no longer needed at every location, and the time from identifying and planning an additional site to actual delivery was reduced to the amount of time it took to identify a local health center staff or community member to assist the activity, as well as train them. This reduced time for expanding to a new delivery and collection site from weeks to a matter of one to two days.
By focusing on facility staff at all nodes of flight operations and building safety precautions into simple user interfaces, this phase demonstrated the possibility of expanding bidirectional drone operations in a faster, cheaper, and more sustainable manner.

Photo Credit: USAID GHSC-PSM

Throughout this phase, the project learned many lessons regarding training and capacity-building. While these lessons were drawn from the Malawian context, they are applicable to all drone operations in international development. For instance, local community-buy in is vital for success. Community leaders in the areas surrounding the health facilities helped the project by identifying capable and reliable individuals for training, which increased local support for the activity as well as the likelihood that individuals would be present for each delivery.

Importantly, the activity found that it took several weeks to reach full operational capacity. Once the activity began, it took time for individual facilities and staff members to witness and buy into the ways in which deliveries by drone facilitated their work. As anticipated, the drones reduced the need for staff to travel long distances by boat and allowed them to better serve the members of their communities. As local testimony as to the usefulness of the drone delivery and collection system spread, participants became increasingly proactive, responsive, and willing to participate and even advocate for the activity. This increased the number of requests made for drone delivery, decreased drone idle time, and ultimately resulted in a more efficient and cost-effective use of the system.

STAKEHOLDER AND PARTNERSHIP MANAGEMENT

Authorizing Bodies:

Authorizing bodies include civil aviation at a minimum but may also include several other possible approvers/collaborators. For example, a health project will closely involve the Ministry of Health at both the central and regional levels. It is also possible that there will be district-level approving bodies. In addition, ministries of communication and technology may be required to give support or even to participate in any drone activity. Defense ministries may have separate tracks for inspections of the hardware and software to be used. Finally, local political leaders or community chiefs may need to be involved for informal approvals.

Figure 1

It is critical that all authorizing and collaborating governmental agencies and authorities are identified as early as possible, and that importation of drones and drone equipment is timed and executed to avoid delays to the project. It is easy to underestimate the amount of time needed for importation, especially of dangerous goods such as batteries. GHSC-PSM spoke to experienced stakeholders to map the importation process and timeline prior to conducting the formal demonstration for operations approval. It is also possible that civil aviation, military authorities, or other parties may require in-person inspections prior to sign-off, which is most easily coordinated during one demonstration event. The same authorities can often facilitate importation itself. If these entities are not identified and positive relationships established early on, the project may later experience delays or setbacks.

Inter-Donor Collaboration:

USAID GHSC-PSM worked closely with UNICEF in Malawi, which assists civil aviation in the management of the Humanitarian Drone Corridor. With UNICEF's experience in overseeing the companies who come to test their technology inside the corridor, USAID GHSC-PSM was able to benefit from the experiences of others who came before. For example, UNICEF provided information vital to preparing for the initial drone demonstration, including directly facilitating the importation and customs clearance of the drones, providing suggestions on available resources versus those which should be procured internationally, and more. The activity was also able to learn from both successes and setbacks experienced by implementers and drone service providers who had previously come to Malawi's drone corridor to test their technology.

Moreover, by serving as the intermediary for drone technology within the corridor (a necessary precursor to operations outside of the corridor), UNICEF was well-positioned to consolidate lessons learned and pass them along to all stakeholders. Both UNICEF and USAID participate in a Technical Working Group for Remotely Piloted Aircraft (here synonymous with drones) that facilitates collaboration among different donors, drone companies, and implementers within Malawi.

Health Facility Personnel:

USAID GHSC-PSM worked closely with health facility personnel at each stage of planning and implementation. The District Health Officers (DHOs) from Nkhata Bay and Likoma Island Districts participated in the scoping visit and were asked to provide feedback to the initial activity design document. The DHOs remained an important resource throughout the activity, providing advocacy, resources, and expertise. For example, they were able to quickly identify facility staff to assist when resources were needed.

Laboratory and pharmacy technicians were also critical to the success of the activity. In addition to providing valuable feedback for the development of the WhatsApp communications protocols for ordering medicines and requesting sample pickups, these technicians became outspoken advocates for the activity over time. In the early stages of the activity and particularly during Phase 1, activity staff and subcontractors found it helpful to visit the technicians regularly.

This ensured timely pickup of needed materials and reinforced relationships between activity and hospital personnel. As staff became more familiar with the service over time, it became clearer to them that a wide range of products could be carried as needed, and requests began to flow into WhatsApp groups without needing to visit these offices.

The modification to the method and frequency of sample collection required staff to be flexible in carrying out work duties. On Likoma Island, for instance, sample collection days—previously only carried out on Fridays—could be any day of the week. On the receiving end in Nkhata Bay, laboratory staff also had to become accustomed to the increased frequency in receiving and sorting samples. All staff involved were asked to communicate sample and medicine movements and requests in the designated WhatsApp group in addition to providing the standard paper forms. Over time, staff not only became accustomed to these changes in their routine, but also began to make an increasing number of requests for medicine delivery or sample pickup. Continuous efforts to educate facility staff are vital, and the first few weeks of implementation were key in building trust of those staff. When more and more facility employees saw the benefits and reliability of sending commodities via drones, they increased requests and became advocates for drones.

INCIDENT MANAGEMENT

As with many technologies and certainly any frontier technology, flight failures (incomplete flights, hard landings or crashes, emergency landings, failure to launch, or aborted missions) should be an assumed risk with planned mitigation and response measures. The sources of flight failures the activity experienced can be grouped into four main categories: hardware, software, operational/procedural, and environmental.

For example, hardware failures may include abnormalities or deformities catalogued during the pre-flight inspections, while software failures may stem from coding errors or version incompatibilities in the event that software upgrades are not made to the entire fleet of drones at the same time. Operational/procedural causes of flight failures include human error in properly following and executing procedures, or insufficiently developed Standard Operating Procedures. This type of failure is preventable through extensive operator training and training refreshers, or by requiring international certification and licensing for drone operators. Finally, environmental causes of flight failures include the drone's ability to withstand meteorological phenomena such as rain or wind, as well as other factors fully outside of the control of the drone operations team such as cellular network failures and manned aircraft scheduling conflicts.

Photo Credit: USAID GHSC-PSM

By this categorization, not all flight failures require the same level of escalation. In this project, events which prevented flight takeoff (e.g. manned aircraft scheduling conflicts, inability to remotely load the flight route onto the drone, etc.) were documented for reference purposes, and the schedule change was communicated to civil aviation and air traffic control through the established WhatsApp channel. In the event of forced landings and mechanical failures, USAID GHSC-PSM project staff informed civil aviation as soon as possible after the event by direct phone contact and directed its drone service providers to follow up in writing for further instructions.

In Malawi, Unmanned Aerial Systems regulation requires that any incidents be reported to the Department of Civil Aviation using a standard template within 48 hours of occurrence. However, the activity team implemented a standard in phase three of the activity that the incident form would be submitted within 24 hours, even if additional or follow-up information is required later.

