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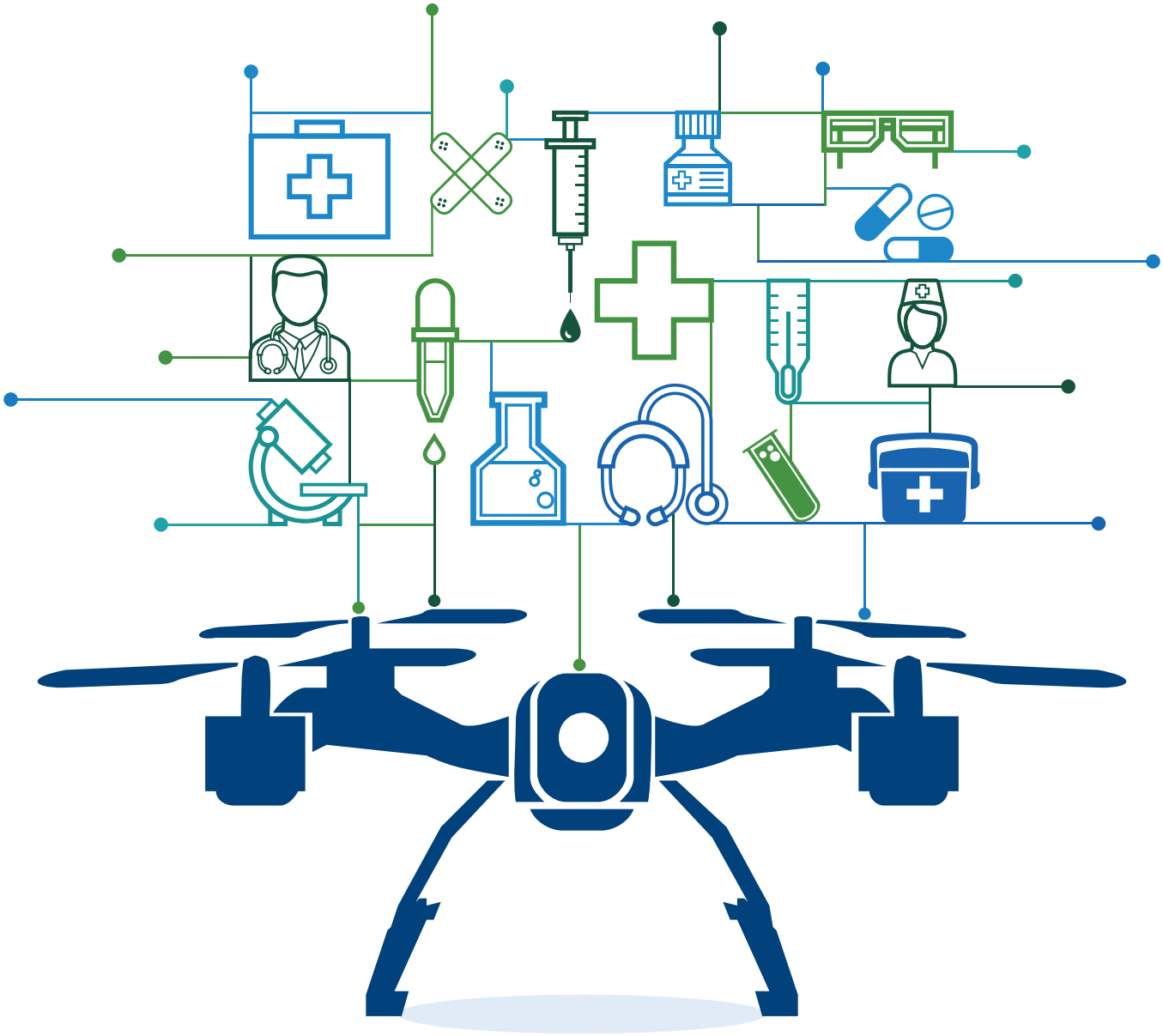
UAVs in Global Health

Defining a Collective Path Forward



From CII's Innovating for Impact Series

USAID's **Center for Accelerating Innovation and Impact (CII)** takes a business-minded approach to fast-tracking the development, introduction and scale-up of health interventions that address the world's most important health challenges. CII invests seed capital in the most promising ideas and novel approaches, using forward-looking business practices to cut the time it takes to transform discoveries in the lab to impact on the ground.

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A tremendous amount of work went into the development of *UAVs in Global Health: Defining a Collective Path Forward*. USAID would like to thank our team of advisors and reviewers for their invaluable input, including experts across USAID. We are especially grateful to the Boston Consulting Group for their partnership in developing this work. Questions and comments are welcome and can be directed to the USAID leads for this guide, Marissa Leffler and Jennifer Fluder.

For contact information, and to download the latest version of *UAVs in Global Health: Defining a Collective Path Forward*, please visit www.usaid.gov/cii

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1. Foreword

We at CII believe that innovation is only meaningful if it leads to impact. This is no more so true than with the potential of UAVs in global health. Over the last few years, we have learned a lot about the role UAVs can play in the humanitarian space. Many donors, including USAID, have made investments in many pilot projects in many different countries across many different use cases to test the efficacy of UAVs. We've seen both promise and skepticism.

Given these advances, we thought it was the right time to take stock of what we've learned and to define a collective path forward. To do so, we have engaged diverse perspectives across many sectors, including Ministries of Health, humanitarian organizations, donors, UAV startups, logistics companies, and beyond; reviewed existing studies and literature on UAVs in the development space; assessed market shaping opportunities; and analyzed the leverage points and roadblocks likely to be encountered in moving on-the-ground UAV pilots from concept to scale.

The good news is there's so much promise, but only if we work together. We are hopeful that the analysis and investment roadmap found in *UAVs in Global Health: Defining our Collective Path Forward* will create better alignment across various UAV actors – including donors – and motivate smarter investments and development that can accelerate the cost-effective and sustainable use of UAVs in global health.

As with all our work, we hope you take a critical look, put this analysis to the test, and join us so we can move forward faster and smarter. We look forward to hearing from you.

David Milestone
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2. Introduction

Opportunity for UAVs in Global Health

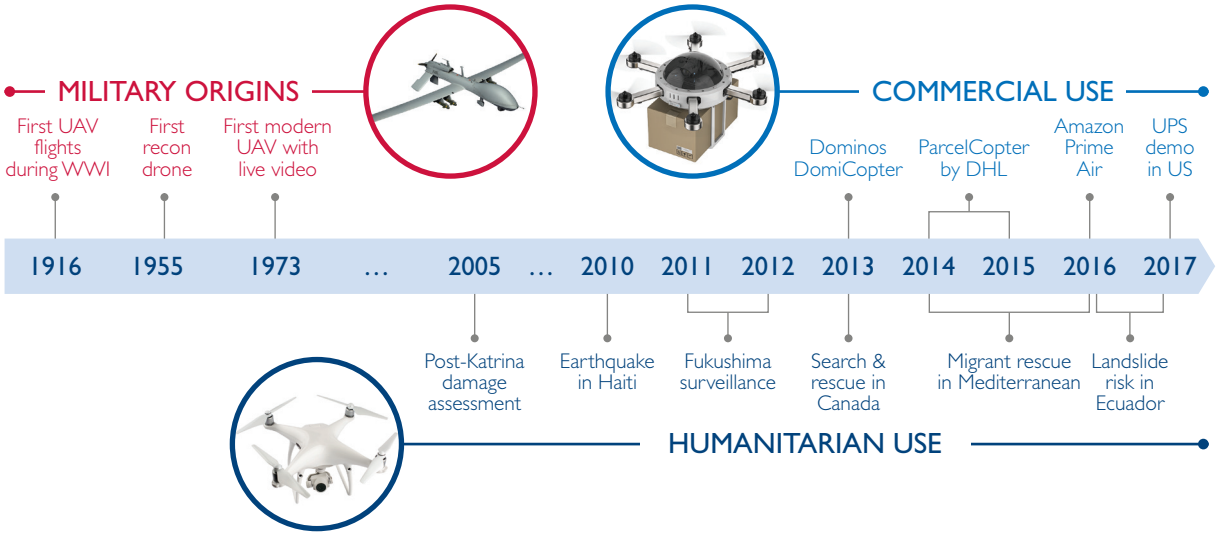
Sanjiv Singh of the Robotics Institute at Carnegie Mellon University describes three uses for UAVs[1]: to **reach** beyond cameras to enable a new point of view, to **reveal** new information by collating data from multiple sensors, and to **transport** materials.

To date, the broadest uptake of UAVs globally has been in the first two categories, as relatively inexpensive UAV-based cameras have supplanted other forms of aerial imaging. While the defense and intelligence sectors were the earliest adopters, the development sector has begun to use UAVs to 'reach' and 'reveal' as well. Hundreds of imaging flights have been successfully carried out in service of humanitarian missions, including surveillance following natural disasters and vector research for malaria.

The use of UAVs to 'transport' materials has also been explored. Militaries have created a suite of UAV systems with large scale transportation capabilities, and commercial entities are investing heavily in drone delivery services. As UAV technology improves, it is likely that the use of UAVs for logistics in global health will become increasingly viable; in fact, several pilots are already exploring this opportunity space.

