Toolkit for Generating Evidence around the Use of Unmanned Aircraft Systems (UAS) for Medical Commodity Delivery

Version 2 – December 2019
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Authors and Acknowledgements

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A. Introduction to the Toolkit

In resource-constrained environments, life-saving health products and services are frequently delayed or don’t reach everyone. Unmanned aircraft systems (UAS, the systems needed to sustainably operate unmanned aerial vehicles/UAVs, often called drones) have the potential to reliably, rapidly, and efficiently deliver medical commodities, but evidence of their use has not been systematically synthesized and disseminated to inform the strategic expansion of the sector. Without coordination, the sector risks duplication of efforts, inefficient use of limited funding, and stagnated progress towards transformational change.

In coordination with the Interagency Supply Chain Group (ISG) UAS Coordinating Body, VillageReach has developed this toolkit to generate evidence around the use of UAS for medical commodity delivery. This toolkit serves the following objectives:

1. Provide governments, technology partners, and implementing partners with the tools needed to generate evidence around the use of UAS for medical commodity delivery to inform programmatic decision-making
2. Provide donors, governments, technology partners, and implementing partners evidence of success which can be compared across projects and countries to enable decision-making around future investment priorities
B. Priority Applications of UAS for Medical Commodity Delivery

This toolkit builds on USAID's Center for Accelerating Innovation and Impact (CII)'s "UAVs in Global Health: Defining a Collective Path Forward," as well as work done by the Boston Consulting Group (BCG), in collaboration with VillageReach, to prioritize global health use cases for further analysis and investment.

First, BCG led an effort to generate a database of all known existing UAS tests and projects, through interviews with more than 30 stakeholders. Through this process, 12 applications of UAS were categorized by use case.

<table>
<thead>
<tr>
<th>Use case</th>
<th>Application</th>
<th>Example payload</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Delivery in response to medical emergencies</td>
<td>1a. Cold chain products</td>
<td>Blood, oxytocin</td>
</tr>
<tr>
<td></td>
<td>1b. Non-cold chain products</td>
<td>Anti-venom</td>
</tr>
<tr>
<td>2. Humanitarian emergency delivery</td>
<td>2a. Outbreak response products</td>
<td>Cholera vaccine</td>
</tr>
<tr>
<td></td>
<td>2b. Basic supplies for outbreaks</td>
<td>Personal protective equipment</td>
</tr>
<tr>
<td></td>
<td>2c. Food and household essentials</td>
<td>High-energy biscuits</td>
</tr>
<tr>
<td>3. Diagnostic two-way delivery</td>
<td>3a. Infectious samples</td>
<td>TB sputum samples</td>
</tr>
<tr>
<td></td>
<td>3b. Non-infectious samples</td>
<td>Dried blood spot samples</td>
</tr>
<tr>
<td>4. Inventory resupply</td>
<td>4a. Resupplying scheduled campaigns</td>
<td>EPI vaccines</td>
</tr>
<tr>
<td></td>
<td>4b. Resupplying essential health products to secondary and tertiary clinics</td>
<td>Blood</td>
</tr>
<tr>
<td></td>
<td>4c. Resupplying basic supplies to secondary and tertiary clinics</td>
<td>Syringes</td>
</tr>
<tr>
<td>5. Vector control</td>
<td>5a. Releasing sterilized mosquitos</td>
<td>Mosquitos</td>
</tr>
<tr>
<td></td>
<td>5b. Aerial spraying of pesticides</td>
<td>Insecticides</td>
</tr>
</tbody>
</table>

The applications listed above were assessed qualitatively based on potential feasibility, health impact, and supply chain impact. Those listed in bold above were prioritized for further analysis and investment.

VillageReach has continued to update the list of UAS projects, generating a database of more than 40 projects as of November 2019. This database will be built out and updated on a quarterly basis to support the sharing of experiences and comparison between use cases and technologies. The use of this toolkit is intended to generate evidence to populate this database in a systematic way that enables comparison between projects.
C. Toolkit User Guide

This toolkit is intended to support implementers, governments, drone companies, and funders to generate rigorous yet practical evidence around the use of UAS to transport public health commodities and services. The toolkit is organized by phase of implementation, described below under “Implementation Roadmap.” For the first implementation phases, the following resources are provided:

- **Logical framework**: Illustration of the results the project aims to achieve
- **Evaluation questions**: High-level questions that data collection answers
- **Means of measurement**: Indicators to measure results, indicator definitions and calculations, and frequency and method of data collection
- **Sample data collection tools**: Data collection tools that have been used in the field and guidance on how to adapt these tools to a project
- **Case studies**: Descriptions from the field of how the toolkit has been applied in the early phases of implementation

In the next version of this toolkit, for release in mid-2020, resources for later phases of implementation will be added, as the sector progresses and gains experience in generating evidence around longer-term use of UAS to deliver medical commodities. Within the toolkit document, links to current online resources are provided.

For technical support in using this toolkit, to provide feedback, or to share your experience using this toolkit, please contact Susie Truog at susie.truog@villagereach.org or Olivier Defawe at olivier.defawe@villagereach.org.

Implementers, governments, drone companies, and funders are encouraged to contribute their results to the Medical Drone Delivery Database (MD3), managed by the UAV for Payload Delivery Working Group (UPDWG). For more information, please see a request for submission in Appendix 1. To view the current database and submit your results, please visit www.updwg.org or email info@updwg.org. Appendix 2 illustrates the current contents of the MD3.
D. Phases of Introducing UAS for Medical Commodity Delivery

In resource-constrained countries, lifesaving medicines and supplies are often not reliably available where they are needed, in part because of challenges in transport due to geographical constraints such as mountains and rivers and poor infrastructure. As a result, delivering medical commodities is expensive and can be delayed or unsafe. Introducing UAS into existing medical commodity delivery systems has the potential to transform health care systems and safely, reliably, and quickly provide lifesaving medicines and services to people as close to where they live as possible.

This toolkit aims to provide governments, technology partners, and implementing partners the resources needed to generate evidence around the introduction of UAS. The toolkit is organized by phase below, but stakeholders should begin identifying resources and partners for all phases from the beginning of implementation. The toolkit also includes criteria to consider before progressing to the next phase, helping governments to make evidence-based decisions.

Figure 1: Introducing UAS for Payload Delivery

Because UAS are a new technology, technology companies and researchers have also conducted standalone technology demonstrations in the country of interest with the aim of proving that the technology can fly or that the payload can be transported safely, without longer-term advocacy for adoption by the government. These technology demonstrations would be considered preliminary activities for Phase 1 or “Phase 0.” Phase 1 expands upon the aims of Phase 0 because it also aims to foster an enabling environment for the use of UAS and studies the potential costs and benefits of introducing UAS. It is still important to generate evidence when standalone technology demonstrations are conducted, and Phase 1 indicators, accompanying guidance, and resources should be applied to the extent possible.

