UAVs in Global Health: Use Case Prioritization

DECEMBER 2018

ISG UAS
Coordinating Body

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The Interagency Supply Chain Group (ISG) Unmanned Aircraft Systems (UAS) Coordinating Body

The ISG UAS coordinating body supports Governments, country stakeholders, donors, technology and implementing partners to make more informed decisions about integrating Unmanned Aircraft Systems (UAS) in supply chain systems to improve global health outcomes. This is achieved by aligning supply-chain strengthening and/or system redesign efforts as a means of better leveraging investments, in the face of future growing demands, and guiding outcomes towards a meaningful impact in country systems.

To learn more, visit https://isg-health.org/uas-coordinating-body.

Executive summary

In June 2018, a coordinating body for unmanned aerial vehicles (UAVs) in global health launched under the Interagency Supply Chain Group (ISG). The body is focused on executing key activities outlined in Stage 2 of the Investment Roadmap published in the 2017 paper, *UAVs in Global Health: Defining a Collective Path Forward*. The breadth of this work will include:

- Systemic analyses to prioritize use cases, develop business cases, create M&E frameworks, and define funding models
- Mapping and gap analysis of regulations, infrastructure, and other key enablers to support execution

In this presentation we provide a foundation for both: (1) prioritizing a short list of use cases for UAV's in global health and (2) beginning to detail the requirements to operationalize these use cases.

(1) The four 'shortlisted' use cases for UAV's in global health are:

A Delivery in response to medical emergencies
B "Just in Time" resupply to campaigns
C "Just in Time" resupply to health clinics
D 2-way transport of diagnostic samples and treatment

(2) We have also developed a proposed framework to evaluate the impact, cost, and feasibility of these use cases on a country-level.

Please note that these proposed findings are a version 0 and we will continue to gather input to best reflect the expertise of stakeholders across the UAV and global health space.

- We have developed these requirements based on input from ~30 expert interviews as well as findings from desk research
- We acknowledge that the number of interviews was limited by our timeline and that we may not have captured all points of view

We look forward to hearing your thoughts and feedback on this work, and hope that it can be leveraged to align on a collective set of next steps through the UAV coordinating body as well as the broader global health community as it explores and invests in this area. Please provide any feedback on the ISG UAS Coordinating Body website: https://isg-health.org/.

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Aspiration for UAVs in Global Health

We believe UAVs will play a fundamental role in the global health supply chain

Near-term (0-5 years):

Prove the concept

Field tests gather data on impact & cost of UAVs in global health supply chain

Use cases evolve based on impact, cost, and feasibility assessments

Use cases begin to scale as impacts are validated





Medium-term (5-10 years):

Bring to scale

UAVs are used for multiple use cases and in many geographies, beginning to create at-scale "ecosystems"

UAVs begin to alter the fundamentals of the global health supply chain, e.g., reducing inventory requirements



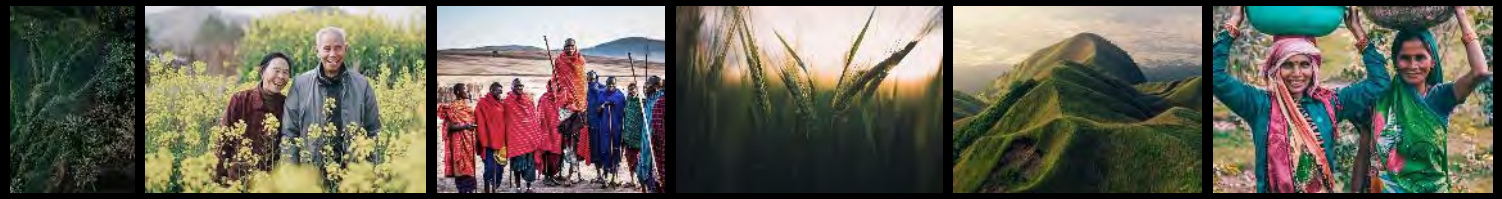


Long-term (10-20 years):