The potential benefits of UAVs within global health are extensive. In particular, the demand for UAVs to transport materials is increasing. UAVs can fly over vast distances and challenging terrain, enabling just-in-time delivery of life-saving medical supplies to those in hard-to-reach communities. The technology could also improve access to non-emergency commodities for villages where health worker visits and commodity deliveries are infrequent, and in emergency settings it could greatly reduce response times. When deployed effectively, UAVs could bring meaningful benefits to global health through improved supply chain performance and health outcomes.

FIGURE 1: Evolution of UAVs from military origins to humanitarian and commercial use



[1] *While the term UAV (unmanned aerial vehicle) is used throughout this paper, this should be interpreted as broadly inclusive and synonymous with drones, UAS, aerial robots, and other similar terms.*

Current State of UAVs in Global Health

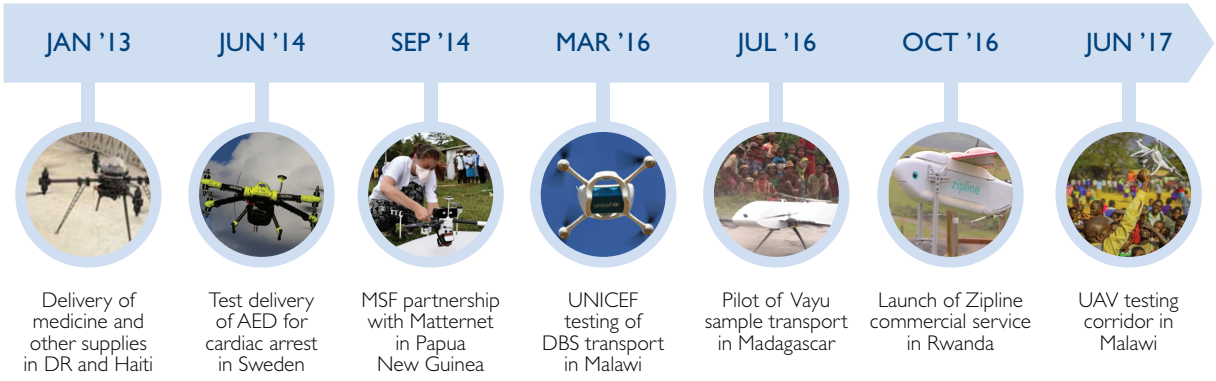
While UAVs' dynamic feature set and capabilities make them a potential game changer in global development and humanitarian use, it is important to acknowledge that adoption of UAV technology in global health is still at a nascent stage.

Even at this early stage, UAV programs and pilots are generating useful learnings that will help fuel further development. Past pilots serve as initial proof of concept that UAV technology can work in the global health context, and several studies have been conducted to demonstrate the conditions under which UAVs might be cost effective. Best practices have been captured and shared with others, and the Humanitarian UAV Network has created a *Code of Conduct* to ensure safe and effective use of UAVs in humanitarian and development settings. Today, the potential of UAVs is being explored further in the drone testing corridor established in Malawi through coordination of UNICEF and the government of Malawi.

Experience from specific programs and pilots will also help smooth the path for future use by teaching us how to engage critical stakeholders. Zipline's commercial operations in Rwanda have demonstrated that health ministries may be willing to pay for UAV delivery in a fee-for-service model. Vayu's experience with regulators has led to a better appreciation for the range of stakeholders that must be consulted and the intricacies of the regulatory pathway. And WeRobotics Flying Labs, currently in Peru, Tanzania, and Nepal, are building local capacity that will ultimately be required to operate and maintain UAVs in-country.

A number of working groups and informal coalitions have also been established, ranging from the UAV Payload Delivery Working Group (UPDWG) to the UAViators network. While these groups have made meaningful contributions to advance the use of UAVs, deeper coordination and collaboration is needed to accelerate development and appropriate application of this technology within global health.

FIGURE 2: History of UAVs in global health



3. Our Approach

Call to Action

To build upon past efforts and unlock the future potential of UAVs in global health, additional action and investment will be required. A broad community of users, funders, innovators, and implementers must work together to identify the most pressing needs as well as prioritize and coordinate future efforts to ensure that resources are deployed efficiently and benefits are maximized.

As UAV innovators continue pushing the bounds of technology, a range of additional stakeholders will also need to be engaged to support the development of a broader ecosystem. The automobile industry is a helpful analogue to show the key contributions of varying stakeholders in order to optimize the industry's impact and reach: automakers continue to innovate as they manufacture cars, highway authorities or private sector players build and maintain roads, and governments play an important role in ensuring traffic safety.

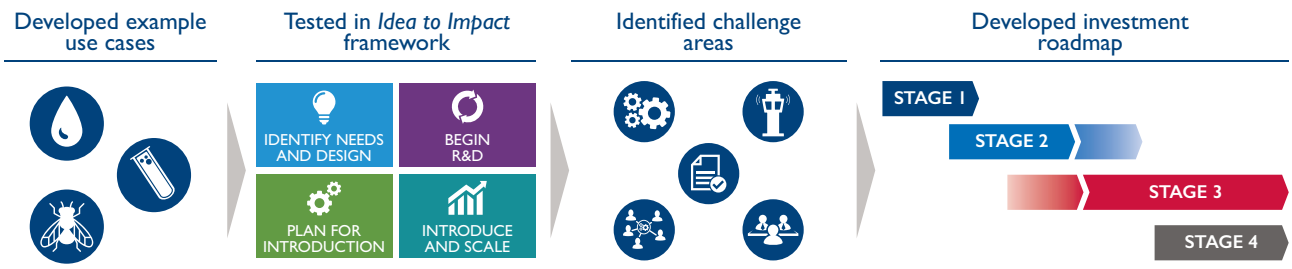
Over time, greater alignment and coordination across innovators, manufacturers, implementers, governments, beneficiaries, funders, and other stakeholders will help UAVs achieve scale. The purpose of this paper is to align donors and other stakeholders around opportunities to catalyze development and scale-up of UAVs in global health as efficiently and effectively as possible. The proposed investment roadmap will help bring clarity and focus to future efforts based on a shared understanding of the current landscape and the challenges anticipated as UAVs transition from initial concept to wide-scale use.

Approach

A broad, consultative approach was taken to document the current landscape and develop recommendations to accelerate the field. This began with a comprehensive review of existing literature, including FSD's *Drones in Humanitarian Action*, SESAR's *European Drones Outlook Study*, and USAID's *Unmanned Aerial Vehicles Landscape Analysis*. Additionally, the team attended a working session of 45 experts convened by the Center for Strategic and International Studies in April 2017. To supplement this preliminary research, more than 20 interviews were conducted with experts across sectors, including UAV innovators, NGOs and humanitarian organizations, implementing partners, Ministries of Health, global health funders, aerospace industry leaders, and academia.

To understand the journey that UAVs will take as they move from concept to scale, three example use cases were developed, based loosely on current UAV projects. The use cases were taken through a modified version of USAID's *Idea to Impact* framework, which was adapted to focus on activities specific to UAVs. This holistic assessment of the scale-up journey for different UAV use cases led to the categorization of activities that can be accomplished relatively easily versus those which are more likely to generate challenges.

With a collective view of both opportunities and challenges, a proposed investment roadmap was developed and vetted in an incubator with relevant funders interested in accelerating the UAV market for global health.



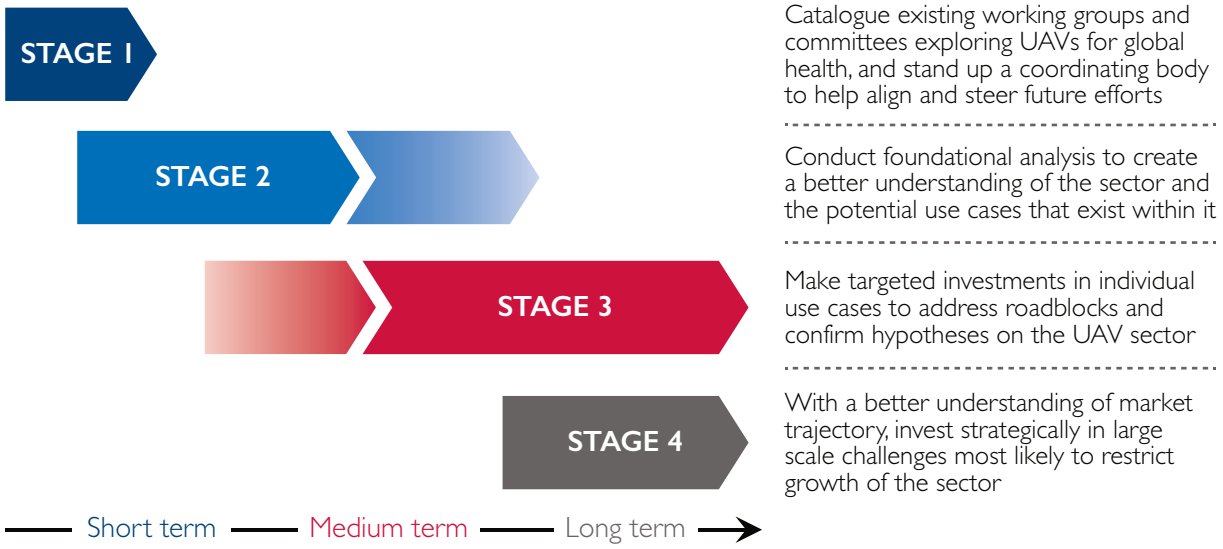
4. Investment Timeline

Our analysis uncovered several opportunities and challenges that would benefit from coordinated investment across multiple stages. It is proposed that Stage 1 would entail cataloguing the efforts of existing working groups and committees considering UAVs in global health, and standing up a coordinating body to help steer future activities across donor groups. Stage 2 would then address near-term opportunities, and two subsequent stages could follow in the mid- to longer term.