This roadmap represents a potential roadmap for implementation in a new context, where the use of UAS has not yet been tested or proven. In some contexts, implementers may determine in coordination with governments that Phase 1 can be condensed or combined with Phase 2, if the enabling political, regulatory, and social environment is already sufficiently conducive to medical commodity delivery by UAS.
Overview of Phase 1: Safety and feasibility testing

To introduce UAS for public health transport in a country for the first time, governments, implementing partners, and technology partners work together to create an enabling environment and then test promising UAS technology in the local context. The first step is advocacy and engagement of key decision-makers, including representatives of the Civil Aviation Authority, Ministry of Health, and other relevant government agencies at the national, provincial, and local levels, as well as local communities. Stakeholders then collaborate to define the targeted product to transport, to select a priority geography to conduct test flights, and to describe the technology to carry out the desired use in the selected area. Implementing partners should consider using the UAV Delivery Decision Tool developed by FHI360 to clearly define a promising use case and help to select testing sites where UAS may address transport challenges.

UAS technology developed outside of the targeted country will need to be tested in local conditions, as experience has demonstrated that variations in weather and environment affect UAS operations.¹ When the sole objective of drone flights is to test the technology, these are considered preliminary activities or “Phase 0: Technology Demonstrations.”² In Phase 1, implementers and technology partners must demonstrate feasibility through safe, repeated transport of public health commodities by UAS on a small-scale over the course of days or weeks in the local context before expanding to wider use. Alongside these initial demonstrations, partners generate evidence around the potential costs and benefits associated with using UAS. Evidence generated in this first phase is used to suggest the UAS technologies and use cases which are sufficiently promising to warrant further investment in the next phase.

Illustrative activities:

- Mobilize multi-sectoral stakeholders around the use of UAS
- Support civil aviation authority to develop UAS regulations
- Support health ministries to develop regulations and policies to enable product transport by UAS
- Import and fly UAS in the local context
- Design and test UAS technology that works reliably in local contexts
- Study the quality of products transported by drones
- Assess community acceptance of the use of UAS to transport public health commodities
- Assess local capacity to use, operate, and maintain UAS to transport public health commodities
- Identification of initial business case to use UAS to transport public health commodities

Criteria for progressing to Phase 2: measuring effectiveness

- Priority use case, including priority product(s) and geography, have been defined by the government or in partnership with the government

¹ For example, experience in Malawi has indicated that although UAS may operate as expected in European or North American contexts, they may not operate as expected locally due to differences in frequency interference, humidity, altitude, and other factors.
² The Medical Drone Delivery Database (MD3), which compiles all implementations globally, differentiates between Phase 1 projects that aim to create an enabling environment and demonstrate the feasibility of repeated use of UAS to transport medical commodities in local conditions, and technology demonstrations that aim to test technological capabilities only. The latter is critically important, but is referred to as “Phase 0” in the MD3.
- UAS technology which can safely achieve the priority use case over a short period of time has been identified and tested and in the target geography
- The potential benefits and cost of the priority use case have been identified and assessed at a high level
- The regulatory environment is supportive of progressing to longer-term implementation

**Overview of Phase 2: Measuring effectiveness**

Once the feasibility, safety and acceptability of the UAS technology and use case have been proven, governments, implementing partners and technology partners work together to identify the optimal scenarios and elaborate the initial business model for the introduction of UAS, selecting geographies and products to transport which have the greatest potential for impact on supply chain performance and health outcomes. In this second phase, UAS are used for ongoing deliveries over several months in select sites and products, and evidence is generated on their **effectiveness** and **efficiency** in comparison to the current and ideal methods of ground-based transport. Stakeholders identify and put in place sustainable financing and operational models to support scale-up. Stakeholder and community satisfaction with the introduction of UAS will continue to be monitored periodically, and local capacity to operate and maintain UAS will be built. At the end of the second phase, governments should have evidence of business models that can achieve the desired outcomes in a cost-effective way.

**Illustrative activities:**

- Build capacity of local personnel to operate and maintain tested UAS technology for targeted use case(s)
- Monitor stakeholder and community acceptance of ongoing use of UAS
- Support civil aviation authority to update and adapt UAS regulations
- Evaluate benefits and costs of new UAS applications
- Identify and develop business model for the scalable and sustainable use of UAS
- Work with multi-sectoral stakeholders to test the business case for the use of UAS
- Deliver commodities over a period of time in select sites
- Development or implementation of Unmanned Traffic Management system (UTM)
- Provide troubleshooting support to routine deliveries
- Document learnings and successful models of operation and financing

**Criteria for progressing to Phase 3: expanding impact**

- Business model for sustainable operations at scale has been elaborated, based on costs and benefits evaluated through ongoing use of UAS on a small scale
- A transition plan has been developed, including the identification of financing sources and local capacity for operations and maintenance of UAS
- System for safe UAS operations and traffic management is in place

**Overview of Phase 3: Expanding impact**
After the use case has been validated in a select number of sites and the business model for sustainable operations has been elaborated, implementers and technology partners support governments to sustainably expand impact by adopting operational and financial models that do not rely solely on donor funding. It is likely that such models will include public-private partnerships such as government contracting an existing logistics provider supported by a proven technology partner. Such models will also gradually transition capacity and responsibility for UAS operations and maintenance from technology manufacturers based outside of the country of operations to local companies. By the end of this phase, governments should have the tools, technology, and systems in place to transform their existing public health supply chains through the strategic use of UAS.

**Illustrative activities:**

- Support the government to expand the use of UAS to additional sites and additional products
- Support the government in implementing promising models of sustained operation and financing
- Support the government to work with the UAS service provider to identify and train UAS operators
- Cultivate a local business environment for the maintenance of UAS in-country

**Criteria for transitioning to government:**

- [Coming in next version]
1. Evidence Generation - Phase 1: Safety and feasibility testing

Phase 1 culminates in the development of an enabling environment for the use of UAS. By the end of this phase, governments, implementers, and technology partners will have identified promising technologies and use cases for further investment in the local context. This phase is particularly important if UAS have never been tested in the local context or local stakeholders and communities are unfamiliar with UAS.

A Case Study will be available in this toolkit in December 2019, including a description of how these resources were applied by the Centro de Innovacion de Drones, WeRobotics, VillageReach and the Inter-American Development Bank (IDB) in the Dominican Republic.

Logical Framework

The logical framework below illustrates the deliverables or outputs that partners will need to achieve in order to have the desired results for Phase 1:

**Figure 2: Phase 1 Logical Framework**

Evaluation questions

Evaluation questions were identified to prioritize indicators for data collection. For Phase 1, the following questions were developed:

1. Is the enabling environment sufficient to promote the ongoing use of UAS technology and use cases?
2. Were stakeholders across sectors and levels engaged in defining the use case and feasibility testing?
3. Were UAS demonstration flights conducted successfully?

After data has been collected and analyzed, these questions can be used to guide discussions with stakeholders to identify next steps for the implementation of Phase 2. If these questions identify gaps or
areas of non-achievement, governments and partners should work together to address these gaps before moving to the next phase. For example, if local stakeholders and communities have not been engaged by the end of Phase 1, a comprehensive community outreach strategy should be developed and implemented, based on a comprehensive study of stakeholder and community perceptions of UAS. If demonstration flights have not been successful or the desired requirements not fully achieved, technology improvements or a new technology provider should be considered before progressing to Phase 2.

Means of Measurement

A full list of indicators for all three phases can be found in Excel format in the Resource Library of the UPDWG website.