Transform

UAVs enable transformational change:

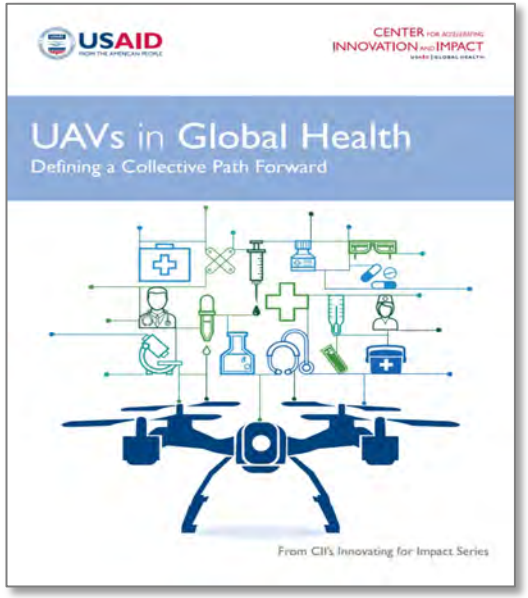
- Eliminate stock outs for key health interventions
- Reconfigure supply chains to function "Just In Time" with central supply hubs
- Reduce deaths due to lack of access to life-saving products



Project Summary

In February 2018, a group of donors in the global health community convened to discuss ways to coordinate UAV investments

USAID's report *UAVs in Global Health: Defining a Collective Path Forward* **laid out an investment roadmap with opportunities for our collective path forward for UAVs in global health.**



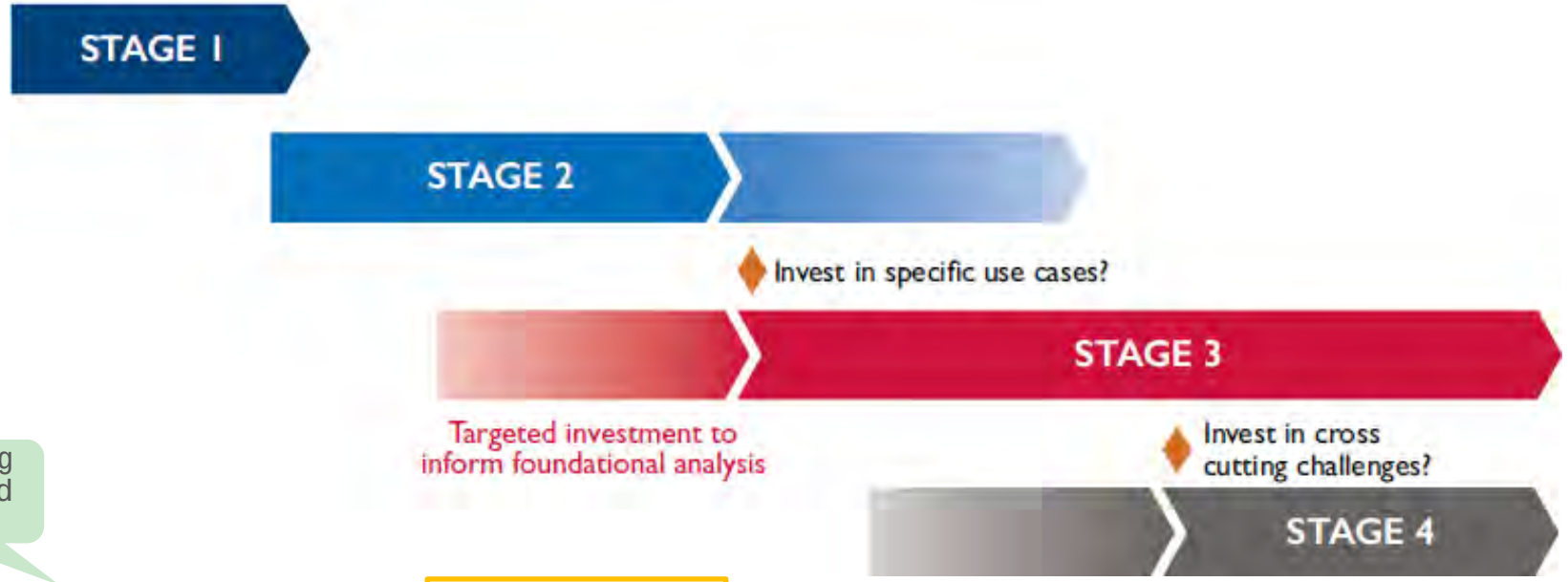
Following discussions led to the **formation of a coordinating body**, launched in June 2018 to support countries, donors, & implementing partners to **make more informed decisions on how to apply UAVs in global health.**