No injury to persons or damage to private property was experienced during the eight months of flight operations under GHSC-PSM in Malawi. However, flight operations staff did maintain local emergency contacts in case of the need to report an injury or fire, and a first aid kit and fire extinguisher were always kept on site. The activity found that the best way to prevent injuries and damage was to plan for them during flight path planning. Flights from Nkhata Bay to Likoma Island, for example, were routed around highly populated areas, even though this was not the most efficient flight route. Wherever possible, flights were routed over water rather than land to minimize risk.

SECTION III: ASSESSING AND COMMUNICATING VALUE

Photo Credit: USAID GSHC-PSM

Life of Project Data	
Distance Flown (km)	**19,750**
Number of Flights (defined as one takeoff and one landing)	**428**
Count of Items Moved	**826**

Flight Summary Data - Service Provider 1	
Maximum Flight Distance (km)	83
Average Flight Distance (km)	63
Maximum Flight Time (minutes)	72
Average Flight Time (minutes)	60
Maximum Flight Speed (km/h)	83 km/h (126 km/h Ground speed due to wind)
Average Flight Speed (km/h)	83 km/h
Maximum Payload (kg)	2.5
Average Payload (kg)	1.0

Flight Summary Data - Service Provider 2	
Maximum Flight Distance (km)	77.4
Average Flight Distance (km)	50.1
Maximum Flight Time (minutes)	52.2
Average Flight Time (minutes)	25.4
Maximum Flight Speed (km/h)	100km/h (146 km/h ground speed due to wind)
Average Flight Speed (km/h)	100km/h
Maximum Payload (kg)	2.5
Average Payload (kg)	1.0

*Average payload is estimated here.

HEALTH IMPACT ANALYSIS

This section contains an analysis of impact based on the Results Framework (RF) developed prior to flight operations. The RF can be found in full in Annex 1, and a historical flight database was submitted to USAID.

There were six targeted indicators defined at the activity outset:

1. **# of laboratory samples collected per week by facility**

   248 viral load (VL), early infant diagnosis (EID), and Tuberculosis (TB) samples were collected over the course of the activity. A straight average over the course of the flight operations would average **13 samples moved per week**, accounting for a break in operations which took place mid-activity.

	Total Samples Picked Up from This Location	Average Weekly Samples Picked Up from This Location
Chizumulu	41	2
Ruarwe	2	Insufficient data to use average as

		a meaningful figure
Usisya	19	Insufficient data to use average as a meaningful figure
Likoma	158	8

2. # of stockouts of serviced products experienced at the facilities included in the activity

This activity focused on just-in-time delivery and did not perform routine distributions of health commodities. Instead, each request for a delivery of medicines or reagent was in response to a distribution point stockout. There were 24 instances of flights conducting just-in-time delivery of medicines, carrying a total of 32 stocked out SKUs.

The vast majority of just-in-time deliveries were fulfilled within 1 business day following a request, except where the request fell on a weekend, or where whether or technical issues prevented flight takeoff. However, there were also many cases where the requested medicine was also out of stock at the district and regional hospitals, underscoring the fact that supply chains face a variety of non-transportation related challenges.

3. # of in-country personnel trained on UAV, by function

Seven local staff members (six contracted through GHSC-PSM and one contracted through Swoop Aero) were trained in flight operations.

** * **

19 Malawians received training in one or more aspects of drone operations.

All seven local contractors were trained in the following functions:

- safely storing and charging the drone batteries
- drone assembly and disassembly
- conducting pre- and post- flight visual inspections for damage
- loading and unloading cargo
- flight tracking and monitoring of in-flight data such as location, speed, and altitude
- crowd control and safety
- creating safe flight paths (all flight paths were approved by one or more RPA holders before use)
- communications protocols

Six of these staff members were also trained in manual flight using off-the-shelf drones, and simultaneously in basic flight dynamics. One staff member who had an aerospace engineering degree was further trained in manually controlling the drone in near-to-ground operations, ensuring the ability to intervene if any obstacle or person appeared in the landing area. This was done under the supervision of a licensed RPA holder.

Additionally, 12 local health facility staff members were trained in the following functions:

- clearing and securing the takeoff and landing zone
- loading and unloading cargo
- communications protocols

	Trained Health Facility Staff
Chizumulu	2
Likoma	4
Usisya	2
Toto	1
Mtawa	1
Ruarwe	1
Khondowe	1

4. # of flight checklist items (including pre-flight, during flight, and post-flight checklists) performed autonomously by cooperating country nationals

Since the drone service vendors maintain proprietary flight checklists, this report is unable to list the checklist items completed by local staff. However, the activity successfully performed bidirectional trips with local staff involvement in 100 percent of the checklist items, supervised by an RPA license holder. Therefore, this report concludes that under the appropriate activity design conditions, it is possible for cargo flights to be safely conducted in remote locations without the presence of any international staff members. However, for the duration of this activity, at least one international staff member was always required, as no local RPA holders were identified.

5. percent of single-leg flight routes completed as planned and without adverse events

94 percent of flights were completed, or 401 out of 428 scheduled flights. Flights were cancelled due to the following reasons:

- Inclement weather (wind, rain, thunderstorms)
- Mechanical failure
- Insufficient cellular connectivity
- Changes to scheduling of manned aircraft activity
- Missed flight windows requiring new flight approvals

6. **# of landings completed with the support of a trained health facility staff member, while flight operations were remotely monitored by an RPA holder**

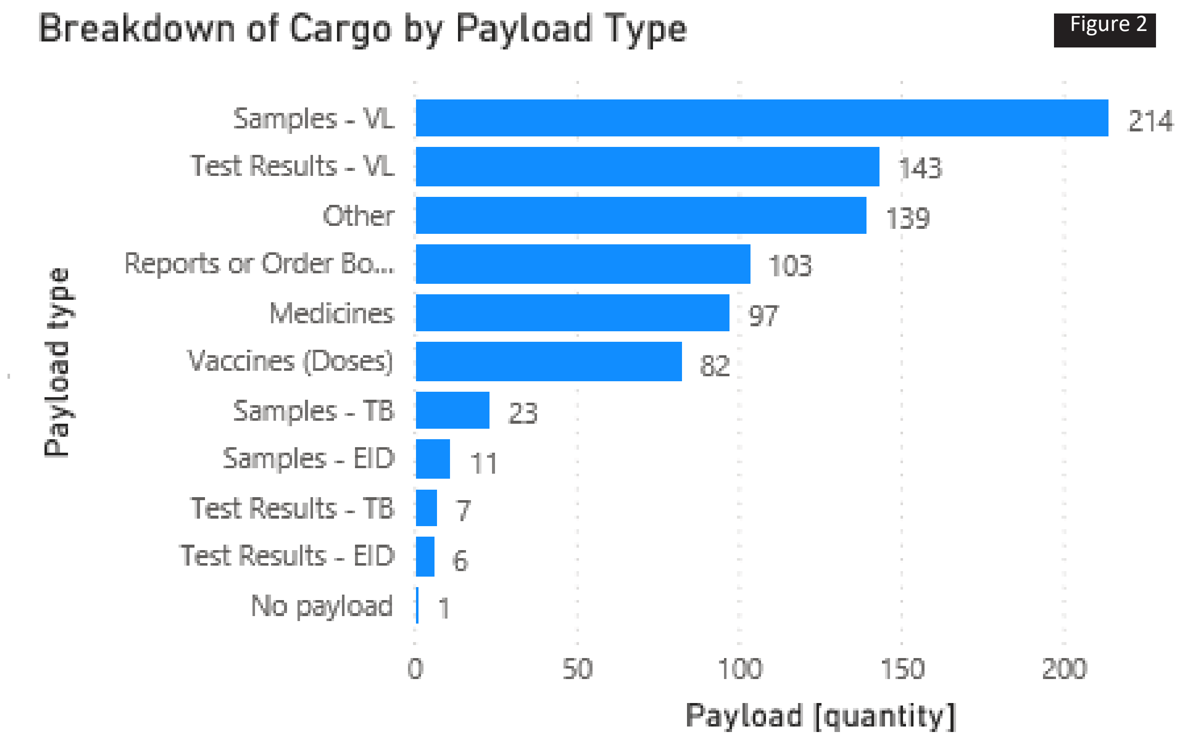
74 percent of individual landings were completed with the local staff presence who could clear the landing and takeoff areas, maintain crowd control, unload and load cargo as needed. In the instances noted here, an RPA license holder controlled and monitored the aircraft remotely.