In Stage 2, the first near-term opportunity is fostering greater, more purposeful, and proactive collaboration among funders, with input from implementers and country governments, to **define and prioritize the most meaningful use cases** for UAVs in global health. Use cases are the applications of UAVs to specific problems, and should include sufficient details of the mission to define technology requirements. These requirements will inform one or more target product profiles (TPP), which will help identify shared designs that could serve multiple use cases and will allow manufacturers to tailor products to the needs and constraints of global health. This assessment of the current landscape revealed that many pilot projects have been driven by a desire to test the use of UAV technology in various settings, rather than a careful analysis of specific problems and a determination that a UAV-based solution was best suited to address these challenges.

A second near-term opportunity is the **creation and application of a standard approach to evaluate cost effectiveness**, followed by a measured effort to improve the data required for such an evaluation. This project showed that there is currently no standard assessment process, yet cost effectiveness assessments are necessary to ensure that prioritized use cases have a path to economic sustainability and to evaluate whether and for which parameters health outcomes are significantly improved. Cost effectiveness assessments should consider supply chain and health benefits alongside any cost savings or increases. They require the availability of baseline data on desired health outcomes, including estimation of interventions *not* provided due to limitations in physical access to commodities. Each of these two near-term opportunities is discussed in more detail in the following section.

FIGURE 3: Four stages of the proposed investment roadmap



To address these two opportunities, it is recommended that Stage 2 of coordinated investment be focused on foundational analysis to identify and understand the highest potential areas where UAVs might be deployed in global health. This effort would include defining clear criteria to evaluate use cases, assessing and prioritizing use cases along these dimensions, analyzing use case economics and evaluating effectiveness, and ensuring that the technical requirements of use cases can be translated into target product profiles. Foundational analysis should also include an assessment of gaps versus requirements in technology, infrastructure, and regulations. In this analysis, benchmarking current system costs and reach will be necessary to gain an honest appreciation of UAVs' potential sustainability. After this foundational analysis is complete, funders and other stakeholders will have the information they need to determine whether further investment is appropriate and how such investments should be directed.

Two additional stages of investment are also envisioned. In Stage 3, donors would select specific, high priority use cases and support them with targeted investments to accelerate the path to scale. Stage 4 would include investment in larger scale, cross-cutting challenges that could accelerate the path for multiple use cases, but may be more costly and complex to resolve. These might include investments in technology, infrastructure, and/or regulatory pathways. These additional investments in Stages 3 and 4 may follow Stage 2, or may happen in parallel depending on donor appetite and the readiness of use cases and countries for further investment.

In Stages 3 and 4, investment should be targeted to address challenges anticipated on the scale-up journey for UAV technologies. By applying USAID's *Idea to Impact* framework to three example UAV use cases, including blood delivery, two-way sample transport, and vector control, five specific challenge areas were identified that could prevent UAVs from reaching full scale in global health if donors and other stakeholders don't intervene. The challenges that would likely come into play for the next stages of investment can be seen in Figure 4 below.

By following the proposed multi-stage investment pathway, initial investment will create better alignment on the highest priority opportunities in global health. The results of foundational analysis will enable funders to better target their support and bring the most promising use cases forward. They will also generate greater clarity around market trajectory which will help de-risk more significant long-term investments in cross-cutting challenges.

FIGURE 4: Anticipated challenge areas

CHALLENGE AREA	REQUIREMENTS
Technology and manufacturability	Solve technical problems for UAV implementation; find manufacturer(s) who can produce to technical specifications at target cost
Infrastructure	Build the necessary infrastructure to support UAVs (e.g. runways or catapaults, cellular and satellite coverage, maintenance, air traffic management, etc.)
Regulations and policy	Navigate regulatory and policy pathways at a global, national, and local level
Community engagement	Engage the community to build trust in the technology and ensure safety and security of UAVs
Business model and partnerships	Identify business models that enable sustainable delivery of UAV solutions

5. Opportunities for Near-Term Investment

Analysis of the current UAV landscape revealed two key opportunities for near-term investment. The first is the opportunity to better define and prioritize the highest potential use cases for UAVs in global health, and the second is the creation and application of a standard approach to evaluate cost effectiveness.

While many pilots have taken place and many innovators have expressed interest in testing UAV concepts in global health, there is not yet sufficient information to understand which use cases have the potential to generate the greatest impact in the most effective way.

> *"To serve as effective stewards of limited funds, donors should support foundational analysis that will ensure further investment in UAVs is directed toward the pilots, projects, and programs that address the biggest challenges and create the most meaningful benefits."*

It is envisioned that an aligned group of donors will address both of these near-term opportunities through foundational analysis in Stage 2 of the proposed investment timeline.

Defining Use Cases and Target Product Profiles (TPPs)

Use cases are the specific applications of UAVs to global health problems, and require clarity around both the problem statement and the intended solution. In the current landscape, many UAV projects have focused on deploying UAVs in global health without a clear analysis of whether UAVs are the most cost-effective way to solve the problems at hand. As the sector transitions from pilots to larger projects with potential for meaningful uptake and impact, a shift in approach is needed. Stakeholders in key countries should be consulted to help more clearly define the specific logistics challenges faced in global health. This will allow donors to determine where UAVs are better positioned than other technologies or investments to address these challenges.

Use cases may start broad (examples could include 'cargo delivery' or 'aerial mapping'), but additional detail will be required to translate a use case into technical specifications and a Target Product Profile (TPP), and to assess cost-effectiveness. This should include key mission characteristics such as distance traveled and volume of cargo, as well as required capabilities such as remote landing and takeoff. As TPPs are defined for priority use cases, opportunities may arise for shared UAV designs which could address multiple use cases. Coordination of stakeholders around desired attributes would help innovators understand where designs could be standardized, which is likely to create advantages for scale and efficiency over time. This coordination could take place not only across stakeholders in the global health space, but also those that are using UAVs for other applications in the developing world; including, for example, agricultural and humanitarian use cases.

Greater clarity around required versus nice-to-have UAV characteristics will be critical to enable pragmatic tradeoffs between optimal UAVs and simpler versions or minimum viable products (MVPs). There is currently no shared language around product requirements and no common template for TPPs, which impedes coordination and communication. Defining these standards and encouraging stakeholders to think about MVPs can help innovators focus on building technology that meets minimum needs rather than creating comprehensive but costly solutions.

More transparency is also required around both manufacturing costs and willingness to pay in global health. There is high potential for disconnect between UAV innovators and global health customers given a lack of candid communication around costs and willingness and ability to pay. Bridging this divide will help innovators

understand target prices, which will also influence the range of potential characteristics and features that can be engineered into UAVs. Funders should also be transparent about their expectations for cost reductions over time, as they may be willing to pay more for a prototype today but expect much lower prices for UAV solutions at scale.

Standardizing Measurement of Cost Effectiveness

The assessment of costs versus benefits of a UAV system is another critical component of future investment cases. Donors and governments need to evaluate the cost effectiveness of UAV-enabled solutions versus other potential investments. At present, there is a lack of consistent methodology for evaluating cost effectiveness and thus uncertainty around which use cases are the most cost effective. Today's pilots and demonstration projects are primarily focused on proving the technology can work for a given use case rather than showing cost effectiveness or generating the data needed to improve cost effectiveness models. Alignment around a shared framework and methodology will help innovators assess and communicate the cost effectiveness of their solutions.

Cost is one critical element of this evaluation and it will be important for innovators to show whether a UAV solution increases or decreases cost relative to alternate transport methods which might include motorcycles, boats, or other means. However, cost effectiveness is a relative measure that considers the cost required to achieve a specific outcome, such as $/DALY (disability-adjusted life year) or $/life saved. Therefore, demonstrating cost effectiveness requires measuring improvements in health supply chain (such as reducing waste) and improved health outcomes (such as lives saved and/or DALYs averted).

Given that cost effectiveness is a relative measure, it is important to align on appropriate comparison points and ensure that sufficient data is available for both the UAV solution and the comparator. While the instinct may be to compare cost effectiveness of UAVs against the status quo, stakeholders should consider whether comparison against an alternative investment is more sensible, particularly in situations where the use of a UAV allows the delivery of health benefits to a population that does not currently have access.

Funders and other stakeholders must also find ways to access the data required to measure cost effectiveness. At present, it is challenging to access cost data on current delivery mechanisms, which makes it hard to assess whether UAVs will increase or decrease costs. Similar challenges exist with health and supply chain data – ministries and health systems are often reticent to share performance or outcome data which will be required as a baseline against which improvements can be measured.