USAID FROM THE AMERICAN PEOPLE
BILL & MELINDA GATES foundation
Gavi The Vaccine Alliance
unicef
UKaid from the British people
The Global Fund To Fight AIDS, Tuberculosis and Malaria
giz

Source: "UAVs in Global Health: Defining a Collective Path Forward," USAID CII (https://www.usaid.gov/cii/uavs-global-health)

By forming this coordinating body, we are now in Stage 2 of our four-stage investment roadmap

Investment roadmap



Coordinating Body formed in July '18

STAGE 1
Catalogue existing working groups and committees exploring UAVs for global health, and stand up a coordinating body to help align and steer future efforts

STAGE 2
Conduct foundational analysis to define and prioritize use cases and understand market trajectory and anticipated challenges

STAGE 3
Make targeted investments in select use cases to address roadblocks and help smooth path to scale

STAGE 4
With a better understanding of market trajectory, invest strategically in larger scale cross-cutting challenges

Source: "UAVs in Global Health: Defining a Collective Path Forward," USAID CII (https://www.usaid.gov/cii/uavs-global-health)

This project is a first step in Stage 2 to prioritize use cases and detail requirements to inform TPPs, business cases, M&E framework, & gap analyses

Analyses defined in "Stage 2" of Investment roadmap

	USE CASE PRIORITIZATION	COST EFFECTIVENESS	GAPS ASSESSMENT
UAV coordination group	Audit and characterize existing use cases		
	Create framework to evaluate use cases	Create framework to assess cost effectiveness	Characterize UAV infrastructure needs
	Define and prioritize global health use cases based on impact, cost effectiveness, and probability of success		Define principles for ideal UAV regulations
	Create standardized TPP framework		*Note: Preliminary output; to be refined*
Individual stakeholders	Establish TPPs for prioritized use cases		Map UAV infrastructure across countries
	Size UAV market for prioritized use cases		Map regulations across countries
			Monitor technology development / gaps

Focus of this effort

Prioritizing use cases is foundational first step

Enables us to be focused in how we invest time and resources going forward to create

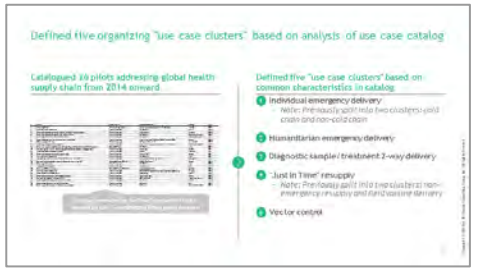
- TPPs
- Market sizing / business cases
- Infrastructure and regulatory gap analysis
- M&E framework

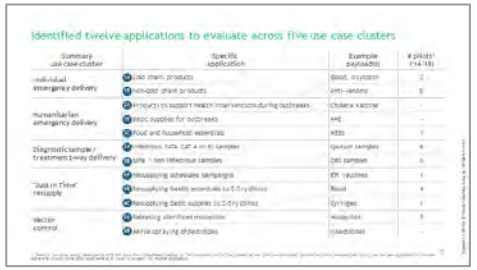
Source: "UAVs in Global Health: Defining a Collective Path Forward," USAID CII (https://www.usaid.gov/cii/uavs-global-health)