**Deliverable 1.1: Permission secured to import and use UAS in-country**

Most governments in low-resource environments lack the regulations or policies to enable the efficient, rapid introduction of UAS into existing public health supply chains. Civil aviation authorities are traditionally adverse to risks and slow to evolve, and many pilots have been conducted as exemptions in the absence of regulations or policies specifically governing the use of UAS to transport public health payloads. It is important for governments, implementers and technology partners to share the details of the type of UAS flight permission they receive to help others learn from their experience and identify governments and political environment which have prioritized the introduction of UAS for further programming investment. This indicator is intended to be descriptive, and ad hoc permission may be sufficient in Phase 1 to begin fostering an enabling environment for the use of UAS. Governments and implementers should consult the World Economic Forum’s Drones and Tomorrow’s Airspace Team’s Advanced Drone Operations Toolkit for recommendations and lessons learned from leaders in using UAS for medical commodity delivery.

**Indicator 1.1.1: Type of UAS flight permission received (Phases 1, 2 and 3)**

*Definition:* Type of flight permission received, dependent on status of regulations in the country. Includes type of flight approved as well as duration and location of flight permission.

<table>
<thead>
<tr>
<th>Method</th>
<th>Sample data collection tool</th>
<th>Frequency of data collection</th>
<th>Data use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Review of documentation of flight permission received</td>
<td>Regulation checklist defining type of permission received (<a href="#">Appendix 3</a>)</td>
<td>Once per project or each time a new type of permission is received</td>
<td>Track maturity of regulations in the country and inform other implementers about regulatory maturity within each country</td>
</tr>
</tbody>
</table>

**Deliverable 1.2: Feasibility of introducing UAS use case is evaluated**

*Stakeholder and community perceptions assessment:* It is critical to generate evidence around stakeholder and community acceptance before implementation to ensure that demonstration testing does not exacerbate existing negative opinions or concerns about potential misuse of UAS, for example, military or surveillance purposes. The results of a qualitative stakeholder perceptions assessment can be used to inform a community outreach strategy, which should be conducted before the first demonstration flights...
in an area to ensure that all community members are aware of the purpose of the UAS flights and safety precautions to take in case of an adverse event.

<table>
<thead>
<tr>
<th>Indicator 1.2.1: Stakeholder and community acceptance of UAS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Definition:</strong> The extent to which stakeholders at all levels are aware or have concerns about the use of UAS to transport medical commodities, and identification of any traditional beliefs or local preferences.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Method</th>
<th>Sample data collection tool</th>
<th>Frequency of data collection</th>
<th>Data use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Focus group discussions (FGDs) with national, district, and community level at take-off and landing sites</td>
<td>FGDs &amp; KIIIs for stakeholder and community acceptance (Appendix 4)</td>
<td>Before first flight and updated with each new area</td>
<td>Qualitative results are used to inform demonstration flight design and outreach strategy content and audiences.</td>
</tr>
</tbody>
</table>

*Costs and benefits analysis:* In order to prove that the use of UAS to deliver public health commodities is feasible within a country, it may be necessary to generate evidence evaluating the potential costs and benefits of UAS transport in comparison to a ground-based transport system. These comparisons should be made between the current ground-based transport system, if one exists, and to the ideal ground-based transport system, which would reach all targeted individuals within a catchment area and transport sufficient quantities of the targeted product to meet the demand. This evidence will help decision-makers begin to weight the costs and benefits of introducing UAS into existing public health supply chains. In the first phase, evidence should be rigorous yet practical, and it is recommended to limit data collection to comparison of key cost drivers and transport time. The stakeholder perceptions assessment can also identify other benefits of UAS use which decision-makers may be interested in. In previous assessment, stakeholders have also been interested in the potential of UAS-enhanced systems to better maintain product quality and to reduce the public health supply chain system’s reliance on fuel.

<table>
<thead>
<tr>
<th>Indicator 1.2.2: Cost drivers identified for UAS in comparison to current or ideal transport</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Definition:</strong> Identify key cost drivers that might have a significant impact on the cost-effectiveness of introducing UAS</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Method</th>
<th>Sample data collection tool</th>
<th>Frequency of data collection</th>
<th>Data use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Collection of average cost data for key system cost inputs for UAS and current or ideal transport</td>
<td>Excel-based costing tool, such as JSI Cost Simulation Tool</td>
<td>Once (aligned with demonstration flights)</td>
<td>To share with Ministry of Health and other implementers considering transporting the same products and to inform a potential expected benefit of UAS</td>
</tr>
</tbody>
</table>
### Indicator 1.2.3.a: Transport time for UAS in comparison to ground transport

**Definition:** Comparison of average transport time needed for UAS to travel a given route in comparison to ground transport.

<table>
<thead>
<tr>
<th>Method</th>
<th>Sample data collection tool</th>
<th>Frequency of data collection</th>
<th>Data use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quantitative data collected for the average time needed for UAS to travel a certain route compared to quantitative data collected for the average time needed for ground transport to travel</td>
<td>UAS flight monitoring data or data gathered by entering GPS points into Google Maps or other mapping software, entered into a Transport Time Comparison Database (Appendix 5)</td>
<td>Each UAS demonstration flight and once for ground transport (if data collected from flights)</td>
<td>To share with Ministry of Health and other implementers considering transporting the same products or in the same geography and to inform a potential expected benefit of UAS</td>
</tr>
</tbody>
</table>

### Indicator 1.2.3.b: Product quality measurement when transported by UAS vs. current or ideal transport (optional, based on stakeholder interest and use case relevance)

**Definition:** Confirm that product quality can be ensured at the same or better standard than ground transport.

<table>
<thead>
<tr>
<th>Method</th>
<th>Sample data collection tool</th>
<th>Frequency of data collection</th>
<th>Data use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Product quality measurement based on product and global standards collected before and after flight, in comparison to these measures for a random sample of ground transport trips.</td>
<td>Product quality monitoring database</td>
<td>Once (aligned with demonstration flights)</td>
<td>To share with Ministry of Health and other implementers considering transporting the same products and to inform a potential expected benefit of UAS</td>
</tr>
</tbody>
</table>

### Indicator 1.2.3.c: Comparison of CO2 emitted by UAS transport system vs. current or ideal transport (optional, based on stakeholder interest)

**Definition:** Estimate whether CO2 emissions may be reduced through UAS transport system

<table>
<thead>
<tr>
<th>Method</th>
<th>Sample data collection tool</th>
<th>Frequency of data collection</th>
<th>Data use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Estimate CO2 emitted by UAS based on electricity needed to charge UAS batteries or fuel to power UAS, in comparison to an estimate of CO2 emitted, in comparison to average measures for the current and ideal ground transport system</td>
<td>CO2 emissions calculation database</td>
<td>Once (aligned with demonstration flights)</td>
<td>To share with Ministry of Health and other implementers considering transporting the same products and to inform a potential expected benefit of UAS</td>
</tr>
</tbody>
</table>
**Deliverable 1.3: Safe and locally reliable technology is tested**

Each UAS operator will collect data on each flight to monitor the performance of their technology and equipment. To enable other implementers, technology partners, governments, and donors to understand the results of UAS demonstration flights, the indicators listed below are recommended, at a minimum, for consolidation across all flights. Although each context is different, approximately 25-75 one-way flights completed over multiple days or weeks and in different weather conditions may be sufficient to indicate that the technology is safe and locally reliable enough to consider progressing to Phase 2.