CARGO DATA

During the design phase, the project looked for opportunities to demonstrate improvement in outcomes in as many health areas as possible. The areas explored during this phase included movement of:

- HIV/AIDS diagnostic samples (e.g. VL and EID)
- Tuberculosis diagnostic samples
- Laboratory test results
- Emergency medicines (e.g. oxytocin)
- Vaccines and other cold chain items
- Stocked out commodities (to meet needs between regular distributions)
- Commodities requested infrequently or not typically held in remote clinics (e.g. snake antivenom)

A key identified goal of the activity identified early on was to collect Viral Load (VL) and Early Infant Diagnosis (EID) lab samples from remote facilities and transport them to the district hospital for processing and return the test results to patients. In these districts, and across Malawi, results are not returned to patients electronically, the paper-based results need to be returned to each facility along regular distribution routes. Early communications around the activity emphasized the goal of transporting VL and EID samples and results to reduce lead times, and this represents much of what was transported in the first weeks of the project. However, as the project also supported cargo delivery across other health commodity groups, the demand for these services increased over time. The chart below (Figure 2) captures other commodity groups transported, including medicines, vaccines, reports and order books, and more.



Further breaking down the data reveals additional information about the types of health commodities requested. For example, a wide array of pharmaceutical goods is captured under the "medicines" category. Annex 4 shows the Mission Notes collected for all cargo items coded as medicines. A review of the raw data shows medicines for anti-malaria efforts, maternal and child health, family planning, water sanitation, and more were in demand for the health facilities drones serviced.

Medicines for anti-malaria efforts, maternal and child health, family planning and water sanitation are in demand for the areas where drones

SAMPLE TURNAROUND TIME

The table below demonstrates the total sample turnaround time, time required from when the sample was collected from a patient until results were returned, as averaged across VL, EID, and Tuberculosis (TB) samples. This graph illustrates samples leaving and returning to St. Peter's Hospital on Likoma Island as an illustrative example. The majority of samples were collected here, and include Chizumulu Island samples, which pass through the Likoma Island hospital for processing before being transported onward to the mainland district hospital.

As shown in the Figure 3 below, the turnaround time prior to the onset of the drone activity in July was around four weeks. However, the graph also shows a sharp decrease in turnaround time in May and June, prior to the intervention. Interviews with hospital staff clarified that this four-week turnaround was unusually fast and was attributed to a short-term intervention and increase in personnel. Further investigation revealed that sample turnaround time for the same period the year before was 13 weeks or longer. The spike in turnaround time in September reflects the interim period between drone service providers when flights were not consistently offered. With the introduction of the drone, and achievement of a steady state of operations, sample test results were consistently returned to patients within 2 weeks or less. This enabled faster diagnoses and more effective treatments, as patients were able to begin treatment regimens sooner. In other cases, HIV-positive individuals already receiving antiretroviral treatment were transitioned to different regimens based on their viral load test results. However, as there is no comparison group of facilities tracked for the same period of time, this relationship can be called correlational.

SAMPLE COLLECTIONS

In addition to sample turnaround time, the drone activity resulted in patterns of behavioral change at the facility and community level. As beneficiaries began to trust the reliability of drone delivery, sample collections were made more frequently. For example, prior to the drone intervention, Likoma Island collected VL and EID samples every Friday. Patients wishing to give a sample any other day of the week were asked to return on Friday. In some cases, patients were unable to return to give a sample or came back weeks later. In areas in the North (Ruarwe, Khondowe, Mtawa, and Toto), patients would, after walking multiple hours to reach a facility, be turned away and asked to return at a time when sample transportation was possible. Therefore, both facility staff and patients learned that the drone made local health systems more efficient which resulted in an increase in the number of samples collected. The graph in Figure 4 shows the first six months of flight operations in 2019 compared to the same months in the prior year for Likoma and Chizumulu Islands, where the majority of sample collections were made.