Defining a standard approach to evaluating cost effectiveness will ensure UAV solutions are assessed in a fair and consistent way, and the application of this approach to potential use cases will help donors target their funding to those solutions likely to have the biggest impact on health outcomes.

6. Longer Term Challenges Anticipated on the Scale-Up Journey

In addition to early stage opportunities, analysis of the current UAV landscape revealed potential scale-up challenges where longer term investment in UAVs should focus. The following section outlines three illustrative use cases and a summary of challenge areas that may be observed across the industry.

Illustrative Scale-Up Journeys

In order to understand the challenges that can be encountered as UAVs progress from pilot projects to use at scale, the Center for Accelerating Innovation and Impact's *Idea to Impact* framework was adapted and applied to three use cases that reflect current efforts to deploy UAVs in the global health context.

A range of use cases were deliberately chosen to test for challenges that might be driven by different aspects of the potential programs, including varying payloads, geographies, distances, HR requirements, and types of cargo, to name a few.

A short description of each use case follows, and additional detail about the use case journeys, as well as the adapted *Idea to Impact* framework, can be found in the appendix.

Anticipated Challenges

By looking across these illustrative use cases, five challenge areas were identified. These are likely to arise, to varying degrees, as UAVs proceed along the path to scale. It is important to note that many of these challenges are not only unique to UAVs but may also be experienced when introducing other new technologies in the global health context.

Technology and Manufacturability

The ability of UAVs to complete global health missions depends on mature, reliable technology that can be manufactured beyond the prototype stage to enable large scale deployment.

Manufacturers' ability to produce reasonably priced UAVs capable of fulfilling global health missions at scale is uncertain. Many elements of the required technology exist today (mostly in military contexts), but the cost of the underlying technology may be too high for the development context. Technology development was noted as a particular challenge for the two-way delivery illustrative use case, as affordable and reliable technology for remote Vertical Takeoff and Landing (VTOL) does not yet exist. Additionally, while quad- or multi-copter UAVs could potentially fulfill this mission, there is a significant tradeoff in current technology between price and limitations of range and payload.

There is optimism that technology will continue to improve in military and commercial UAVs, but there is no guarantee that these improvements will translate to lower cost UAVs suited for use in global health without active intervention from the global health community.

The reliability of current UAVs also remains unproven and there is no clear methodology or metrics to compare reliability across use cases and technologies. More transparent sharing of reliability data and a standard assessment framework would be broadly beneficial.

Infrastructure

Infrastructure needs include physical infrastructure, human capital, and integration into the existing health system. Examples of infrastructure needs are listed at the top of page 14.

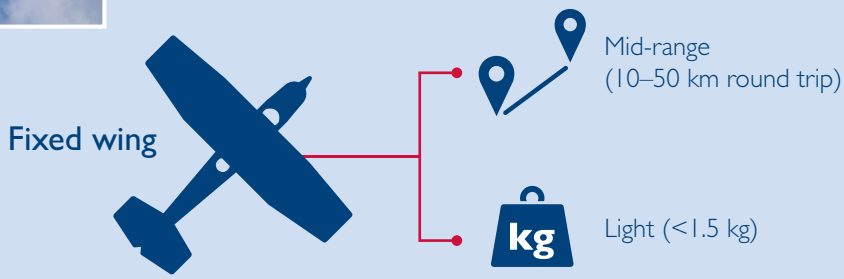
Availability of infrastructure remains uneven across and within countries and it is unclear for innovators which countries currently have or are developing the necessary infrastructure. Infrastructure needs are likely to vary by use case and type of UAV. For example, fixed wing UAVs will require infrastructure for launch and landing versus multi-copters which have the ability to take off and land anywhere. Looking across use cases, infrastructure appears to be most challenging for blood delivery given the need to co-locate UAV launch/capture hardware with centralized blood storage facilities. It may also be a challenge for two-way sample transport, which is likely to require reliable connectivity to the UAV via cellular and satellite networks.

Courtesy of Zipline

BLOOD DELIVERY

One use case is direct delivery of blood to satellite health clinics for life-saving transfusions. It is envisioned that this would require fixed wing UAVs with capacity to travel medium range distances (10–50 km round trip), and rapidly dispatch lightweight units of blood (<1.5 kg) in a primarily peri-urban setting. It may be possible to extend this use case into more urban settings for routine deliveries.

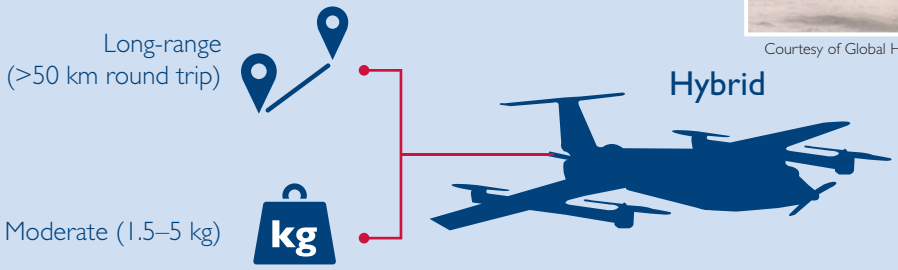
ILLUSTRATIVE MISSION DETAILS



TWO-WAY SAMPLE TRANSPORT

This use case involves delivery of medical diagnostic testing kits and return of samples to a central laboratory. This is envisioned to require hybrid fixed wing/multi-copter UAVs capable of remote vertical takeoff and landing (VTOL). Range is estimated to be long (>50 km round trip), with payload of moderate weight (1.5–5 kg). This use case could also extend to emergency pickup/delivery of highly infectious samples during an outbreak, such as Ebola.

Courtesy of Global Health Institute, Stony Brook University, and Vayu, Inc



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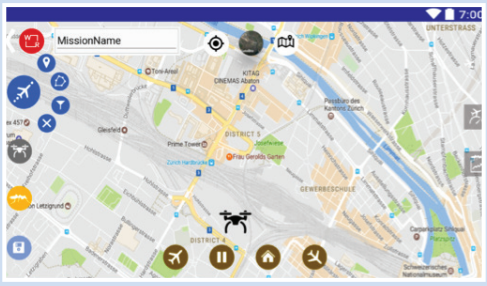

Courtesy of WeRobotics

VECTOR CONTROL RELEASE

Another use case is aerial release of novel vector control solutions, including Wolbachia and sterilized male mosquitoes. It is envisioned that this use case could start with customization of commercially available multi-copter UAVs with shorter range capabilities (<10 km round trip) and the ability to carry moderate payload (1.5–5 kg) for efficient deployment in urban and peri-urban areas.

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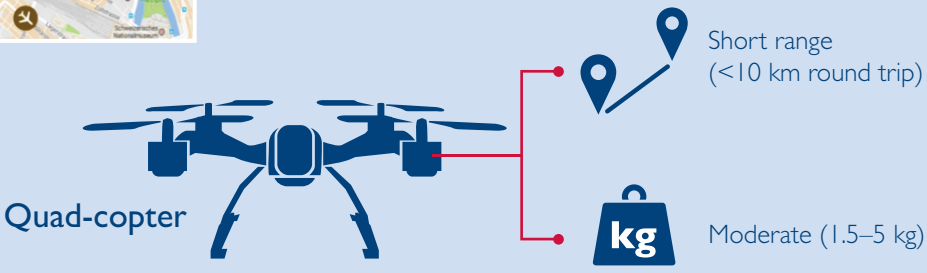
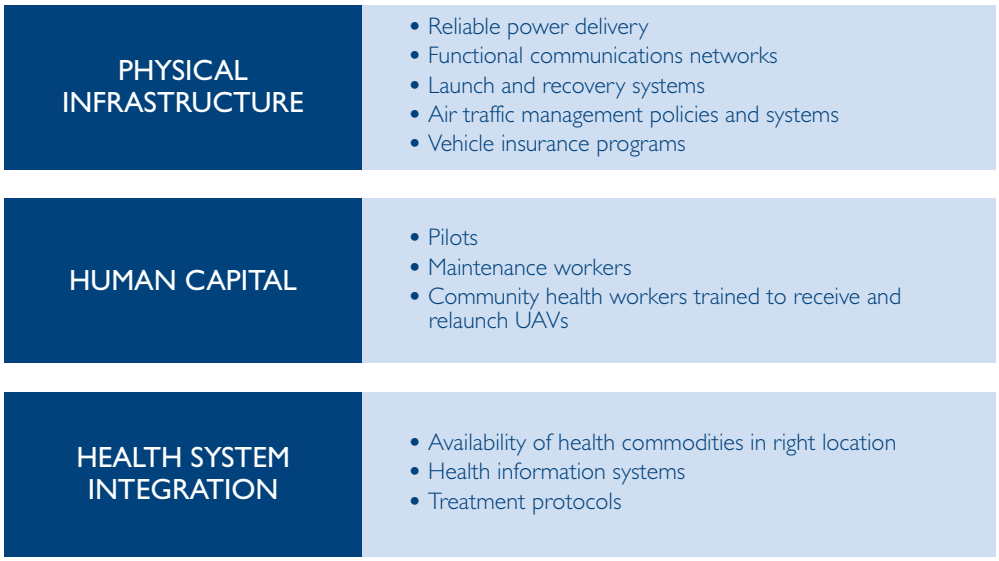


FIGURE 5: Additional detail on infrastructure needs



Building the necessary infrastructure for UAVs could require high up-front capital costs, and the magnitude of these up-front costs versus expected annual benefits could impact willingness to pay. It may also be challenging to coordinate infrastructure provision across multiple stakeholders given that there is no clear incentive for individual parties to invest in common goods such as cell phone coverage. There is also high potential for duplication of infrastructure when multiple UAV programs invest to address their own needs such as runways or maintenance services.