| Indicator 1.3.1: Number of successful flights conducted (Phase 1, 2 and 3) |
| Definition: The total number of flights conducted with successful take-off and landing |

| Indicator 1.3.2: Maximum flight distance achieved before landing, in kilometers (Phase 1) |
| Definition: The maximum distance reached by the UAS with successful take-off and landing, without needing to recharge batteries or re-fuel |

| Indicator 1.3.3: Maximum payload carried per flight, in kilograms and liters (Phase 1) |
| Definition: The maximum weight and volume of payload transported by the UAS with successful take-off and landing |

<table>
<thead>
<tr>
<th>Method</th>
<th>Sample data collection tool</th>
<th>Frequency of data collection</th>
<th>Data use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Review of operational checklists completed before and after each flight</td>
<td>Pre- and post-flight checklist (<a href="#">Appendix 6</a>)</td>
<td>Consolidation at the end of demonstration flights</td>
<td>To share with government, other implementers and technology partners, and donors to aid in comparison across implementations</td>
</tr>
</tbody>
</table>
2. Evidence Generation – Phase 2: Measuring Effectiveness

Once the safety, feasibility and acceptability of UAS technology and the prioritized use case have been proven, the efficiency and effectiveness of introducing UAS is proven and potential supply chain performance and health impacts are studied. Before progressing to Phase 2, governments and partners should discuss the evaluation questions presented under Phase 1 and identify steps to address any remaining gaps. Phase 2 culminates in the implementation of a business model to sustain UAS operations and maintenance.

Logical Framework

The logical framework below illustrates the deliverables or outputs that partners will need to achieve in order to have the desired results for Phase 2:

*Figure 3: Phase 2 Logical Framework*

<table>
<thead>
<tr>
<th>Deliverables</th>
<th>Results</th>
<th>Impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enabling environment: Strengthen with regulatory support and stakeholder engagement</td>
<td>More reliable availability</td>
<td>Increased consumption</td>
</tr>
<tr>
<td>Local capacity: Knowledge and skills for UAS</td>
<td>Increased coverage</td>
<td></td>
</tr>
<tr>
<td>Technology system validation: Demonstrate ongoing reliability and safety</td>
<td>Improved health worker efficiency</td>
<td></td>
</tr>
<tr>
<td>Use case validation: Study benefits and costs of continued UAS delivery</td>
<td>Improved health outcomes</td>
<td></td>
</tr>
<tr>
<td>Business case: Operations and financing models</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Evaluation Questions

Evaluation questions were identified to prioritize indicators for data collection. For Phase 2, the following questions were developed:

1. Is the enabling environment sufficient to enable scale-up of UAS technology to new geographies and medical commodities?
2. Is local capacity to operate and maintain the UAS sufficient to enable scale-up of the UAS system?
3. Are ongoing deliveries by UAS occurring as expected within the public health supply chain?
4. Are ongoing deliveries by UAS having the expected results on supply chain performance?
5. Has the business case for ongoing use of UAS to transport commodities been successfully applied?
After data has been collected and analyzed, these questions can be used to guide discussions with stakeholders to identify next steps for the implementation of Phase 3. If these questions identify gaps or areas of non-achievement, governments and partners should work together to address these gaps before moving to the next phase. For example, if local capacity for UAS operations has not been sufficiently and sustainably built, it is not advisable to continue to scale-up. If UAS deliveries are not occurring reliably on a regular basis, then technology improvements may be needed before progressing to Phase 3.

**Means of Measurement**

A full list of indicators for all three phases can be found in Excel format in the Resource Library of the UPDWG website.

**Deliverable 2.1: Enabling environment to use UAS is strengthened**

In Phase 1, implementing partners and technology partners work with governments to foster an enabling environment for the introduction of UAS. In Phase 2, data should continue to be gathered around the progression of the enabling environment, including whether the regulations necessary to import and use UAS are maturing and whether stakeholder and community perceptions of UAS continue to be positive and conducive to continued use.

**Regulatory approvals and maturation:** As the use of UAS continues in a country, regulations are expected to mature and adapt to evolving UAS uses and technologies. This indicator should only be updated once per project, or as frequently as it changes.

**Indicator 2.1.1: Type of UAS flight permission received (Phase 1, 2 and 3)**

**Definition:** Type of permission received, dependent on status of regulations in the country (ad hoc permission, permission for visual line of sight/VLOS or beyond visual line of sight/BVLOS flight, and formal regulations).

<table>
<thead>
<tr>
<th>Method</th>
<th>Sample data collection tool</th>
<th>Frequency of data collection</th>
<th>Data use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Review of documentation of permission received</td>
<td>Regulation checklist defining type of permission received (<a href="#">Appendix 3</a>)</td>
<td>Once per project or each time a new type of permission is received</td>
<td>Track maturity of regulations in the country and inform other implementers about regulatory maturity</td>
</tr>
</tbody>
</table>

**Stakeholder perceptions monitoring:** As UAS are used over longer periods of time, stakeholders and community members will have an opportunity to gain first-hand experience with the technology and observe its initial impact on their community. It is important to generate evidence around these perceptions to identify any operational concerns that need to be addressed during ongoing validation of the UAS business model.
**Indicator 2.1.2: Stakeholder and community satisfaction with the use of UAS**

*Definition:* The extent to which stakeholders at all levels are satisfied with the use of UAS to transport medical commodities in their communities.

<table>
<thead>
<tr>
<th>Method</th>
<th>Sample data collection tool</th>
<th>Frequency of data collection</th>
<th>Data use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Focus group discussions (FGDs) with national, district, and community level in purposively sampled sites</td>
<td>FGDs &amp; KIs for stakeholder and community satisfaction (<em>Coming in next version</em>)</td>
<td>At mid-term and endline of Phase 2</td>
<td>To inform refinement of the use case to ensure that the introduction of UAS is adapted to local needs</td>
</tr>
</tbody>
</table>

**Deliverable 2.2: Local capacity to operate and maintain UAS is evaluated and built**

Once the use case has been defined and the UAS technology proven feasible in the local context, an assessment should be conducted to identify the existing level of knowledge and skills available locally to operate and maintain the selected UAS. These results can then be used to inform local capacity building plans for implementation in the long-term, including the establishment of a public-private structure to provide UAS services and a plan for ongoing capacity building. If the capacity building plan includes formal training, partners should monitor the number and topic of trainings conducted and the number and demographics of training participants.