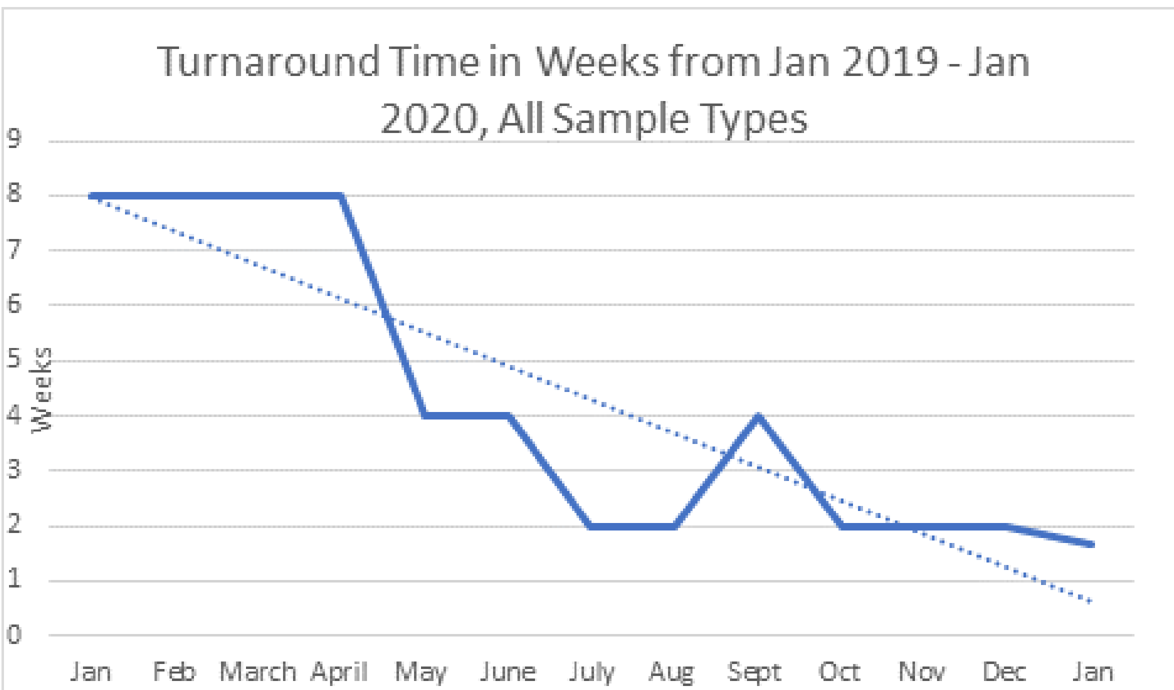
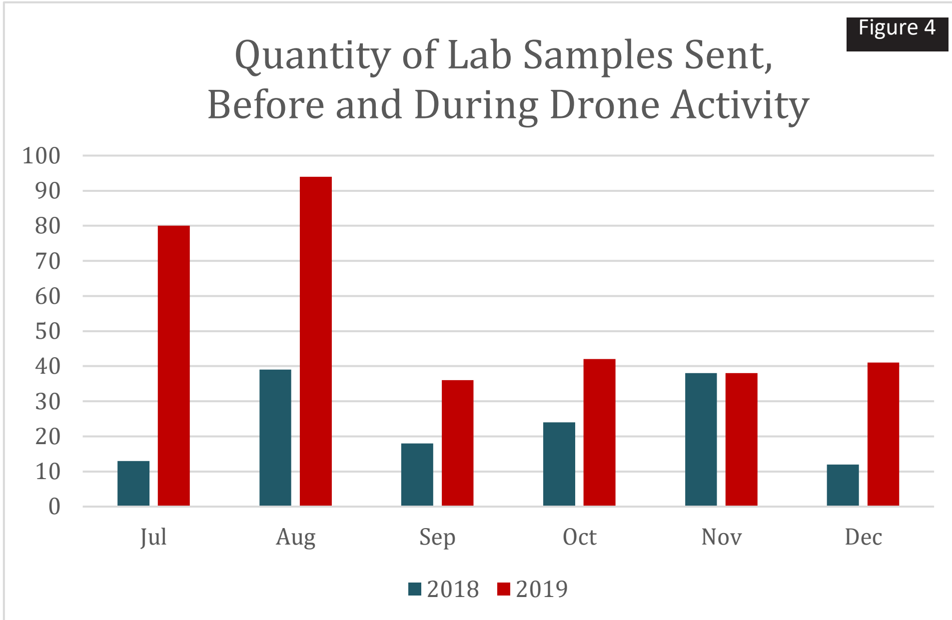


Figure 4 demonstrates there is a significant increase in the number of samples collected after the beginning of the drone activity as compared to the year prior. In November 2018, there appeared to be no increase, likely an outlier, but in every other month there is a sharp increase ranging from a 75 percent increase to a high of a 515 percent increase in July of 2019. On average, the number of samples collected during the drone activity increased by 130 percent as compared to prior to the onset of flight operations for Likoma and Chizumulu Islands. In other words, the samples collected, on average, more than doubled during this activity. This resulted in more patients being tested, more rapid deliveries being made, and ultimately more sick or infected patients being effectively treated.



COMMUNICATING VALUE

Although the cost efficiency of a distribution system is important to supply chain effectiveness and sustainability, drone technology for cargo deliveries has not yet reached a level of cost efficiency where it makes sense to calculate return on investment in strictly monetary values. While there are several models using theoretical data to look at cost, USAID GHSC-PSM's implementation experience indicates that for most currently available drone deployment models, these estimates are overly optimistic and/or indicate a steady state of full-capacity operations which would likely take several months to achieve.

Drones can overcome obstacles that trucks and motorcycles cannot, enabling new methods and timing for health access that is not otherwise possible.

Moreover, there are returns on investment in terms of reach and impact that are difficult to calculate in financial terms, such as the value of enabling a lifesaving delivery which would not have been possible using motorcycle or truck, or the value of an emergency delivery made in time to address the need. As noted in the introduction to this report, drones are best suited to overcoming logistical barriers where other forms of transportation and distribution prove too slow, too risky, or too unreliable to be effective. The value of a drone intervention cannot be based on cost alone since drones make new forms of distribution achievable where they were not otherwise possible and can reach target populations which are not adequately served by the existing health system.

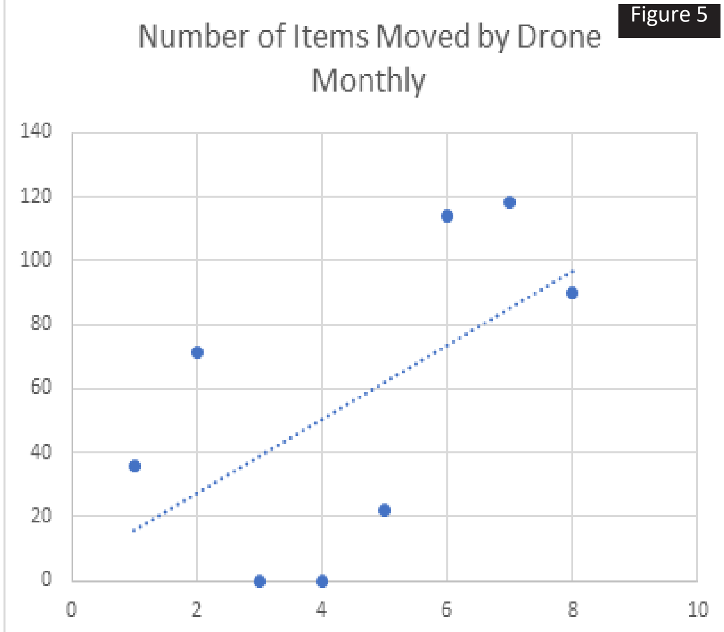
While the cost of deliveries by motorcycle and by truck are stable, the cost for delivery by drones will decrease over time. A few of the reasons for this include:

Efficiency of long-term operations. USAID GHSC-PSM observed rapid and continuous improvements in operational efficiency as the project learned how to best source service providers and manage day-to-day flight operations (see Figure 5 for an illustration of this effect).

Growth in scale of serviced network. A project which has achieved steady-state operations will continue to see increases in efficiency as most costs related to operations are "sunk costs."

Continuously improving technology. Drone technology is still in a phase of rapid and iterative development. The technology that will be available in six months is not the same as that available to us today. This innovative technology is predicted to continue to increase in application and decrease in cost over time. Moreover, the battery life and maximum range of drones will continue to increase, thus expanding the pool of beneficiaries.

Figure 5



Other advantages. In addition to improved health outcomes, drones offer high levels of reliability, accountability, transparency, and commodity security.

Drones will not always be the best fit solution to a health commodity distribution challenge. However, there is no doubt drones have enabled health supply chains to expand their impact and improve health outcomes for those who are hardest to reach.