As UAV technology proliferates in global health and other sectors, the need to ensure safe air traffic will become more acute. While the safety risks of flying a single UAV are low, flying dozens or hundreds of UAVs increases the risk of mid-air collision among unmanned vehicles, or worse between UAVs and manned aircraft. Industry experts and regulators, through ICAO leadership, are working to develop a new system for UAV air traffic management (UTM), but there is not yet an agreed methodology or technology for implementing this at scale.

Given these challenges, the automobile analogy may be particularly relevant here: just as automobile manufacturers relied on other parties to build roads for their cars, UAV innovators would benefit from third party investment in the infrastructure required for UAVs to fly.

Regulations and Policy

Regulations in many countries remain largely unfavorable toward UAVs, and restrictive UAV regulations could inhibit development of global health use cases. While the lack of policies in some countries has created the opportunity for experimentation, it is clear this is not a sustainable path for UAV use at scale.

Regulatory approval was noted as particularly challenging in the case of blood delivery given the need for frequent Beyond Visual Line of Sight (BVLOS) flights, the transport of blood substance, and the mid-air release of detachable payload. It will likely also be a significant challenge for two-way delivery given that the payload will include biological specimens and the requirements for transporting infectious materials can be onerous.

There is currently no single country leading the charge on creating 'gold standard' regulations on which others can build, so individual countries are left to create their own regulatory frameworks. Even if 'gold standard' regulations existed, it is unclear if this would actually pave the way to a smoother regulatory pathway in other countries. Additionally, it is not yet known whether guidelines created by international bodies like ICAO will translate to adoption of favorable regulation within individual countries.

Lack of political will may also be a roadblock to developing UAV-friendly regulations and policy. Many of the best examples of UAV use in global health come from countries with a combination of high political will and high health need, while expansion to countries without these attributes has been challenging. In some cases, even a motivated heath ministry may face challenges in aligning with other key players such as the aviation authority.

Because of government perceptions of the high risk and costs of UAVs relative to potential benefits, it appears

that many countries are taking a 'wait and see' approach rather than being proactive. This may be compounded by the fact that many populations that would benefit from UAVs, including women and residents of remote communities, are unlikely to have a strong voice in the government.

Community Engagement

Community engagement comprises interactions between those using UAVs and all individuals and communities impacted by the UAV. Community engagement could include sensitization to UAV technology, notifications prior to flights, and a clearly articulated plan for crisis response in the event of an emergency. Interaction with direct beneficiaries, such as those receiving blood delivered by UAV, is expected to be easier than engagement with broader communities.

This challenge seems especially acute in the use case of vector control release. For flights in challenging urban areas such as favelas in Brazil, substantial engagement will be needed to gain local trust and make the community aware of the program.

Given the potential range and variety of flight paths that may be needed, it could be challenging to identify which communities to engage before implementing a UAV solution. Further, it is not yet clear how best to engage communities likely to see limited impact from UAVs. Lessons and best practices from pilot projects are helpful, but additional research may be needed to inform real world guidelines. Further adaptation would also be required to tailor engagement to the differing cultural contexts of individual countries and localities.

Today's UAV innovators and manufacturers generally lack experience operating in the global health context. This may require education on the needs and concerns of individuals and communities in developing countries. It is important that innovators leave a favorable impression, as problems with one project could have the potential to create a detrimental impact on broader uptake of UAVs.

The lack of UAV-specific crisis management tools could also create challenges, particularly if standard practices are modeled too closely on commercial aviation. The larger scale and higher potential for catastrophic impact in that sector means that current policies may be poorly suited for UAV use cases where airframe loss could be a more common occurrence.

Business Model and Partnerships

Viable business models are needed to ensure long-term financial sustainability, and should outline how an organization intends to fund their innovation, organize key stakeholders, and operationalize their intervention. Business models must specify how up-front and ongoing costs will be covered and define the key stakeholders involved, including partners.

While the requirements of a business plan are clear, the early stage nature of most UAV programs means that many innovators have not yet taken the steps to document and codify their plans. To ensure future success, UAV innovators will need to create sound business plans and demonstrate how they plan to deliver against them.

At this stage, optimal business models have not yet been defined for any use case, and innovators have limited visibility into how they will achieve long-term sustainability. Potential models could include governments running their own UAV programs, innovators developing full service offerings with flights sold as a service, or existing 3PLs integrating UAVs into their logistics networks. Sufficient evidence has not yet been generated to assess the long-term economics of these and other potential options.

Finally, high up-front costs for UAVs and the related infrastructure mean UAV programs are likely to require startup funding, but donors and other investors may be unwilling to support scale-up without a path to sustainable funding of ongoing costs. Even as innovators look to finance their up-front costs, they should also develop a clear plan to transition longer term ongoing costs to current funders of the health supply chain like health ministries or select donors such as Gavi, the Vaccine Alliance.

7. Investment Roadmap

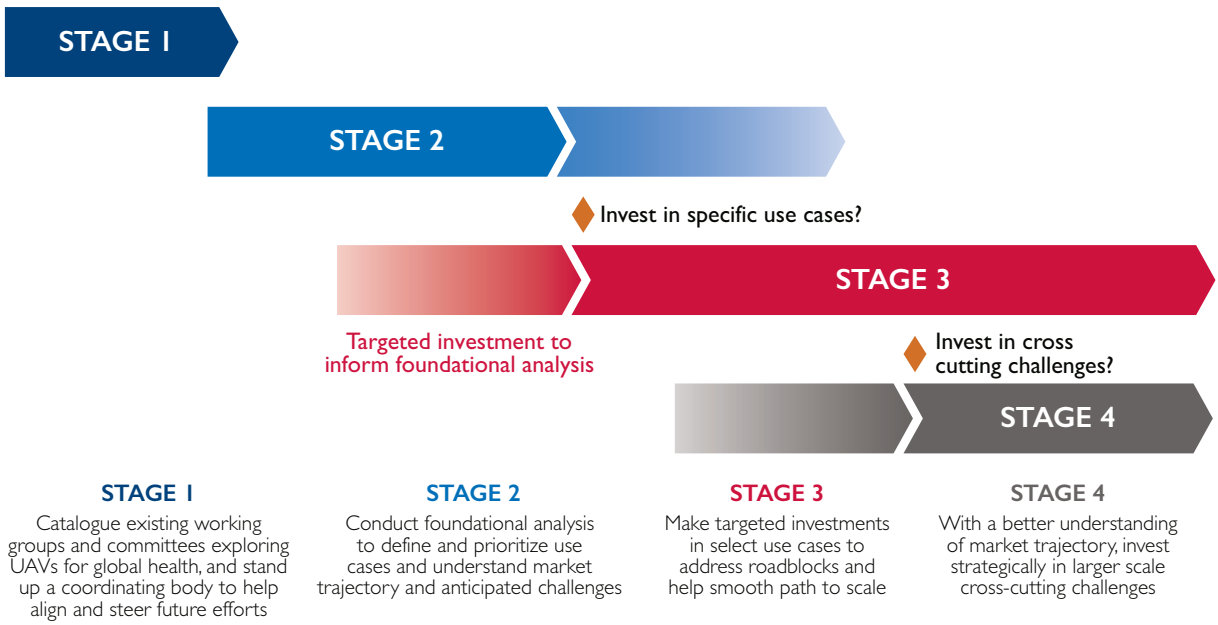
Given the relatively early and dynamic state of the UAV field, and the lack of experience applying UAVs to global health, a coordinated multi-staged approach to investment is recommended.

Stage 1 will create the structure needed to approach Stages 2-4 with the greatest potential for sustainability, and should be viewed as a critical first step in the journey. The activities in Stage 1 will institutionalize donor/investor coordination in the implementation of UAVs in global health activities and investments, including streamlining collaboration across all key stakeholders. This will entail standing up a coordinating body which may be similar to the 'uptake coordinators' that are being deployed to promote use of new drugs and other global health innovations. To ensure engagement and accountability of multiple funders, this coordinating mechanism could be co-funded with a clear mandate and milestones to measure progress. This coordinating body could also look outside global health to evaluate potential opportunities for cross-sector collaboration.

Stage 2 of coordinated investment should focus on foundational analysis to better understand UAV opportunities. The primary outcome of this analysis should be the definition of a short set of specific use cases that funders agree should be prioritized for investment based on a data-driven assessment of benefits, costs, and probability of success, as well as consensus on desired outcomes and metrics that would be used to measure success. Additional output from this phase should also include an estimate of the overall market size for UAVs in global health and a refined view of the UAV landscape and gaps against requirements.