**Indicator 2.2.1: Local knowledge and skills available to operate and maintain UAS**

*Definition:* The extent to which local actors have the knowledge and skills to operate and maintain the UAS

<table>
<thead>
<tr>
<th>Method</th>
<th>Sample data collection tool</th>
<th>Frequency of data collection</th>
<th>Data use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Key informant interviews (KIs) with health workers, local entrepreneurs, technology companies, and technology students</td>
<td>KIs for local capacity assessment (<em>Coming in next version</em>)</td>
<td>Once, at the end of Phase 1 or at the beginning of Phase 2</td>
<td>To describe the current level of knowledge and skills</td>
</tr>
</tbody>
</table>

**Deliverable 2.3: UAS technology reliably and safely delivers medical commodities**

During ongoing use of UAS, UAS operators and health center staff receiving the UAS will collect data on each flight to monitor the performance of the technology and equipment. To enable other implementers, technology partners, governments, and donors to understand the results of UAS demonstration flights, the indicators listed below are recommended, at a minimum, for consolidation across all flights. During Phase 1, the total number of flights, maximum distance achieved, and maximum payload transported inform decision-makers about what is feasible in the local context, while in Phase 2, the average number of flights over a time period, average distance achieved, and average payload transported describe the typical use of UAS within the new system.
**Indicator 2.3.1**: Number of successful flights conducted (Phase 1, 2 and 3)  
*Definition:* The total number of flights conducted with successful take-off and landing

**Indicator 2.3.2**: Number of days of sustained flights (Phase 2 and 3)  
*Definition:* Number of days on which UAS flights continued as expected, without interruption due to issues with flight permissions, technological issues, or weather conditions. The number of days of sustained flights does not include days when flights are not planned, for example, weekends if flights are not scheduled.

**Indicator 2.3.3**: Average distance achieved before landing, in kilometers (Phase 2 and 3)  
*Definition:* The average distance reached by the UAS with successful take-off and landing, without needing to recharge batteries or re-fuel

**Indicator 2.3.4**: Average payload transported, in kilograms and liters (Phase 2 and 3)  
*Definition:* The average weight and volume of payload transported by the UAS with successful take-off and landing

<table>
<thead>
<tr>
<th>Method</th>
<th>Sample data collection tool</th>
<th>Frequency of data collection</th>
<th>Data use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Review of operational checklists completed before and after each flight</td>
<td>Pre- and post-flight checklist (<a href="#">Appendix 6</a>)</td>
<td>Consolidated periodically, either monthly or quarterly depending on frequency of flights</td>
<td>To share with government, other implementers and technology partners, and donors to aid in comparison across implementations</td>
</tr>
</tbody>
</table>

**Deliverable 2.4: Use cases for introducing UAS into public health supply chain are validated and refined**

To validate the use case defined and potential benefits and costs identified in Phase 1, the benefits of ongoing use of UAS should be quantified in Phase 2 based on actual experience. Benefits are expected to include an increase in the reliability and timeliness of deliveries and reduced transport time. At the same time, the actual costs of ongoing use of UAS to transport public health products and services need to be evaluated, including the cost of maintaining the UAS within the existing medical commodity delivery system.

**Indicator 2.4.1**: Cost of delivery per kilometer traveled or kilogram delivered for UAS-enhanced transport in comparison to current transport system  
*Definition:* The cost of transporting a product by UAS in comparison to the current transport system, or if no transport is currently in use, the optimal transport system

<table>
<thead>
<tr>
<th>Method</th>
<th>Sample data collection tool</th>
<th>Frequency of data collection</th>
<th>Data use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Collection of actual cost to deliver targeted products through UAS system in comparison to collection of actual cost in a comparison area through ground-based transport</td>
<td>Transport system costing tool (Coming in next version)</td>
<td>Collected over period of time depending on use case, at least one month and ideally six month with regular deliveries</td>
<td>To inform stakeholder planning and identification of sustainable financing</td>
</tr>
</tbody>
</table>
Indicator 2.4.2: Percentage of requested or scheduled deliveries made on-time and in-full, in comparison to current transport system (Phase 2 and 3)

**Definition:** Proportion of deliveries requested by health facilities which are fulfilled as expected, within the timeframe expected and in the quantity expected

Indicator 2.4.3: Average time elapsed between delivery request and arrival, in comparison to current transport system (Phase 2 and 3)

**Definition:** Average time between delivery request and delivery arrival at health facility

<table>
<thead>
<tr>
<th>Method</th>
<th>Sample data collection tool</th>
<th>Frequency of data collection</th>
<th>Data use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Review of health facility UAS request and reception forms completed before and after each requested flight, in comparison to data from current transport system</td>
<td>Health facility UAS request form database (<em>Coming in next version</em>)</td>
<td>Consolidated periodically, either monthly or quarterly depending on frequency of flights</td>
<td>To describe performance of UAS and identify gaps for improvement</td>
</tr>
</tbody>
</table>

**Deliverable 2.5: Sustainable UAS operations and financing models are identified**

In Phase 2, implementing partners should work together with governments to develop and formalize operations and financing models, which are expected to include public-private partnerships.

Indicator 2.5.1: Number of operations and financing models developed and formalized

**Definition:** Operations and financing models identify all human, operational, strategic, and financial resources needed to maintain the use of UAS within the existing medical commodity delivery system

<table>
<thead>
<tr>
<th>Method</th>
<th>Sample data collection tool</th>
<th>Frequency of data collection</th>
<th>Data use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Document review</td>
<td>Operations and financing model checklist (<em>Coming in next version</em>)</td>
<td>Once, end of Phase 2</td>
<td>Determine whether the criteria has been met to progress to Phase 3</td>
</tr>
</tbody>
</table>

**Result I: More reliable availability of targeted public health products and services**

The first observable effect of introducing UAS is more reliable availability of transported products. When it is available and of sufficient quality, existing logistics management information system data should be used to minimize the data collection burden on the government.

Indicator I.1: Percentage of health facilities with full availability of targeted products and services as a result of the introduction of UAS

**Definition:** Proportion of health facilities served by UAS which have full stock of targeted products and services, in comparison to similar health facilities not served by UAS

<table>
<thead>
<tr>
<th>Method</th>
<th>Sample data collection tool</th>
<th>Frequency of data collection</th>
<th>Data use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Review of existing logistics management information system data, if available and reliable, or collection of regular stock data</td>
<td>Direct distribution inventory and stock data collection tool (<em>Coming in next version</em>)</td>
<td>Monthly or bi-monthly (aligned with government policies)</td>
<td>Describe the impact of using UAS on public health supply chain performance</td>
</tr>
</tbody>
</table>
Result II: Increased coverage of targeted public health products and services

Another effect expected as a result of ongoing use of UAS is an increase in the number of people with access to targeted products and services. UAS are expected to be able to reliably reach populations not able to be reached by traditional ground-based transport systems.

<table>
<thead>
<tr>
<th>Indicator II.1: Percentage increase in number of people with access to targeted product or service as a result of the UAS-enhanced system</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Definition:</strong> Total population of people who are targeted with a product or service who had access before the UAS was introduced in comparison to after it was introduced.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Method</th>
<th>Sample data collection tool</th>
<th>Frequency of data collection</th>
<th>Data use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Population data per health facility served by UAS</td>
<td>Coming in next version</td>
<td>Once, at the end of Phase 2</td>
<td>Describe the population impacted by UAS</td>
</tr>
</tbody>
</table>

Result III: Health worker efficiency and effectiveness improved as a result of the introduction of UAS

The introduction of UAS is expected to result in improvements to supply chain performance as well as effect health workers’ perceptions of their efficiency and effectiveness. Because health workers will no longer need to procure products from central medical storage, they will be able to spend more time with patients. With a reliable supply of medicines, health workers may also feel an improved sense of effectiveness, as they are better able to meet their patients’ needs.