Our approach to identify and prioritize use cases in the first phase of this project

Created catalog of use cases

Organized catalog around 5 use case clusters with 12 detailed applications:



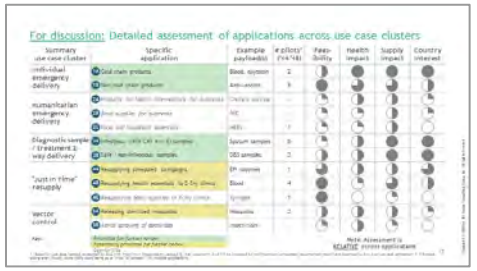


Aligned on prioritization criteria

Identified lenses to prioritize use cases: feasibility, potential health impact, potential supply chain impact, country interest

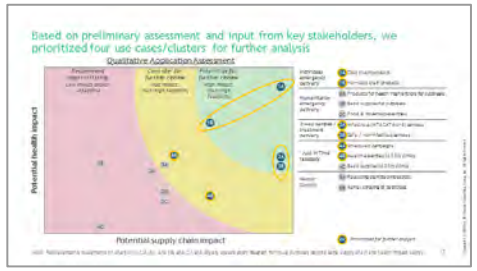
Evaluated use cases based on criteria

Synthesized insights from desktop research and expert interviews to qualitatively assess each use case:



Facilitated workshop to prioritize use cases

Conducted workshop on 9-27 with USAID, VillageReach, and the UAV Coordinator for the ISG Group to prioritize use cases



Many interviewees provided input as part of this project

- Amy Lehman, Lake Tanganyika Floating Health Clinic
- Andrew Schroeder, WeRobotics
- Ansgar Kadura, Wingcopter
- Astrid Knoblauch, Stony Brook University
- Barry Koperberg, Wings for Aid
- Brittany Hume Charm, Zipline
- Christian Vazquez Paez, UNICEF Vanuatu
- Clifford Sweatte, WFP
- Dan Singer, CDC
- Denise Soesilo, FSD
- Dirk Rabien, GIZ
- Edward Anderson, World Bank
- Edward Llewellyn, Africa Resource Centre
- Enrique Paz, UNICEF Madagascar
- Hastings Jailosi, CAA Malawi
- Helena Samsioe, GLOBHE
- Joanie Robertson, PATH
- Judith Sherman, UNICEF Malawi
- Julia Bem, USAID
- Kameko Nichols, The Nichols Group
- Katie Qutub, USAID
- Kevin Etter, UPS
- Marga Eichleay, FHI360
- Martin Ellis, Global Fund
- Matiko Machagge, JSI
- May Chu, Office for Science and Technology Policy (OSTP), formerly CDC
- Scott Dubin, Chemonics
- Simon Grandjean Lapierre, Stony Brook University
- Timothy Amukele, Johns Hopkins University
- Xavier Tomsej, USAID