COST CONSIDERATIONS

With the above information under consideration, there are nonetheless several areas of cost which may not be anticipated or well-defined at the outset. For example, the amount of airtime and cellular data was an unknown factor at the beginning of the activity but was a crucial component, not only for project staff, but also for facility staff receiving the drone cargo. In the case that a staff member ran out of cellular data, the flight team would not be able to schedule a flight time and conduct the communications necessary for safe operations. The activity also found that costs were significantly higher during startup months and tapered off as operations reached steady state. However, over the course of eight months, USAID spent an average of approximately $75,000 per month combined for the following non-exhaustive list of costs:

- Human resources
  - Salaries (pilots, local staff, management) and benefits as applicable
  - Per diem, where applicable, or lodging in instances where staff are required to operate away from their home of record

    - Per diem for government counterparts participating in scoping visits, if outside of their regular scope of work

- Materials and Expendable Supplies
    - Locally sourced tools and supplies (e.g., extension cords, plug adaptors)
    - Tarps and tents for covering the drone and drone equipment in case of rain
    - Training materials (e.g., off-the-shelf drones for training, office supplies, etc.)
    - Fuel for generators
    - Printers, if no office or print shop is accessible
    - Safety equipment (fire extinguishers, first aid kits)

- Non-Expendable Supplies
    - Power generators for use in locations with unreliable or no power
    - Laptops for live monitoring of flight data

- Communications
    - Cellular data for staff, as communications before and during every flight are crucial
    - Reproduction materials and charges

- Transportation
    - Transportation for scoping visits
    - Transportation for staff and equipment to specified locations for certification (or re-certification) when outside of the regular place of performance

- Fees
    - Shipping, importation, and in-country courier costs for internationally sourced tools and supplies
    - License application fees

- Other
    - Drone service provider fee
    - Implementing partner fee
    - Replacement parts, as applicable

ACKNOWLEDGEMENTS

The authors would like to extend a heartfelt thank you to the many individuals who contributed to this body of work. From USAID, Xavier Tomsej and Julia Bem provided expertise and guidance from the inception of the activity to its completion. From UNICEF, Tautvydas Juskauskas and others provided insight and information which proved essential to achieving approvals to move beyond the drone corridor, and to carrying out the work successfully. The two drone service providers we worked with--Wingcopter GmBH and Swoop Aero Pty Ltd--worked tirelessly to fulfill USAID's objectives for the activity, often showing great personal dedication to improving health outcomes in the Nkhata Bay and Likoma Island districts of Malawi. From these districts, the District Health Officers and District Medical Officers played important roles in securing resources and approvals, and the health facility pharmacy and laboratory staff, as well as health surveillance assistants, were critical to the objective of safely carrying out deliveries and collections for improved health outcomes. The Christian Health Association of Malawi also provided staff and other resources necessary to implement flights to Likoma and Chizumulu Islands.

Thank you to the Government of Malawi, the Ministry of Health, and the Ministry of Information and Communications Technology.

Finally, this activity would not have been possible without the support of the Department of Civil Aviation, with special thanks to Captain Hastings Jailosi, Sunganani Kalirangwe, Simplex Salima, and their colleagues who continue to support drone work. Their dedication and pioneering efforts toward creating and maintaining an enabling environment for future innovations in aviation will have lasting impact for the people of Malawi.

ANNEX 1. RESULTS FRAMEWORK

Global Health Supply Chain-Procurement and Supply Management Malawi UAV Activity Results Framework

DO 2. Strengthened in-country supply chain systems

IR 2.2. Improved in-country logistics, including effective and efficient delivery of health commodities to service sights

Objective 1. Health outcomes improved due to introduction of Unmanned Aerial Vehicles (UAVs) into the supply chain

ER 1.1. Increased collection of laboratory samples during the implementation of UAVs for moving samples as compared to the number of laboratory samples collected prior to implementation

ER 1.2. Stockout rate decreased for products and facilities serviced in the activity

Objective 2. Scalable and sustainable integration of UAVs into health supply chains for the movement of medicines and health supplies tested and results documented and shared

ER 2.1. Local capacity built to safely and successfully assist with operation of the UAV

ER 2.2. Capacity improved for managing and implementing complex projects utilizing drones for cargo use in health supply chains

ER 2.3. Continuous flight operations established between a minimum of two locations for both delivery and collection of cargo

ER 2.4. Tested solution for landing the drone without the presence of trained safety pilots

Indicators

of laboratory samples collected per week by facility (ER 1.1)

# of stockouts of serviced products experienced at the facilities included in the activity (ER 1.2)

# of in-country personnel trained on UAV, by function (ER 2.1)

# of flight checklist items (including pre-flight, during flight, and post-flight checklists) performed autonomously by cooperating country nationals (ER 2.2)

% of single-leg flight routes completed as planned and without adverse events (ER 2.3)

landings completed without the presence of trained safety pilots (ER 2.4)

ANNEX 2. FLIGHT DATA REQUIREMENTS

Other Required Data Collection	
Fleet and Vehicle Information	**Flight-Specific Information**
▪ Vehicle ID (Serial number) ▪ Make ▪ Model ▪ Stated max Range ▪ Max payload ▪ Maximum take-off weight ▪ Maximum and cruise speed ▪ Stated Endurance Time ▪ Dimensions ▪ Level of automation (what supervision or control is required)	▪ Date ▪ Vehicle ID used (across overall flight profile, will allow tabulation of number of flights by each aircraft, statistics by vehicle etc.) ▪ Flight plan ▪ Origin location (geocode and name) ▪ Destination location (geocode and name) ▪ Payload included (content, weight, volume, cold chain requirements) ▪ Time to load payload ▪ Contextual Weather Descriptions of flight (at take-off and landing) ▪ Temperature ▪ Humidity or Precipitation ▪ Wind velocity ▪ Time take-off ▪ Time landing ▪ Energy consumption (battery reading at start and finish, as well as the more precise information when recharging the batteries) ▪ Time to unload payload ▪ Delivery successfully completed? (Yes/No) ▪ Diversion from intended path (preferably in the form of altitude-distance and aerial-time profiles comparing the intended and actual paths) ▪ If any issues – classification of issue (e.g. mechanical, electrical, telemetry, operational, etc.) ▪ If any issues – qualitative description of issue ▪ Time before failure (if failure has occurred) ▪ Maintenance logs (time-stamped)

ANNEX 3. UAV PROCUREMENT GUIDE

A PDF copy of the UAV Procurement Guide can be found here: https://www.chemonics.com/wp-content/uploads/2019/06/GHSC-PSM_UAV_Procurement_Guide.pdf

USAID GLOBAL HEALTH SUPPLY CHAIN PROGRAM
Procurement and Supply Management

Unmanned Aerial Vehicle Procurement Guide

SPECIFICATIONS, QUESTIONS, AND OTHER CRITERIA TO CONSIDER

GHSC-PSM, a USAID project, is working to explore utilizing Unmanned Aerial Vehicles (UAV) to move HIV/AIDS supplies and other health commodities through public health supply chains to serve hard-to-reach health facilities. The project is focusing this UAV initiative in rural settings with limited distribution systems and infrastructure that create gaps in servicing patients. GHSC-PSM will assess UAV technology by integrating UAVs into country supply chains to improve health outcomes through increased speed and access.

Purpose of this guide

Many organizations are determining how an UAV could be applied to their work. For those organizations moving to the next step of testing or implementing, the procurement of a UAV or UAV services is uncharted territory.