<table>
<thead>
<tr>
<th>Indicator III: Effect on health workers’ perceptions of their efficiency and effectiveness as a result of the introduction of UAS into existing public health systems</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Definition:</strong> Identification of positive and negative effects on health workers’ efficiency and effectiveness as a result of UAS, in comparison to before UAS were used.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Method</th>
<th>Sample data collection tool</th>
<th>Frequency of data collection</th>
<th>Data use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Key informant interviews (KIs) with a purposive sample of health workers</td>
<td>Key informant interviews (KIs) with health workers (Coming in next version)</td>
<td>Baseline, midterm and endline of Phase 2</td>
<td>Describe the effect of introducing UAS on health workers’ job performance</td>
</tr>
</tbody>
</table>

Impact A: Health outcomes related to targeted products and services improve (optional)

Depending on the health outcomes of interest for products transported by UAS, it may be possible to generate evidence around the impact of using UAS on health outcomes. For example, if UAS are used to transport blood or oxytocin in response to maternal emergencies, it may be possible to quantify the number of times these products are used as well as the number of maternal deaths averted after the introduction of UAS in comparison to a control site where UAS were not introduced. However, for some uses of UAS, it may not be feasible to measure the rate of consumption or health outcomes over the period of time that products are transported. For example, if UAS are used to transport vaccines over a period of 12 months, the targeted health outcomes of reduced incidence of vaccine-preventable diseases cannot be observed within the 12-month project period. However, it may be possible to estimate consumption of the vaccines provided to sites served by UAS.
**Indicator A.1: Percentage change in consumption or use of targeted products and services as a result of the introduction of UAS**

*Definition:* Relative difference in percentage change in consumption or use of targeted products and services between sites served by UAS and a comparison group.

**Indicator A.2: Percentage change in targeted health outcomes as a result of the introduction of UAS**

*Definition:* Relative difference in percentage change in targeted health outcomes between sites served by UAS and a comparison group.

<table>
<thead>
<tr>
<th>Method</th>
<th>Sample data collection tool</th>
<th>Frequency of data collection</th>
<th>Data use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compile administrative data or data on consumption or health outcomes for sites served by UAS and comparison sites</td>
<td>Coming in next version</td>
<td>Baseline and endline</td>
<td>Evaluate the impact of UAS on consumption or health outcomes</td>
</tr>
</tbody>
</table>

After the use case has been validated in a select number of sites and the business model for sustainable operations has been put in place, governments, implementers and technology partners sustainably expand impact by adopting operational and financial models that do not rely solely on donor funding. By the end of this phase, governments should have the tools, technology, and systems in place to transform their existing public health supply chains through the strategic use of UAS.

Because the UAS for payload delivery sector has not generated rigorous evidence around the achievement of Phase 3 to date, this section will be expanded upon in the next version. At present, only an illustrative logical framework and initial evaluation questions have been identified. It is expected that the means of measurement will build off of the indicators used in Phase 2. Notably, this section will benefit from the experience of Zipline in Rwanda, and its planned evidence generation activities there.

Logical Framework

The logical framework below illustrates the deliverables or outputs that partners will need to achieve in order to have the desired results for Phase 3:

![Figure 4: Phase 3 Logical Framework](image)

**Evaluation Questions**

Evaluation questions were identified to prioritize indicators for data collection. For Phase 3, the following questions were developed:

1. Have the mechanisms for scale-up and sustainability been successfully applied?
2. Are public and private actors sufficiently resourced to manage UAS at-scale?
3. What is the measurable impact on health outcomes because of the use of UAS?
After data has been collected and analyzed, these questions can be used to guide discussions with stakeholders to evaluate readiness for transition. If these questions identify gaps or areas of non-achievement, governments and partners should work together to address these gaps before transitioning. For example, if financial resources have not been sufficiently mobilized to sustain UAS operations in the long-term, transition should not yet be considered. If the use of UAS is not having an impact or not a sufficient impact on health outcomes, further optimization and prioritization may be necessary.

**Means of Measurement**

*Means of measurement for Phase 3 will be added in later versions, as the sector gains experience.*
4. Case Study Phase 1: Feasibility Testing in the Dominican Republic
Centro de Innovacion de Drones, WeRobotics, Dominican Republic Flying Labs, VillageReach, and Inter-American Development Bank

Background
With support from the Inter-American Development Bank (IDB), through its Innovation Lab, Centro de Innovación de Drones demonstrated the feasibility of safe, repeated deliveries of medical commodities by UAS in San Juan Province, Dominican Republic. From 2017 to 2019, a total of 157 flights were conducted between three hospitals and five health facilities, evaluating the use of three different technologies in partnership with WeRobotics and Matternet. VillageReach provided technical support to Centro de Innovacion de Drones to generate evidence around the acceptability, potential benefits and costs, and the creation of an enabling environment for the introduction of UAS to deliver medical commodities, using the resources presented for Phase 1 of this toolkit. Phase 1 resulted in recommendations for consideration by the government and implementing partners around next steps to progress to Phase 2, which would seek to measure the effectiveness of a UAS transport system over a longer period of time.

Project partners share a commitment to advancing the sector through transparent information sharing, as WeRobotics says on their blog, “We proactively share our operations, findings and recommendations in an open, transparent and public manner. We do this to help advance and spread a more informed understanding of the opportunities and limitations around the use of cargo drones for public health.”

Evidence Generated

Indicator 1.1.1: Flight permission type
In the absence of formal regulations governing the use of UAS to transport medical commodities in the Dominican Republic, Centro de Innovación de Drones received special permission from the Dominican Institute of Civil Aviation (Instituto Dominicano de Aviación Civil) to fly UAS in San Juan de la Maguana Province. This permission allowed beyond-visual-line-of-sight (BVLoS) flight for a limited duration between specified sites.

Indicator 1.2.1 Stakeholder and community perceptions
To evaluate the extent to which stakeholders and the community accepted the use of UAS to transport health commodities, focus group discussions (FGDs) were conducted with community members residing within close proximity to the take-off and landing sites. Key informant interviews (KIIs) were conducted with community leaders and health workers. FGDs and KIIs collected feedback on the use of UAS and can

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be used to inform community outreach strategies. A total of 108 people participated in FGDs or KIIs, including 47 men and 40 women in FGDs and 9 men and 12 women in KIIs.

Respondents agreed that UAS have the potential to save patients time and money and ensure product quality and security during transport, but expressed concern that UAS might crash or cause harm to people, the environment, or the payload. They felt that all UAS should contain clear, simple instructions for what to do in an emergency, with instructions for who to call for help. Community members also advised that use of UAS should be limited to daylight hours during the week, and that UAS operations should be overseen by a local committee to ensure adherence to local preferences.

1.2.2 Cost drivers identified for UAS in comparison to ground transport

A costs associated exercise aimed to provide insights into the costs of using drones to transport medical commodities between the San Juan Provincial Warehouse and last mile health facilities within the province. An Excel-based tool developed by InSupply, JSI and LLamasoft was used to compare drone transportation costs to existing ground transport by road. The largest cost driver in the land-based transport system was the salary of the drivers, and the largest cost driver in the drone-based transport system was the drone operator salary. The analysis also found that drone transport may yield cost savings per kilometer of up to 69% in comparison the land transport system.