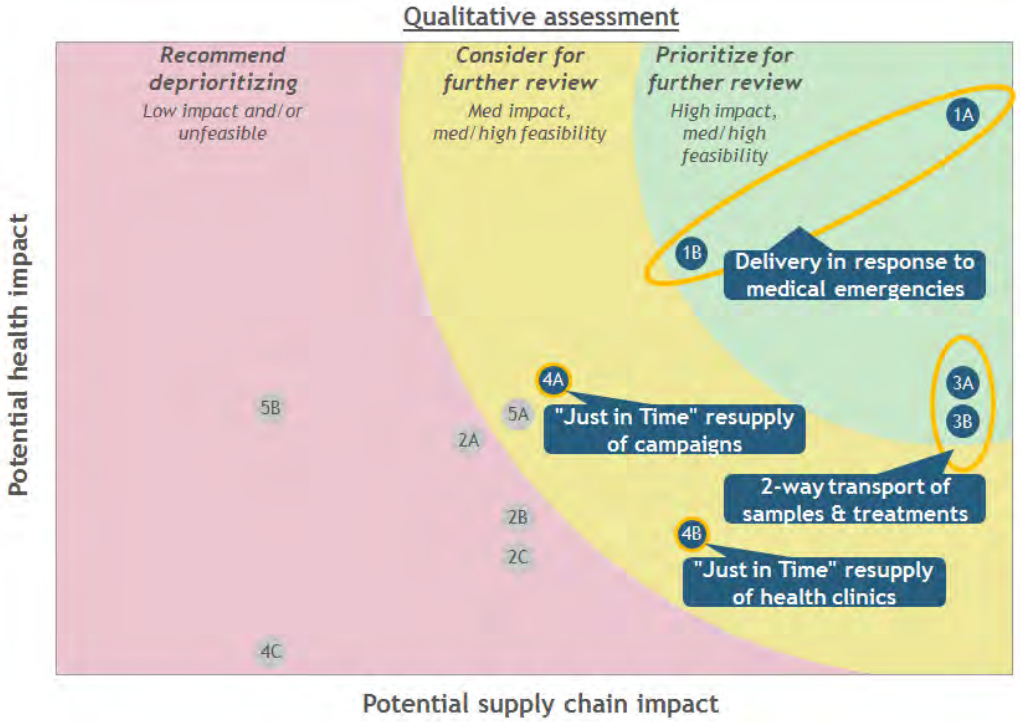
Note: Interviewees listed in alphabetical order by first name

Our ingoing assumptions in assessing use cases

- ✓ **Evaluating feasibility in terms of executing use case over five-year horizon**
- ✓ **Only evaluating supply chain-related use cases, e.g., excluding mapping / surveillance**
- ✓ **Excluding cargo-related supply chain use cases from consideration (i.e., payloads >100kg)**
- ✓ **Assessing use cases against each other as opposed to defined benchmarks**

Based on preliminary assessment and input from key stakeholders, we prioritized four use cases /clusters for further analysis

1. **Delivery in response to medical emergencies**
2. **"Just in Time" resupply of campaigns**
3. **"Just in Time" resupply of health clinics**
4. **2-way transport of samples and treatments**



Long-list of use cases for prioritization

Use case	Use case application
Individual emergency delivery	1A Cold chain products
	1B Non-cold chain products
Humanitarian emergency delivery	2A Products for health interventions for outbreaks
	2B Basic supplies for outbreaks
	2C Food & household essentials
2-way samples / treatment delivery	3A Infectious (IATA CAT A or B) samples
	3B Safe / non-infectious samples
"Just In Time" resupply	4A Scheduled campaigns
	4B Health essentials to 2-3ry clinics
	4C Basic supplies to 2-3ry clinics
Vector Control	5A Releasing sterilized mosquitos
	5B Aerial spraying of pesticides

XX *Prioritized for further analysis*

It's important to note that "prioritized" use cases reflect current understanding of impact and feasibility as of 2018 and are intended to help focus efforts on the areas where UAVs are likely to provide the most value in the near term. This is not intended to proscribe investment in other use cases if donors and other stakeholders have a good appreciation of the likely impact and feasibility.