In an effort to contribute to the UAV community's knowledge base and prevent organizations from reinventing the wheel or starting from zero, GHSC-PSM would like to share our experiences to benefit others undertaking similar efforts.

GHSC-PSM developed this resource guide based on our experience in completing the UAV procurement process for cargo application. This guide provides:

- A list of general considerations for evaluating manufacturers.
- A thorough list of specifications and relevant questions for inclusion in a request for proposals (RFP). This structured approach will help you easily compare and analyze UAV companies and service providers to determine the most qualified and ensure they meet organizational needs.
- A sample short list of recommended criteria to use when visiting manufacturers or attending demonstrations.

We Want to Hear From You

GHSC-PSM is dedicated to sharing information and collaborating with the greater UAV community. All those pursuing the application of an UAV have valuable experiences and lessons to share. This UAV procurement guide is meant to be a living document that we will update periodically with the UAV community's contributions.

To that end, please contact with your feedback:
Scott Dubin
GHSC-PSM Warehousing and Distribution Team Lead
sdubin@ghsc-psm.org

The USAID Global Health Supply Chain Program-Procurement and Supply Management (GHSC-PSM) project works to ensure uninterrupted supplies of health commodities to save lives and create a healthier future for all.

GHSC-PSM is implemented by a Chemonics International-led consortium. To learn more, visit **ghsupplychain.org**

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General Considerations When Evaluating Manufacturers

Platform	Capabilities and design of the UAV, and required infrastructure
Flight System	Ease of use and robustness of the flight software system
Flexibility	Manufacturer's willingness to make adjustments to meet your needs
Evolving Technology	Manufacturer's vision and ability to innovate and improve on their technology
Staff Availability	Manufacturer's availability to participate in the various phases of the project (regulatory approval, set up, training, flight operations, etc.)
Partnership	With the current level of maturity in the sector, the organization/supplier relationship will be more of a partnership than a one-off procurement. Personalities, vision, and approaches should be considered

Manufacturer Visits Are Critical

Since manufacturers often provide prototypes or newly released technology, visits are critical to ensure their claims can be demonstrated. Visits are also an opportunity to get to know senior management and staff, and to determine if there is potential to form a good working relationship. In addition to confirming specifications provided in a proposal, GHSC-PSM recommends having the manufacturer carry out a demonstration that is aligned with the purpose for which the UAV will be used. It is also recommended that visitors interact with the UAV in: assembling/disassembling, flight planning, carrying, loading/unloading, battery changing, etc.

RECOMMENDED SPECIFICATIONS

This table provides specification recommendations that organizations can use when procuring UAV services.

	SPECIFICATIONS	NOTES
UAV (HARDWARE) STRUCTURE & DESIGN	Type	Indicate if the model or models include motor, fixed-wing, or hybrid (VTOL). Indicate what year model was created. Include pictures and design drawings of the UAV.
	Propulsion system	Indicate manufacturer and model used. Indicate how all essential elements of the propulsion system are reliable and meet commercial standards.
	Ergonomics	Describe how the design minimizes the chances of human error.
	Dimensions	Indicate the physical dimensions of the UAV and the box used to transport the UAV.
	Weight	Provide the weight of the UAV including batteries, the maximum take-off weight, the UAV's weight when empty, and the weight of the box used to transport the UAV.
	Movement, transportation	Indicate the number of people typically required to manually move the assembled UAV from one position or location to another.
	Flight Controls	Describe how flight control design provides continuous control of the UAV by means of a controller unit whose display provides unambiguous operations and clear indications of UAV flight status both in autonomous and manual modes.
	Power Source	Indicate if the platform is powered by battery, fuel, or a hybrid of energy sources. Also indicate what type and number of batteries or fuel are required.
	System power/electrical load	Indicate maximum electrical load factor, system management during power failure, etc.
	UAV control station/remote pilot station and ground support equipment	List and describe any additional ground support equipment to be utilized.
	Navigation system and data link	Describe ability for continuous monitoring, signal strength monitor, protection against signal failure, etc.

	SPECIFICATIONS	NOTES
UAV (HARDWARE) STRUCTURE & DESIGN	Infrastructure and Equipment	Identify other equipment that is necessary for flight operations in addition to the UAV and tablet/computer/controller.
	Imaging/Mapping Camera	Indicate whether it is possible to attach a camera to the UAV. If so, is it easily attachable/detachable?
	POV Camera	Is a point of view (POV) camera already a part of the UAV hardware, or is this an optional addition to the structure? Is it possible to connect with 3G or 4G networks to provide a live video feed?
	Replacement parts	Indicate whether replacement parts are commercially available. If so, which parts are and are not? What are the costs of replacement parts?
	UAV Communication	On which frequency is the UAV communicating? How is communication managed beyond visual line of sight? Is it possible to communicate with the UAV using 3G or 4G as well as manage navigation?
SOFTWARE DESIGN	Flight logs	Describe the software capabilities to log flights and store flight data. How is the data transmitted from the flight system?
	Flight planning	Indicate the software used for planning and programming flight paths, whether custom-built or commercially available.
	Automated return feature	Describe how the UAV is prepared for return after it lands at the target site and whether the UAV has an automated return feature.
CONSIDERATIONS SPECIFIC TO CARGO-CARRYING UAV	Payload capacity	Describe maximum payload capabilities (weight) for the distances the UAV is able to travel. Provide a table illustrating the trade-off between distance and payload capacity.
	Cargo hold	Describe the physical dimensions and volume of the cargo holding space. Is the hold internal or external? Can the cargo hold be customized? What is the maximum weight the cargo area holds? Include pictures of the cargo hold.
	Configuration options	Indicate whether the UAV can hold a large camera or monitoring device (such as LiDAR or a sensor).
	Cargo placement	Indicate any requirements for balancing the cargo. Does the UAV require counter weights, or specific cargo placement in the hold?
	Cold chain capabilities	Indicate whether there is an option to insulate the cargo hold and/or monitor temperatures internally.
	Cargo hold capabilities	How is payload delivered? Is it directly accessed by the recipient? Can UAV land and leave cargo behind? Can UAV release cargo while flying? How does payload attach/detach? Is it dropped and left behind, or opened manually and potentially repacked?
PERFORMANCE CHARACTERISTICS	Maximum altitude	Indicate maximum altitude from ground and sea level, as well as the cruising altitude.
	Maximum range	Indicate the maximum flight range. Note some general parameters for how the range is affected by altitude, payload, and battery life as applicable. At a minimum provide maximum ranges at these altitudes for each 1, 2 and 5 kg: 1. Sea Level; 2. 1000 m ASL (above sea Level); 3. 2000 m ASL.
	Performance envelope	Indicate the performance envelope through a written description or graphic.
	Airspeed	Describe the airspeed necessary for take-off, cruise, landing, and stall maximum airspeed.
	Maximum rate of climb	Indicate the maximum rate of climb.
	Maximum rate of descent	Indicate the maximum rate of descent.
	Maximum bank angle	Indicate the maximum bank angle.