1.2.3.a Transport time for UAS in comparison to ground transport

Alongside costs, the analysis also considered potential benefits of introducing drones. GPS points were used to estimate transport distance and time savings between the provincial warehouse and health facilities. On average, transport by drone has the potential to decrease transport distance by an average of 30%, from an average of 28.6 kilometers to 19.9 kilometers, and to decrease transport time by an average of 38%, from an average of 37.9 minutes to 23.5 minutes.

1.3.1 Number of successful flights conducted; 1.3.2 Maximum flight distance achieved without stopping, in kilometers; 1.3.3 Maximum payload carrier per flight, in kilograms

In addition to demonstrating the feasibility of introducing drones in the DR, including considering potential costs and benefits, the project also completed 157 test flights. By the end of the test flights, the drones had reached a maximum distance of 12.5 kilometers before stopping and carried a payload of up to 2.5 kilograms.

Lessons Learned

Table: Phase 1 results

<table>
<thead>
<tr>
<th>Deliverable</th>
<th>Indicator</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1: Permission secured to import and use UAS</td>
<td>1.1.1 Flight permission type</td>
<td>BVLoS approval, limited duration, site-specific</td>
</tr>
<tr>
<td>1.2: Feasibility of introducing UAS is evaluated</td>
<td>1.2.1 Level of stakeholder engagement</td>
<td>Acceptance evaluated at take-off and landing</td>
</tr>
<tr>
<td></td>
<td>1.2.2 Cost drivers identified</td>
<td>Costs similar or lower than current system</td>
</tr>
<tr>
<td></td>
<td>1.2.3 Benefits identified</td>
<td>Transport time reduced</td>
</tr>
<tr>
<td>1.3: Safe and locally reliable technology is tested</td>
<td>1.3.1 # of flights completed</td>
<td>157</td>
</tr>
<tr>
<td></td>
<td>1.3.2 Maximum distance</td>
<td>12.5 km</td>
</tr>
<tr>
<td></td>
<td>1.3.3 Maximum payload</td>
<td>2.5 kg</td>
</tr>
</tbody>
</table>
Based on these analyses, the following key lessons learned were identified:

1. **Drones should be considered as one part of an integrated, responsive medical commodity delivery system.** Drones will not replace all forms of ground transport, but have the potential to optimize the existing transport system under certain circumstances. There may be scenarios in which ground transport is already reliably and effectively transporting products, and drones should not be introduced under these circumstances.

2. **It is important to consider not only the costs but also the potential benefits of using drones to transport medical commodities.** Even if drones may be more expensive to use than ground transport, if the ground transport isn’t working well enough to ensure that people have the medicine they need, it might be worth the additional financial cost.

3. **Drones are a new technology, and local stakeholders and community members might not understand their use of might have concerns about their use.** From the very beginning, it is important to engage the community about how they want to see drones used and whether they think their use is appropriate. Before drones are flown, outreach programs are needed to make sure that all community members are prepared and have the information they need to inform the program.

4. At first, the drone technology and its operation are coming from outside the country, but right at the beginning, it is important to identify local operators and local companies who can operate and maintain the system. A sustainable business model is key to transporting products by drone in the long-term.

Overall, generating evidence around the use of drones, including not only operational performance but also community perceptions and potential costs and benefits, provides government and programmatic decision-makers the information needed to identify next steps and priorities to introduce drones in the Dominican Republic.
Appendix 1: Request for Submission to the Medical Drone Delivery Database (MD3)

VillageReach and the UAV for Payload Delivery Working Group (UPDWG) are seeking submissions of evidence collected about drone tests, projects, or implementations to include in the Medical Drone Delivery Database (MD3), which will be available in interactive and downloadable formats on the UPDWG website.

1. **What is the MD3?**
   VillageReach and UPDWG have developed the MD3, a user-generated, publicly-available database consolidating evidence from all actors in the medical drone delivery sector. The Drone Evidence Generation Toolkit developed by VillageReach provides guidance on how stakeholders can generate this evidence, including indicators, sample data collection tools, and suggested data collection methods.

2. **Why did we develop the MD3?**
   Although the use of drones presents a significant opportunity to transform the way medical commodities are delivered and reliably provide lifesaving medicines for all, progress has been slow and achieved in silos. The MD3 aims to accelerate the strategic integration of drones into existing health systems by providing all stakeholders timely access to evidence about what works and what doesn’t work in an easily accessible and easily updated manner.

3. **Why should stakeholders submit to the MD3?**
   Including your project in the MD3 will:
   1. Further the evidence-based progress of the medical drone delivery sector as a whole
   2. Enable other stakeholders to connect with you around shared experience and shared objectives
   3. Help potential donors and partners find you

4. **Who should submit to the MD3?**
   Any drone company, non-profit organization, government, or donor involved in using drones to transport health payloads can submit to the MD3. Only one entry per drone test, project, or implementation should be submitted.

5. **Where will updated versions of the MD3, including my submission, be stored?**
   MD3 submissions will be reviewed by UPDWG organizers and any clarifications will be made with the contact person listed in the submission. Confirmed database entries will be stored in:
   1. Interactive world map available on the UPDWG website (www.updwg.org) to facilitate rapid analysis
   2. Excel database available for download from UPDWG website for detailed information

6. **How can I submit to the MD3?**
   Complete the Excel submission form available on the UPDWG website or from info@updwg.org
Appendix 2: Summary of MD3 Contents as of November 2019

**Phase 1:** Safety & feasibility testing (Days to weeks)
- WellRobotics (10)
- UNICEF (6)
- VillageReach (4)
- Stony Brook University (2)
- Others (13)

**Phase 2:** Measuring effectiveness (Months)
- SwissPost (Switzerland)
- UPS (USA)
- GHSC-PSM (Malawi)

**Phase 3:** Expanding impact (Ongoing)
- Zipline (Rwanda, Ghana)

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Appendix 3: Flight Regulations Checklist (Indicators 1.1.1, 2.1.1)

Indicators 1.1.1 and 2.1.1: Type of UAS flight permission received

Instructions: This checklist is intended to consolidate information about the type of flight permission received to fly drones in-country. This checklist provides helpful definitions of terms and prioritizes information to be shared with other implementers.

Adapted from: Cyclops Air

Country: ____________________________

Contact or Reporting Organization: ____________________________

Date Checklist Completed: ____________________________

1. Type of flight permission secured

☐ No permission required: Flights completed without written, signed permission or approval from the local Civil Aviation Authority (CAA)

☐ Visual line of sight (VLoS) approval required: CAA provided written, signed permission specifically mentioning VLoS operations, in which the operator maintain visual contact with the aircraft and surrounding airspace

☐ Beyond visual line of sight (BVLoS) approval required: CAA provided written, signed permission specifically mentioning BVLoS operations, in which the aircraft flies past the operator’s sight and is controlled by data provided by on-board instruments

☐ Other approval required: ____________________________

2. Date of flight permission secured: ____________________________

3. Duration of flight permission

☐ One-time: One flight or one day of flights is permitted

☐ Limited duration: An end date is specified

☐ Unlimited duration: Permission for ongoing operations without an end date specified

4. Location of flight permission

☐ Site specific permission

☐ Broad geographic permission

☐ Other: ____________________________
Appendix 4: Stakeholder and community acceptance interview tools (Indicator 1.2.1)

Indicator 1.2.1: Stakeholder and community acceptance of UAS (qualitative)

Adapted from: VillageReach

When adapting these tools for qualitative data collection:

- Conduct key informant interviews (KIIs) with individuals who have influence in the area, such as community leaders, provincial officials, and health workers. Consider 2-3 respondents from each take-off and landing site.
- Conduct focus group discussions (FGDs) with groups of community members at 2-3 take-off and landing sites so that you have data from multiple perspectives.
- Participants in FGDs should be the same sex, so men should participate in separate FGDs from women.
- Use locally acceptable terms in the interview guide, such as drones instead of UAS.
- Prepare photographs of the drone technology that will be flown in the targeted area to show FGD participants because they may not have heard of drones before.
- Train FGD facilitators and ensure that they understand drone technology and are able to answer any questions that arise.