Note: Representative placements on chart only

Although we have assessed use cases independently, we expect operators to "layer" use cases to maximize utilization

Prioritized use cases

- Delivery in response to medical emergencies
- "Just in Time" resupply to campaigns
- "Just in Time" resupply to health clinics
- 2-way transport of diagnostic samples & treatment

Other global health use cases, e.g.,

- Aerial image and mapping
- Deliveries in response to humanitarian emergencies

Other commercial use cases, e.g.,

- Deliveries of commercial goods and packages
- Transport of specialized payloads (e.g., semen for artificial cow insemination)

Use case definition: Underlying characteristics of four prioritized use cases

Use case	Description	Example focus conditions[1]	Example payloads
A **Delivery in response to medical emergencies**	• Urgent delivery of light payloads of products for health interventions for individuals suffering from common emergencies with defined treatments but in situations in which necessary products are unavailable	• PPH, venomous snake bites, Rabies, Tetanus, Birth Asphyxia, (Pre)-eclampsia	• Blood, Oxytocin, anti-venom, emergency vaccines, Bubble CPAP parts, magnesium sulfate
B **"Just In Time" resupply of campaigns**	• Delivery of multiple vaccine doses on an as-needed basis to field sites for scheduled campaigns like EPI and for semi-scheduled campaigns as needed for outbreak response	• Diphtheria / Tetanus / Pertussis (DTP Vx), Tuberculosis, Measles / Mumps / Rubella (MMR Vx), Polio	• Vaccines
C **"Just In Time" resupply of health clinics**	• Delivery of moderate payloads of medical supplies on an as-needed basis to 2ry-3ry health clinics (and not field sites) as required to maintain pre-determined inventory levels	• Varies	• Blood, medications, high-value medical supplies (e.g., specialty syringes)
D **2-way transport of diagnostic samples and treatment**	• Collection of medical samples for diagnosis for individuals or groups of individuals and delivery of treatment for diagnosed conditions	• Tuberculosis, HIV, Cholera, Ebola, Measles, HBV	• Sputum samples, blood samples (live, dried), stool samples

1. Ranked by indicative relevance of UAVs (combination of severity of health condition and incremental value of using UAVs to address health condition)

Use case definition: Different tiers of potential payloads based on incremental value of using UAVs to carry payload *(note: exact tiers vary by use case)*

Increasing incremental value of using UAVs

	Tier 1: High-value, short shelf-life products	Tier 2: Other high-value products	Tier 3: Other often out-of-stock products	Tier 4: Remaining products
Description	• Expensive products that quickly become unfit for use because of cold chain or packaging requirements	• Other products that are expensive on unit cost basis and therefore not always stocked	• Other products that are often out-of-stock (e.g., because of cold chain requirements)	• Remaining products that do not fit into first three tiers • Products with unpredictable demand to be prioritized in tier
	• Across these tiers, unpredictability of demand for given product can exacerbate out-of-stock situations			
Examples	• Blood for transfusion • Oxytocin • Live samples (e.g., blood) • Emergency vaccines (e.g., rabies)	• Anti-venoms	• Antibiotics such as amoxicillin or Flagel • Magnesium Sulfate	• Varies
Potential supply chain impact	• Enable use of products at clinics that cannot store them • Reduce cold chain storage costs for other clinics • Reduce other holding costs by centralizing inventory • Reduce risk of stock-outs • Reduce inventory waste	• Enable use of products at clinics that do not typically stock them • Reduce stock-outs at other clinics • Reduce holding costs by centralizing inventory	• Increase availability and reduce stock-outs of these products at clinics that need them by facilitating resupply	• Limited

Note: Payloads that fit into multiple tiers would be considered as part of most important tier classification

Considering requirements for each use case across three categories: UAV technology, infrastructure, and regulation / policy

UAV Technology

What does each use case require in its UAV equipment with regard to

- Payload weight and volume
- Specialized handling, e.g.,
  - Cold chain
  - Packaging
- Flight characteristics, e.g.,
  - Takeoff / landing
  - Range

Infrastructure

What does each use case require in support infrastructure with regard to

- Physical, e.g.,
  - Ground equipment
  - Navigation
- Human capital, e.g.,
  - Resources
  - Training
- Supply chain integration, e.g.,
  - Sending
  - Receiving
- Process design

UAV Technology and Infrastructure requirements considered on a "Minimum Viable" and "Optimal" basis