	SPECIFICATIONS	NOTES
PERFORMANCE CAPABILITIES & LIMITATIONS	Turn rate limits	Indicate the maximum turning rate.
	Environmental endurance	Describe UAV performance limitations due to environmental and meteorological conditions (e.g. wind, ice, humidity, temperature, rain, hail).
	Take-off and landing	Indicate required distances and/or surface areas required for take-off and landing. List any equipment required, such as catapult or net, or the need to be thrown. Also include the measurement between the landing gear and the body of the UAV.
	Autopilot	Describe autopilot type, manufacturer, and working method.
	Navigation systems	Describe all components, together with horizontal, vertical position, and velocity accuracy.
	GPS Technology	Describe the use of real-time kinematic (RTK) or post processed kinematic (PPK) GPS systems for improving performance positioning. Is RTK or PPK GPS system an option?
	Sensors and/or telemetry	Describe the controls on the UAV controller, sensors, computers, and actuation parts necessary to control the UAV. What systems are in place for continued control of the UAV in the event of a propulsion or power generation system failure?
EMERGENCY PROCEDURES FOR SYSTEM FAILURES	Briefly describe procedures for documenting and handling each of the following scenarios, if applicable.	Loss of autopilot
		Loss of flight control due to server failure
		Loss of propulsion power
		Loss of engine power (one engine out)
		Low battery voltage
		Loss of navigation components (heading or altitude)
		Loss of Global Navigation Satellite System
		Loss of data link (radio control link failure)
		Remote pilot station communication failure
		Loss of power at remote pilot station
		Loss of remote pilot/UAV observer communication
		Structural damage to UAV
	Flight control surfaces and actuators	Note: The UAV flight management system shall include the controls on the UAV controller, sensors, computers and actuation parts necessary to control the UAV. Any single failure of the flight control system should not affect the functions to control UAV recovery.
	Failure modes or scenarios other than those listed above that can endanger safe flight shall be identified, described, and managed in a safe manner.	
HAZARD CONSIDERATIONS AND FAILSAFE FEATURES	Identification of UAV functions	Describe how indications and warnings necessary to ensure safe control of the UAV flight path, including collision avoidance, are available in real time with continuous data transmission and with a high level of protection against hacking.
	Identification of degradation and failure conditions	Describe how the UAV system provides immediate notification of a system failure.
	Management and mitigations of the failure conditions	Describe how the UAV would automatically switch to an alternate or degraded mode of operation.
	A list of alarms and methods for troubleshooting	Describe how the UAV system software monitors and identifies safety critical aspects.
	Flight termination	Describe the fail-safe system which provides recovery to a predetermined recovery area with programmable capability for maintaining safe flight control or operation within design parameters.
	Location of all air data sensors, antennas, radios, and navigation equipment with respect to segregation and redundancy	Include a drawing of the UAV with the locations identified.

QUESTIONS FOR OFFERORS

These are additional questions that organizations can consider integrating into RFPs and writing into scopes of work for UAV services.

QUESTIONS	NOTES, FOLLOW-UP QUESTIONS
Personnel	
Does the offeror have pilots on staff?	If so, how many? Describe the experience and licenses of the pilot(s).
If requested, what would be the availability of pilots on staff to assist and oversee flight operations?	If requested, how many staff would the offeror request to have on site overseeing flight operations?
What is the offeror's company structure?	How many staff members are there? How many are full-time versus part-time consultants? Who would be responsible for liaising with the company extending the RFP? What would their availability be during the time of the proposed activities? Describe the staff's maintenance and production experience.
Relevant Experience	
Has the offeror ever participated in a certification or approval process with a country outside of their own?	How long did this process take and where?
Has the offeror ever participated in a UAV activity?	Describe the activity or activities. What was the duration of the activity and what were the outcomes?
Has the offeror ever participated in culturally appropriate community outreach and education programs in developing countries?	
Has anyone outside the offeror's company or organization ever operated the UAV independently?	Where and in what contexts is the UAV currently used?
Operations and Maintenance	
Does the offeror manufacture the UAV?	If so, is UAV manufactured in-house? What is order and production lead time?
Does the offeror produce their own UAV replacement parts or order them from other companies?	Does the offeror maintain a stock of available replacement parts? What is the lead time required to order various replacement parts?
What data is available on the operation and maintenance requirements of the UAV?	
Are there written SOPs for various stages of flight (e.g. pre-flight checklist, in-flight checks)?	
How many flights has the proposed model completed (testing/in-service)?	What was the distance and duration of flights? What modifications were made as a result of the analysis of the flight and of previous flights?
Can the offeror provide the option to lease the UAV or must it be purchased outright?	
What is the process to change the battery?	Can it easily be completed by untrained staff? How long does it take?
Are there different sets of rotors for takeoff/landing and forward flight?	If so, why?
What is the lead time for availability and delivery of a UAV from the time the order is placed?	What is the production capacity per month?
Technical Specifications & Training	
Is the UAV commercially available?	For which applications is it commercially available? When did it become available? How many units have been sold?
Does the offeror have a training curriculum for pilots/flight operations?	Is it theoretical or practical training? Does successful completion of training result in officially recognized certification or license?
What is the flexibility in the design of the cargo area?	Is the offeror willing and able to adopt the design of the cargo hold to meet the needs of the proposed activities?
What is the amount of time required to assemble or disassemble the UAV?	Can this be done by untrained staff? What tools are required?
Can the offeror demonstrate power or fuel consumption over the course of a flight (e.g. during takeoff, during continuous flight, during landing procedures)?	What is the battery or fuel consumption required for each take-off and landing?
What is the offeror able to demonstrate during a manufacturer visit? (keeping airspace regulations in mind)	
If battery-powered, what is the type and size of the battery used?	If for a cargo-carrying UAV, do the batteries take up space in the cargo hold?

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ANNEX 4. MEDICINE DELIVERIES MISSION NOTES

Mission notes are details captured by the flight operations team prior to or following each flight. This annex consists of documented mission notes for all cargo items delivered which were categorized as "medicines" during data collection.

Payload [quantity]	Mission Notes
1	Eupenta, Atovaquon/Proguanilhydrochlorid; temp logger
1	RH Drugs 200g
1	Injectable contraceptive for family planning
4	4 bottles chlorine
4	4 bottles chlorine
4	4 bottles chlorine
4	4 bottles chlorine
2	2 bottles chlorine
2	2 bottles chlorine
2	2 bottles chlorine
3	3 boxes Eupenta
7	7 ophthamic ointment packs
3	Malaria Antigen (HRP2)
3	BC pill packs
3	Depo provera injections
1	1 Zinc Sulphate dispersible
2	2 Amoxicillin Dispersible
1	1 Artefan Dispersible
3	Pill packs
1	Bottle paracetamol tablets
1	Zinc sulphate tablets
2	Amoxicillin tablets
1	Artefan tablets
20	20 sachets oral rehydration salts
20	Bottles of muscle relaxant
1	Iodine solution

ANNEX 5. SAMPLE INITIAL SCOPE OF WORK FOR DRONE SERVICE PROVIDER

A. Scope of Work

As part of the goal of the activity to contribute to a growing body of knowledge around the use of UAVs in development, including the comparative advantages of various UAV service providers, business models, pricing, maintenance, staffing, and more, a second Service Provider will be selected to roll out delivery and collection flights using Usisya, Nkhata Bay District, Malawi as the base of operations. Deliveries and collections from this base of operations will be made to Ruarwe and Khondowe villages, or other targeted sites as communicated to the selected Service Provider in the event that either of these villages does not have a suitable takeoff and landing site. Expansion to an additional 1-5 targeted villages within the Nkhata Bay District is anticipated once flights to Ruarwe and Khondowe villages have reached a steady state.