Funders may also wish to consider limited, parallel investment in use case pilots to test targeted hypotheses or provide data to improve model inputs and assumptions. Assuming that UAVs will generate meaningful impact in a cost effective way, a broader tranche of Stage 3 investments would include funding individual use cases in order to help innovators or programs accelerate development and launch.

FIGURE 6: Detailed investment roadmap



Assuming that foundational analysis suggests the overall market for UAVs in global health will have a strong growth trajectory, investment Stage 4 would comprise larger investments to address challenges likely to impede the sector from reaching its full potential. Given the complexity of these challenges and the size of investment required, this stage should only be considered once de-risked by data from foundational analysis. Depending on timing of this analysis and donor appetite, some Stage 4 investments may happen in parallel to Stages 2 and 3.

STAGE 1

Establish Coordinating Mechanism

Before launching foundational analysis and additional investments, it is critical to stand up a coordinating mechanism which positions the full investment roadmap for success.

It is recommended that this stage start with an evaluation of existing working groups and other committees exploring the use of UAVs in global health. This should consider the purview and members of each body, as well as potential capacity to take on a larger coordinating role.

With a thorough understanding of existing bodies, a choice can then be made between nominating an existing organization to coordinate efforts or creating a new coordinating position or body.

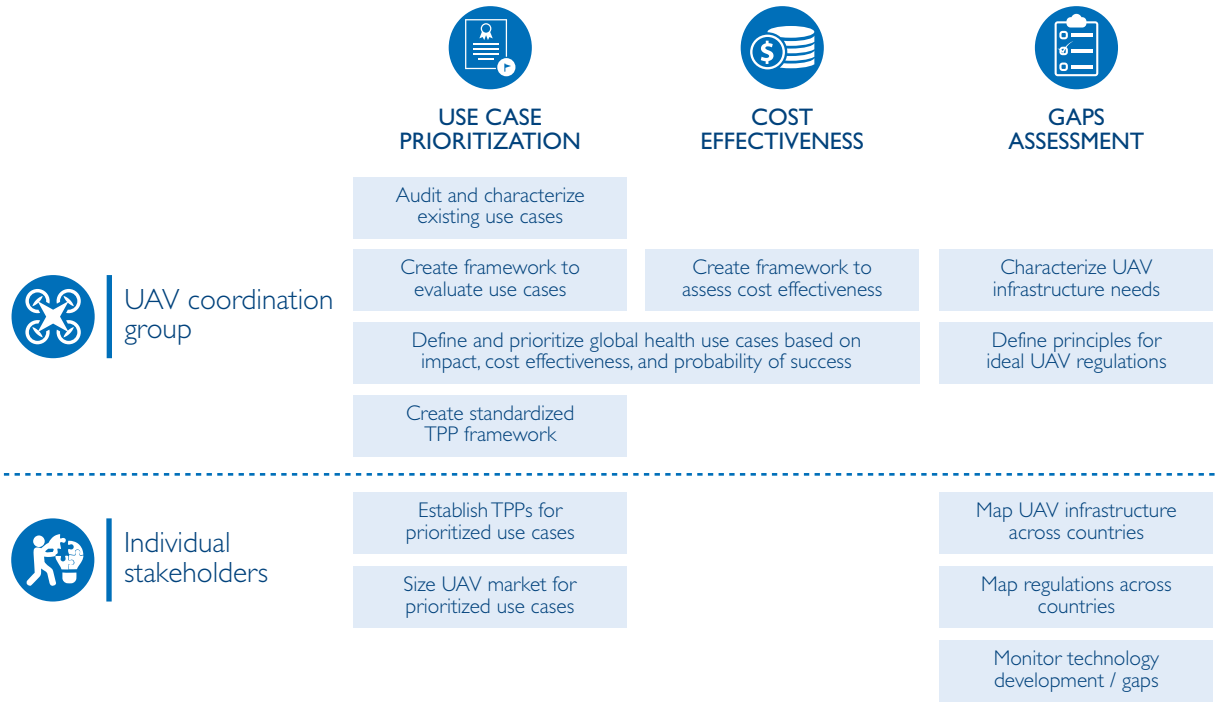
STAGE 2

Foundational Analysis

Foundational analysis will help donors and other stakeholders prioritize the most promising use cases, capture technical requirements in the form of target product profiles (TPPs), and assess cost effectiveness. It is imagined that this work can build on approaches and tools used in other global health programs, including:

- WHO's definition of *preferred product characteristics* for personal protective equipment
- UNICEF's *target product profile* for an Acute Respiratory Infection Diagnostic Aid
- *Tools for introduction and access* from the Microbicide Product Introduction Initiative
- *Tools* from the Initiative for Multipurpose Prevention Technologies (IMPT)

FIGURE 7: Potential investments in foundational analysis in Stage 2



Foundational analysis will also help build a more informed perspective on the likely trajectory of the market and a better understanding of gaps in the current landscape.

Specific activities in Stage 2 can be broken into several categories: use case prioritization, cost effectiveness assessment, and gap assessment.

To facilitate prioritization of use cases and measure cost effectiveness, seven specific activities are recommended:

Audit and characterize existing use cases

- Compile list of past/current examples of UAVs used in global health as an input to and starting point for analysis of potential use cases
- Characterize use cases along several dimensions (e.g. UAV type, mission type, range, payload, etc.)
- Determine where additional data is needed in order to adequately evaluate use cases. This could involve consulting with experts in the field

Create framework to evaluate use cases

- Define key criteria and standard metrics for evaluation (e.g. technology capabilities, potential for impact, scalability, cost effectiveness, demand, sustainability of business model)
- Determine how each criterion will be evaluated

Create framework to assess cost effectiveness

- Define approach for assessing baseline costs and evaluating cost increase/decrease
- Determine which health outcome and supply chain benefits should be included
- Design an approach to capture both quantitative and qualitative benefits
- Identify data requirements and determine how to gather required data
- Determine which comparators should be used in assessing cost effectiveness
- Consider creation of a shared M&E platform that all donors can use

Define and prioritize global health use cases

- Identify challenges/unmet needs in global health supply chain, including a careful consideration of needs in specific geographies
- Translate needs into use cases
- Apply use case and cost effectiveness frameworks to evaluate use cases
- Based on results, identify highest priority use cases

Create standardized target product profile (TPP) framework

- Determine which attributes should be included in the TPP
- Align on common language to describe requirements for each attribute

Establish TPPs for prioritized use cases

- Apply framework to create one or more TPPs for prioritized use cases, with particular emphasis on standardizing TPPs that may support multiple use cases
- Document must-have and nice-to-have technical specifications
- Determine if a scaled back minimum viable product (MVP) would be acceptable

Size UAV market for prioritized use cases

- Assess demand and willingness to pay in target countries
- Use findings to estimate size of global market

Additional foundational analyses to understand the gaps in the UAV landscape include:

Characterize UAV infrastructure needs

- Determine likely infrastructure needs for prioritized use cases
- Characterize needs as must-haves vs. nice-to-haves

Define principles for ideal UAV regulations

- Identify desired prescriptive/proscriptive regulations
- Define ideal package of regulations
- Create advocacy document to outline desired regulations

Map UAV infrastructure across countries

- Identify current infrastructure and future plans in target countries
- Document gaps vs. infrastructure needs for prioritized use cases

Map regulations across countries

- Review UAV regulations around the world
- Assess strength of regulations in each country vs. ideal regulatory package
- Document gaps vs. regulatory needs of prioritized use cases

Monitor technology development / gaps

- Review technical requirements of prioritized use cases
- Assess gaps in current technology vs. requirements
- Identify key technology categories to monitor
- Periodically review developments and update gaps assessment

Ideally these activities will be executed by the coordinating body established in Phase 1. While several formal and informal groups are already thinking about UAVs in global health, these bodies could be strengthened through refined focus on high priority topics, additional funding, and dedicated resources. It is also important that these actors share their investment priorities amongst each other to better understand overlaps and differences to optimize the use of funds.

STAGE 3

Support Promising Use Case(s)

The prioritized list of use cases that results from foundational analysis will help donors and other stakeholders to determine if and how to make direct investments in promising use cases. In some cases where country needs are acute and/or use cases are more mature, donors may pursue limited investment in specific use cases prior to completion of foundational analysis. Regardless of timing, investments in specific use cases will help create direct impact on the ground by smoothing the path to scale, and will also generate further data to confirm models and hypotheses created in the foundational analysis stage.

It is envisioned that direct support of promising use cases would likely focus on the challenges outlined in Section 6 and would take place in three steps: selection, support, and sharing of information.

Selection: Funders would first select a specific use case, or several use cases, from the longer list of use cases that are collectively designated as global priorities. This may require additional evaluation, or may be a simple process of choosing use cases related to an organization's core mission, priority programs and geographies, or capabilities.

Support: After a use case is selected, funders will need to determine where to target their investment based on the challenges that the use case is most likely to face. The suggested approach is to apply the UAV-specific *Idea to Impact* framework that was developed as part of this effort to identify activities that are likely to be the most challenging. Funders should directly engage with the innovators, governments, or NGOs that are developing a UAV solution to unveil areas along the pathway where support is needed. Once challenges are identified and prioritized, targeted investments or interventions can be made against these roadblocks.