Focus group discussion (FGD) tool for community members

Instructions for the facilitator: Near the hospital and near the health clinics, focus group discussions (FGDs) will be held separately with men and with women from the community. Each FGD should consist of approximately 10 people (8 at minimum, 12 at maximum).

Participants in the FGD for community members should NOT be:

- Health workers
- Religious, political or other leaders
- Members of the same family

Informed consent must be obtained from each participant before the FGD begins. Read the informed consent form to the group. Offer to answer any questions, then ask if the participants want to sign or place their fingerprint. If anyone does not want to sign or place their fingerprint, you will thank them for their time and continue the FGD without them.

After informed consent has been completed for each participant, ask the questions below. Encourage all participants to respond to all questions to the best of their ability, but it is ok if participants choose not to answer all questions.

Introduction (to be read by facilitator): [Insert name] is an organization that is working with the Ministry of Public Health to help improve the transportation of medical products to rural health facilities. In this study, we want to find out how a technology called drones could deliver vaccines.

(Show the photographs of drones, and pass them around.)
I would like to ask your thoughts on this technology. Any information you share here is confidential and will not be associated with you. Your participation is voluntary, and you can stop participating at any time. There is no penalty or benefit for participating. You don’t have to answer any of the questions if you don’t want to.

**If FGD:** Number of participants in the FGD: ________   Sex of participants: ________

**If KII:** Title of KII respondent: ____________________   Sex of respondent: ________

### Questions

#### Familiarity with drones

1. Before today, how many of you had heard of drones?
   a. For those who have heard of drones, what do you know about them?
   b. For example, what are they used for?
2. Drones are small airplanes that can fly without a pilot onboard, and sometimes, they can carry items or take photos. What are your opinions of drones, now that you know about them?

#### Benefits of drones

3. Do you think there are any benefits to using drones to carry medicines? If yes, what?
4. Are there other health products that you think drones could be used to transport?
5. Are there any other ways that you think drones could be used in your country, other than transporting health products?

#### Risks of drones

6. Do you think there are any risks to using drones to carry [insert name of health product or category of products]? If yes, what?
7. Thinking about the concerns you have identified, do you think any of these are very serious? If yes, which ones?

#### What to transport, when, and where

8. If you or a family member were to go to the health center to receive treatment, and the treatment had been delivered by drone, would you have any concerns? If yes, what?
   a. Allow the group to respond, then ask: Would you think that the medicine is the same quality and effectiveness as medicine transported by ground methods? Why or why not?
9. Are there any items that you do NOT think drones should be used to transport?
   a. Why should they not be used for those products?
   b. Allow the group to respond, then ask: Are there any products that you think would not be kept safe or would not be good quality if transported by drone? Why or why not?
10. Are there times of day or days of the week when a drone should not fly in the community? If yes, why?
11. Are there places in the community where people might feel uncomfortable seeing drones flying overhead? If yes, why?
12. In general, would you recommend that the Ministry of Health use drones to transport medicines to health centers? Why or why not?

#### Communication strategies for drones

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13. Are there any groups of people or individuals that you think would be particularly interested in the drone flights? Why?

14. Are there any groups of people or individuals that you think would be particularly concerned about, afraid of, or confused about drone flights? Why?

15. Before we test the use of drones in your community, who should we share information with? What information should we share to help them understand?

16. How should we share information with your community about drones?
   a. Allow the group to respond, then ask: Do you think that if we show videos, photos, or demonstrate how the vehicle flies, this will help people understand the technology?

17. Is there a particular person or group in your community that you can trust to share information like this with the rest of the community?

18. Is there any other information or recommendations about the introduction of drones that you would like to share?
Appendix 5: Transport Time Comparison Database (Indicator 1.2.3.a)

**Indicator 1.2.3.a: Transport time for UAS in comparison to ground transport**

*Adapted from: VillageReach*

**Instructions:** This table is intended to compare ground transport time and distance to drone transport time and distance. As presented, it facilitates calculation of point-to-point transport time and distance (from product warehouse to delivery site and back), but can be adapted to calculate average time and distance over multi-stop routes. To estimate transport distances or times, GPS points can be input into an online mapping tool such as Google Maps or ArcGIS or local health staff can provide this information.

Warehouse name: ________________________

GPS points: ______________________________

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<th>#</th>
<th>A. Health facility</th>
<th>B. GPS points (Latitude, longitude)</th>
<th>C. Distance</th>
<th>D. Time</th>
<th>E. Distance</th>
<th>F. Time</th>
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Average

Average
Appendix 6: Pre- and post-flight checklist (Indicators 1.3.1-1.3.3, 2.3.1-2.3.4)

Indicator 1.3.1, 2.3.1: Number of successful flights conducted
Indicator 1.3.2: Maximum flight distance achieved before landing, in kilometers
Indicator 1.3.3: Maximum payload carried per flight, in kilograms
Indicator 2.3.2: Number of days of sustained flights
Indicator 2.3.3: Average flight distance achieved before landing, in kilometers
Indicator 2.3.4: Average payload carried per flight, in kilograms

Adapted from: WeRobotics

Instructions: Operational performance data should be collected for every flight at take-off and landing to document achievement and challenges. Each flight should be recorded in a single row in a database consolidating all flights. The data points in bold below should be totaled to respond to the indicators listed above, and the maximum (Phase 1) or average (Phase 2) achieved can be totaled for distance (Indicators 1.3.2 and 2.3.3) and payload weight (Indicators 1.3.3 and 2.3.4). If two-way product transport is achieved, the below form can be adapted so that the sending and receiving team can both record the payload contents, weight, and conditions upon sending.

Sending team:
Date: ________________
Person completing form: ________________
Person sending drone: ________________
Flight #: ___________
Payload contents (number and type):
_____________________________________
Payload weight (kg): ____________________
Payload conditions: _____________________
Takeoff location: _______________________
Battery voltage at take-off: ______________
Take-off weather conditions: _____________
Take-off time: _________________________
Expected flight distance: _________________
Expected flight time: ____________________
Receiving team contacted (yes/no): ________
Communications maintained (yes/no): ______
Observations: __________________________

Receiving team:
Person completing form: ________________
Person sending drone: ________________
Sending team contacted (yes/no): __________
Landing site: ___________________________
Condition of drone: _____________________
Battery voltage at landing: _______________
Weather conditions at landing: _____________
Landing time: ___________________________
Distance flown (km): _____________________
Payload conditions: _____________________
Observations: __________________________
_____________________________________