To affect these goals, the Service Provider must first provide a demonstration of capabilities to Department of Civil Aviation in Malawi and receive approvals to proceed with the project activities outside of the Kasungu Humanitarian Drone Testing Corridor. Therefore, the Service Provider shall:

1. **Submit the Service Provider's Operations Manual, completed Application for Authorization to Carry Dangerous Goods as Cargo, and RPA Operations Specifications.**

All three of the requirements stated above must be submitted to Malawi's Department of Civil Aviation (DCA) as soon as possible upon signing this Fixed Price Subcontract (SUB-XXX), but no later than three (3) business days after final execution of the Subcontract.
A copy of the Application for Authorization to Carry Dangerous Goods as Cargo can be found in Annexure 1 to this Subcontract.

You may classify DG substances by following classes below:

- All those containing toxic substances are Class 6.1
- Those in form of solids or liquids containing environmental hazardous substances are Class 9
- Injections containing flammable liquids are Class 3

A copy of the RFP Operations Specifications form required by Malawi DCA can be found in Annexure 2 to this Subcontract.

2. **Conduct a live operational and technical demonstration of the drone's capacity to perform bi-directional deliveries (delivery and collection of cargo) within the established Kasungu Humanitarian Drone Corridor of Malawi, and in coordination with UNICEF as the managers of the corridor.**

This demonstration will take place in the Kasungu Humanitarian Drone Corridor of Malawi—which is collaboratively managed by the Government of Malawi Department of Civil Aviation (DCA) and UNICEF—and must satisfy the requirements set forth by DCA in order to receive approval to fly Beyond Visual Line of Sight (BVLOS) outside of the corridor. This is per Malawi Civil Aviation law and is a legal requirement in the implementation of this Subcontract award. The demonstration itself will last one to two days although setup in the corridor and initial testing is anticipated to require a week or longer. The demonstration performed for Malawi DCA must occur on a date that is agreed-upon by DCA representatives who are expected to be in attendance. Chemonics will arrange the logistics (including transportation, daily stipend, and accommodation if needed) for the DCA participants. Service Provider must be able to describe and demonstrate all aspects of their Concept of Operations (or Company Manual) and answer any questions posed by the DCA participants.

3. **Communicate daily with DCA and ATC including timely reporting of incidents, requests for flight approvals and other notifications as necessary.**

The Service Provider will be responsible for regulatory compliance for flight operations, including daily notifications to stakeholders and requests for approvals of the next day's flight schedule and ensuring all approvals are in place prior to flights. The Service Provider will also be expected to conduct notifications and communications as requested by DCA, and to submit reports of incidents or adverse events within 72 hours of the occurrence and, if unresolved, each 96 hours following until resolved.

Chemonics anticipates a follow-on contract (Phase 2) which will cover an estimated period of performance of X to X. Phase 2 will establish Key Performance Indicators (KPIs) for flight operations and minimum performance standards for successful commodity delivery and project implementation. The full execution and implementation of Phase 2 is reliant upon the on-time completion of deliverables in this agreement (Phase 1), which will allow for actual flight operations in Malawi to commence.

B. Deliverables

As consideration for the delivery of all of the products and/or services stipulated in Section C. and below, Chemonics will pay the Subcontractor a total of **$ XX,XXX.XX**. This figure represents the total price of this subcontract and is fixed for the period of performance outlined in Section X, Period of Performance.

The Subcontractor shall deliver to Chemonics the following deliverables, in accordance with the schedule set forth in the table in Section C.

- **Deliverable No. 1: Submission of Service Provider's Operations Manual, completed Application for Authorization to Carry Dangerous Goods as Cargo, and RPA Operations Specifications.**

  All three of the requirements stated above must be submitted to Malawi's Department of Civil Aviation (DCA) as soon as possible upon signing this Fixed Price Subcontract (SUB-XXX), but no later than three (3) business days after final execution of the Subcontract.
  A copy of the Application for Authorization to Carry Dangerous Goods as Cargo can be found in Annexure 1 to this Subcontract.

  You may classify DG substances by following classes below:
  - All those containing toxic substances are Class 6.1
  - Those in form of solids or liquids containing environmental hazardous substances are Class 9
  - Injections containing flammable liquids are Class 3

  A copy of the RFP Operations Specifications form required by Malawi DCA can be found in Annexure 2 to this Subcontract.

- **Deliverable No. 2: Report documenting completion of operational and technical demonstration performed for the Malawi Department of Civil Aviation (DCA).**

  This demonstration will take place in the Kasungu Humanitarian Drone Corridor of Malawi—which is managed by UNICEF—and must satisfy the requirements set forth by the Malawi Department of Civil Aviation (DCA) in order to receive approval to fly Beyond Visual Line of Sight (BVLOS) outside of the corridor. This is per Malawi Civil Aviation law and is a legal requirement in the implementation of this Subcontract award. The demonstration itself will last one to two days although setup in the corridor and initial testing is anticipated to require a week or longer. The demonstration performed for Malawi DCA must occur on a date that is agreed-upon by DCA representatives who are expected to be in attendance. Chemonics will arrange the logistics (including transportation, daily stipend, and accommodation if needed) for the DCA participants. Service Provider must be able to describe and demonstrate all aspects of their Concept of Operations (or Company Manual) and answer any questions posed by the DCA participants.

The report documenting completion of the deliverable must be 2-4 pages in Times New Roman 11-point and detail any specific concerns raised by DCA as well as a plan to address these concerns in any activities moving forward in Malawi.

- **Deliverable No. 3: Formal, written approval from DCA to conduct BVLOS flights outside of the established drone corridor in Kasungu, Malawi.**

This deliverable must be received and shared with GHSC-PSM for any follow-on work to be issued. A sample of what this will look like when received can be found in Annexure 3 to this Subcontract.

- **Deliverable No. 4: Log files documenting one complete, bidirectional flight between Usisya and Ruarwe health facility, including landing at Ruarwe, takeoff and return flight.**

This will include work that the Service Provider deems necessary to fulfill the objective of the deliverable. Work that the Service Provider may need to undertake to complete the bidirectional flight includes:

- operational relocation and setup at Usisya health center
- in-brief with Usisya health center staff
- visits to the landing site for data gathering and analysis
- scouting flights
- flight mapping and flight path programming

- **Deliverable No. 5: Log files documenting one complete, bidirectional flight between Usisya and Khondowe health facility, including landing at Khondowe, takeoff and return flight.**

This will include work that the Service Provider deems necessary to fulfill the objective of the deliverable. Work that the Service Provider may need to undertake to complete the bidirectional flight includes:

- operational relocation and setup at Usisya health center
- in-brief with Usisya health center staff
- visits to the landing site for data gathering and analysis
- scouting flights
- flight mapping and flight path programming