Information sharing: Whenever funding is provided to a specific use case, a two-way flow of information should be established between the donor and innovator. The donor should share any useful results from the foundational analysis, such as the TPP framework, infrastructure assessment, and regulatory mapping. In exchange, the innovator should be required to provide data related to reliability, cost effectiveness, and other key parameters in an agreed format that ensures comparability across use cases. Ideally this information could then be shared across the UAV coordinating body to inform other investments.

STAGE 4

Address Sector Roadblocks

Because investment in broad sector-level challenges are likely to be more costly, time consuming, and complicated than investment in individual use cases, donors and other stakeholders should wait to invest in these areas until evidence is gathered to show that several conditions are met:

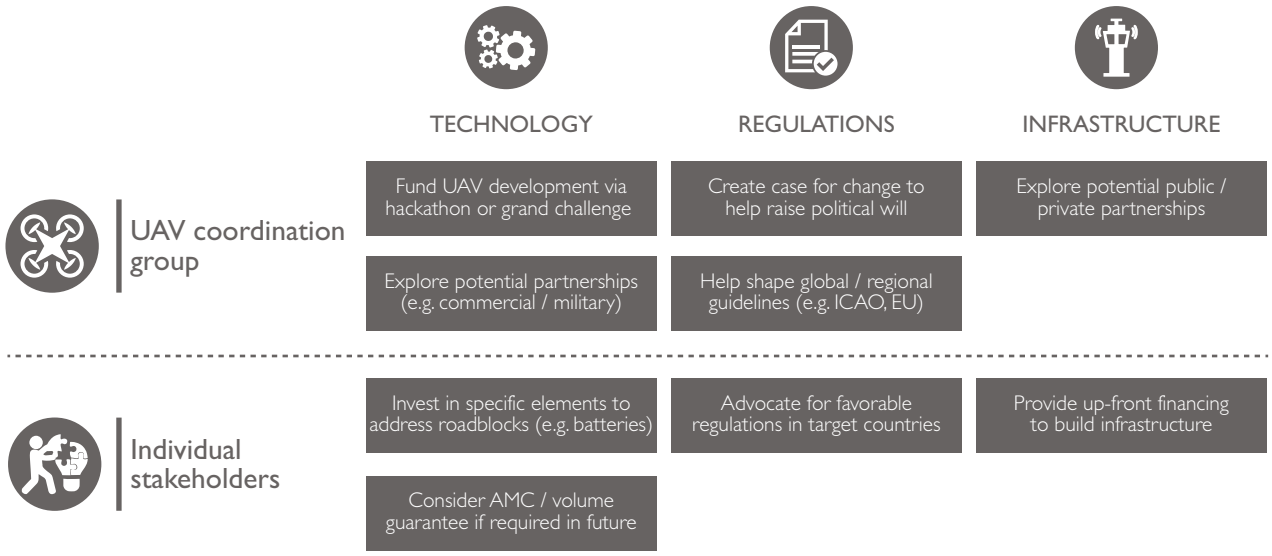
1. The potential impact of global health UAVs is large enough to warrant investment in cross-cutting enablers
2. Sector-level roadblocks are keeping the UAV sector, or a set of high priority use cases, from realizing full potential impact
3. Market failures are likely, as innovators or individual programs are unwilling or unable to address challenges on their own.

Investments in sector-level roadblocks could begin as soon as the criteria above are met rather than waiting for the completion of Stages 2 or 3.

This analysis suggests that three of the broad challenges described previously may eventually require sector level investments: technology, regulation, and infrastructure.

Technology: The definition of priority use cases and TPPs will give funders a better view of the challenges on the ground and the technology requirements to resolve

FIGURE 8: Potential cross-cutting investments in Stage 4



them, as well as any gaps against these requirements. If further development is needed, funders could encourage innovators to develop reasonably priced UAVs through hackathons or grand challenges, or invest in specific UAV components such as higher density batteries. Partnerships with commercial and/or military UAV players may also help improve access to technology developed for other sectors. If technology is available but costs are too high, advance market commitments (AMCs) or volume guarantees could also be considered.

Regulations: To resolve potential regulatory hurdles, a case for change may help raise political will by articulating the potential of UAVs along with recommendations to mitigate perceived risks. To foster top-down change, interested stakeholders may wish to partner with global or regional bodies such as ICAO or the EU to help shape transnational guidelines that could trickle down to individual countries. Advocacy in specific target countries may also be needed to speed the adoption of favorable regulations that support the implementation of high priority UAV solutions. This could involve engagement with counterparts in the host country at a national or even sub-national level.

Infrastructure: For infrastructure issues, direct investment may be costly, complex, and time consuming. Donors could provide funding to help cover a portion of up-front costs, or work with development banks to secure loans that would better align cash outlays with anticipated benefits. Public/private partnerships could also be pursued to spread both costs and benefits across a wider range of stakeholders.

Whether investment will be necessary (or sufficient) to address these cross-cutting challenges is an important question. Expert interviews suggest technology issues may be resolved over time as military and private sector UAV programs evolve, but regulatory and infrastructure challenges are likely to require some direct intervention. Given the rapid evolution of UAVs and the surrounding ecosystem, additional analysis will be required to understand these and other challenges, perhaps in the context of the prioritized use cases, before Stage 4 investments are made.

Linkages across Opportunities and Challenges

Looking across the opportunities and challenges described previously, there are several interdependencies which may mean that investment in one area could unlock potential in another.

The first linkage is between more clearly defined use cases and technology and manufacturability. Identification of the highest priority use cases and translation to target product profiles (TPPs) in Stage 2 could help address technology challenges by clarifying gaps between technology requirements and what is available today. Ensuring that TPPs focus on must-have versus need-to-have features, scaling down to a minimum viable product (MVP), and looking for opportunities to leverage a single UAV design across multiple use cases could then help minimize these gaps and ensure that the needed technology can be produced at a cost that is suitable to global health.

A second interdependency exists between the Stage 2 assessment of cost effectiveness and subsequent development of business models for bringing solutions to scale. It will be important to have clear/standardized information on anticipated impact and cost effectiveness before identifying funders for up-front and ongoing costs. While UAV solutions may not all be cost saving, funders may value their predicted impact more so than their predicted costs. For example, ministries of health may be willing to pay for UAVs that improve health outcomes in hard-to-reach areas more so than alternative solutions, even if costs are higher. Similarly, donors involved in health supply chains may be willing to pay ongoing costs to reduce stock-outs and wastage versus the status quo.

The third linkage is between infrastructure and regulations. While investment in these areas is not envisioned until Stage 4, it is expected that improvements to infrastructure could help resolve regulatory challenges. Given the responsibility of government regulators to protect their territory in the sky and on the ground, investments in UAV traffic management (UTM) will help avoid midair collisions between both unmanned and manned aircraft. Ensuring this higher degree of safety may be helpful or even necessary to convince regulators to adopt more permissive regulations such as allowing BVLOS flight. Demonstrating this higher level of safety assurance may also prove useful in future community engagement.

It is important to keep these linkages in mind as they demonstrate how some up-front investment could reduce future costs. For example, Stage 2 investment in prioritizing use cases and defining TPPs could make Stage 3 support for individual use cases less costly if they can build on prior work and get to workable technology and viable business models more quickly. Similarly, total investment in Stage 4 may be more manageable if regulatory changes are supported by stronger infrastructure for UTM.

8. Conclusion

This assessment of the UAV landscape uncovered two opportunities for near-term investment: defining and prioritizing the most promising use cases, and creating and applying a framework to assess cost effectiveness. Near term investments in foundational analysis should also include an estimate of the growth trajectory for the overall market as well as a closer assessment of anticipated gaps in key areas like technology, regulations, and infrastructure.

The results of the foundational analysis will allow funders to make better decisions on future investments. If it is found that UAVs will generate sufficient impact in a cost effective way, targeted investments in specific use cases could help bring UAV solutions to scale faster. If there is confidence that the market will reach a critical mass, funders may also wish to invest strategically to address larger, sector-wide challenges.

While the UAV space will continue to evolve on its own, the time is right for funders to consider if and how they want to shape the use of UAVs in global health. The decision to invest in UAVs is not a decision to act alone. There are many activities that will require cooperation between funders and collaboration with other stakeholders including innovators, implementers, and country governments.

> *"Working together across the stages of the proposed investment roadmap will ensure meaningful benefit from investment in UAVs for global health."*

PHOTO: SHUTTERSTOCK

Appendix 1

Acronym Dictionary

3PL	Third Party Logistics Providers
ATC	Air Traffic Control
BVLOS	Beyond Visual Line of Sight
CII	Center for Accelerating Innovation and Impact
EASA	European Aviation Safety Agency
EU	European Union
IATA	International Air Transport Association
ICAO	International Civil Aviation Organization
MVP	Minimum Viable Product
TPP	Target Product Profile
UAV	Unmanned Aerial Vehicle
USAID	United States Agency for International Development
UTM	Unmanned Aircraft Systems Traffic Management
VLOS	Visual Line of Sight
VTOL	Vertical Takeoff and Landing

Appendix 2

Additional Detail on Illustrative Use Case Journeys

Idea to Impact Framework

In order to understand how UAVs might progress from small pilots and programs to use at scale, CII's *Idea to Impact* framework was adapted.

Idea to Impact is a guide created to facilitate the introduction and scale-up of global health solutions and a framework for thinking through how to bring new global health ideas (for example medical devices, drugs, diagnostics, vaccines, or consumer products) to users in the developing world. The framework outlines a four stage journey and details specific activities innovators should complete in each stage.

Idea to Impact was initially designed for more traditional health interventions, so some modifications were made in order to make it more applicable to UAVs. First, the activity set was expanded to include additional activities suggested in expert interviews. These modifications resulted in the addition of unique-to-UAV needs such as UAV infrastructure and airspace specific regulations. The framework was also streamlined to exclude activities not relevant to UAV use cases such as conducting clinical trials. This customized version of the *Idea to Impact* framework for UAVs is outlined below:

FIGURE 9: Modified *Idea to Impact* framework for UAVs

*denotes revisions/additions to customize for UAVs

Source: USAID Center for Accelerating Innovation and Impact

Use Case Overview

To bring the UAV pathway to life, three illustrative use cases were chosen and analysis was conducted to determine which activities were likely to be the most challenging for each. The use cases were chosen to reflect a wide range of realistic applications in global health. They were largely based on existing projects and were chosen to represent a wide range of potential dimensions such as payload, range, and function.

As described previously, the three illustrative use cases include:

Blood Delivery: One current use case is direct delivery of blood to satellite health clinics for life-saving transfusions. It is envisioned that this would require fixed wing UAVs with capacity to travel medium range distances (10–50 km round trip), and rapidly dispatch lightweight units of blood (<1.5 kg) in a primarily peri-urban setting. There is potential extension of this use case into more urban settings for routine deliveries.

Two-Way Sample Transport: This use case involves delivery of medical diagnostic testing kits and return of samples to a central laboratory. This is envisioned to require hybrid fixed wing/multi-copter UAVs capable of remote vertical takeoff and landing (VTOL). Range is estimated to be long (>50 km round trip), with payload of moderate weight (1.5–5 kg). This use case could also extend to emergency pickup/delivery of highly infectious samples during an outbreak, such as Ebola.

Vector Control Release: Another use case is aerial release of novel vector control solutions, including Wolbachia and sterilized male mosquitoes. It is envisioned that this use case could start with customization of commercially available multi-copter UAVs with shorter range capabilities (<10 km round trip) and the ability to carry moderate payload (1.5–5 kg) for efficient deployment in urban and peri-urban areas.

FIGURE 10: Chosen use cases represent range of characteristics

	BLOOD DELIVERY	TWO-WAY SAMPLE TRANSPORT	VECTOR CONTROL RELEASE
Description	Direct delivery of blood for life-saving transfusions to satellite health clinics	Delivery of medical testing kits and return of samples to testing center (e.g. TB test kits)	Aerial mosquito release to support novel vector control interventions
Range	Mid-range (10-50 km round trip)	Long-range (>50 km round trip)	Short range (<10 km round trip)
Payload	Light (<1.5 kg)	Moderate (1.5–5 kg)	Moderate (1.5–5 kg)
Function	Delivery (one-way)	Delivery (two-way)	Aerial release
Urgency	Individual emergency	Individual emergency	One-off
Infectious class	Safe	Class B	Safe
Cold chain	Passive cooling	May require active cooling	Not required
Population	Primarily peri-urban	Rural	Urban and peri-urban
Stretch case	Routine deliveries in urban setting	Transport of highly infectious samples during outbreak	N/A

Use Case Journey Mapping Process

To identify anticipated challenges and roadblocks for UAVs on the scale-up journey, each illustrative use case was assessed using the modified *Idea to Impact* framework. This enabled characterization of activities that could be addressed relatively easily using existing resources, and identification of challenges most likely to prevent use cases from achieving full scale. The journey descriptions on the following pages focus mainly on these challenge areas, though it will be important for innovators to complete all activities outlined in the *Idea to Impact* framework.

Blood Delivery Use Case Journey

The blood delivery use case involves transport of individual units of blood weighing less than 1.5 kg to peri-urban health clinics via flights of less than 50 km round trip, with mid-air release of the payload. The primary anticipated roadblocks for this use case include infrastructure, regulation and policy, cost effectiveness, and business model.

Infrastructure could be a challenge for blood delivery given that the optimal network is most likely a hub-and-spoke model. Dispatch bases will serve as hubs in this network, and must collocate UAV launch/capture hardware and maintenance services with blood supply. In many countries, blood supply is limited and centralized, which may make it challenging to establish more than one hub. Spokes connect a hub to a number of receiving clinics, which require workers trained in requesting and receiving UAV deliveries and clinical staff capable of safely handling and transfusing blood. To achieve full benefits, behavior change may also be required to ensure health workers take timely action to request, receive, and transfuse blood.

Regulation and policy challenges are anticipated for blood delivery because of the need for frequent, BVLOS (Beyond Visual Line of Sight) flights over populated areas and mid-air release of detachable payloads. Each of these requirements is likely to spawn complex regulatory issues, and it may take time to convince regulators and the public that dropping blood from the air can be done safely. It is likely that these regulatory roadblocks must be addressed separately in each country, which means that early successes may not directly support scale-up in additional locations.

The cost profile of aerial blood delivery is likely to vary across locations, with some sites showing cost savings and others showing possible increases in costs relative to traditional delivery methods like motorcycles and trucks. Therefore, the value narrative for this use case is likely to focus more on health benefits, including saving lives by more quickly reaching patients in need. This measure of success may appeal to some funders, but the use case could face barriers in proving *cost effectiveness* and identifying local stakeholders who are willing and able to pay.

Finally, the *business model* for long-term financial sustainability of this use case is not yet clear. While a health-oriented value narrative may attract donor funds to cover startup costs, these donors are likely to expect an exit plan that would require health ministries or other funders of the health supply chain to assume longer term responsibility for ongoing operating costs.

Two-Way Sample Transport Use Case Journey

The two-way sample transport use case assumes long range flights of greater than 50 km round trip with landing and subsequent takeoff from remote locations to deliver moderate weight (1.5–5 kg) medical testing kits and return samples to a central lab. The primary roadblocks anticipated for this use case include technology and manufacturability, infrastructure, and regulation and policy.

The required *technology* for two-way sample transport is not fully mature and *manufacturability* has not yet been established beyond prototypes. Given the highly demanding technical requirements for remote VTOL (Vertical Takeoff and Landing) and BVLOS flights, finding manufacturers capable of producing these UAVs at scale is likely to be difficult. Once potential manufacturing partners are identified, further challenges may arise in negotiating a price that is palatable in global health but still covers the manufacturer's development and production costs. This is likely to be particularly challenging if the market for these UAVs is believed to be small.

The technical complexity of UAVs used for two-way sample transport may eliminate the need for some components such as launch and capture hardware, but this use case is likely to come with other *infrastructure* needs. Deployment sites must have both medical testing and recharging capabilities, and a robust program must be established to ensure sufficient in-country capacity to maintain these sophisticated UAVs. On the receiving end, remote health workers must be trained in unloading and relaunching the UAV along with any other requirements of the specific health intervention, such as collecting sputum samples for TB diagnosis. To support long flight paths, reliable connectivity with the UAV is likely to require strong cellular and satellite networks.

Finally, *regulation and policy* challenges are anticipated given the need to secure regulatory approval for long range, long duration, BVLOS flights with potentially infectious cargo. The burden of medical supply transport requirements for infectious cargo is very high, so categorization of specimens

as IATA Category A or Category B will be a key determinant of the requirements and complexity of regulatory approval. Even with existing regulations addressed, there will also be a need for new health policies to integrate UAVs into testing protocols.

Vector Control Release Use Case Journey

The vector control release use case involves using a UAV to deliver treated mosquitoes to support novel vector control techniques such as population replacement or population suppression. The primary roadblocks anticipated for this use case include technology and manufacturability, regulation and policy, and community engagement.

Technology and manufacturability challenges are anticipated given that vector control release technology is still in early stages of development. While prototypes are being developed, significant testing will be required and it may be challenging to find manufacturers who can produce highly customized, niche vector control release hardware. Even if manufactures with the required capabilities are found, it is unlikely that this technology will be purchased in sizable volume, which could translate to high costs given the lack of scale.

The combination of flights over heavily populated areas and the use of vector control release technology requires both air transport and public health *regulatory* approval, which will likely be challenging given the novelty of both aspects of the intervention. Since vector control release may require flights over different areas at different times, ongoing regulatory coordination with host governments may be needed.

The *community engagement* needs for vector control release will be especially high, given the likely need to release mosquitos in challenging areas such as favelas in Brazil. Substantial community engagement will be necessary in advance of flights to gain local trust, and the time-bound nature of some vector control strategies could require additional community education before each round of flights in a new location. Where possible, this challenge area could be mitigated by integrating community engagement activities with the broader engagement plan of the vector control innovator or implementing partner.

Appendix 3

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