Regulation / Policy

What requirements does each use case have with regard to

- Regulations affecting
  - Flight
  - Payload
- Policy guidelines

Work in Progress

Summary: Likely need 2 UAV models designed to minimum viable requirements in near-term; more models needed over time to realize optimal requirements

	Minimum Viable	Optimal
A Delivery in response to medical emergencies	**Type 1** • **Payload:** ~1-2kgs weight and ~1.2L volume • **Cold chain:** N/A if short flight, otherwise ice pack for passive cooling (1 ice pack is ~0.5kg and ~0.5L, number of required units TBD) • **Remote take-off/landing:** No landing required at destination; payloads can be dropped • **Range (1-way):** >50km	**Type 3** • **Payload:** ~4-6kgs weight and ~7L volume • **Cold chain:** Replaceable containers: no cooling and active cooling • **Remote take-off/landing:** No landing required at destination; payloads can be dropped • **Range (1-way):** TBD but expect >100km one-way
B "Just In Time" resupply of campaigns		
C "Just In Time" resupply of health clinics		**Type 4** • **Payload:** ~10-14kgs weight and TBD volume • **Cold chain:** Same as Type 3 • **Remote take-off/landing:** Landing possible at dest if heavy payload • **Range (1-way):** TBD but expect >100km one-way
D 2-way transport of samples & treatments	**Type 2** • **Payload:** Same as Type 1 • **Cold chain:** Same as Type 1 • **Remote take-off/landing:** Landing req'd at dest • **Range (1-way):** Same as Type 1	**Type 5** • **Payload:** ~4-6kgs weight and TBD volume • **Cold-chain:** Same as Type 3 • **Remote take-off/landing:** Landing req'd at dest (multiple stops) • **Range (1-way):** TBD but expect >100km one-way

Differences in operating environments may drive need for additional UAV types

Work in Progress

Existing technology can support payload and range of prioritized use cases on a "Minimum Viable" basis

Type 1 "Minimum Viable" Specifications

	Payload (~1.2kg weight, ~1.2L volume)	Cold chain (N/A if short flight otherwise passive cooling	Remote take-off / landing (no landing req'd at dest, payload drop)	Range one-way >50 km one-way
Small hybrid 1 (e.g., Vayu)	• ~2kg • ~8L ✓	• No active ✓	• TBD; VTOL capable ✓	• ~30km ✗
Small hybrid 2 (e.g., Wingcopter)	• ~2-6kg • ~13L ✓	• No active ✓	• TBD; VTOL capable ✓	• ~50 - -100km ✓
Multicopter (e.g., Matternet)	• ~2kg • ~10L ✓	• No active ✓	• TBD; VTOL capable ✓	• ~10km ✗
Small fixed wing (e.g., Zipline)	• ~1.5kg • ~10L ✓	• No active ✓	• No ✓	• ~150km ✓

Type 2 "Minimum Viable" Specifications

	Payload (~1.2kg weight, ~1.2L volume)	Cold chain (N/A if short flight otherwise passive cooling	Remote take-off / landing (landing req'd at dest)	Range one-way >50 km one-way
Small hybrid 1 (e.g., Vayu)	• ~2kg • ~8L ✓	• No active ✓	• TBD; VTOL capable ✓	• ~30km ✓
Small hybrid 2 (e.g., Wingcopter)	• ~2-6kg • ~13L ✓	• No active ✓	• TBD; VTOL capable ✓	• ~50 - -100km ✓
Multicopter (e.g., Matternet)	• ~2kg • ~10L ✓	• No active ✓	• TBD; VTOL capable ✓	• ~10km ✗
Small fixed wing (e.g., Zipline)	• ~1.5kg • ~10L ✓	• No active ✓	• No ✗	• ~150km ✓

✓ Meets min viable specs ✓ Potentially meets min viable specs ✗ Does not meet min viable specs

Note: Specifications for different UAV technologies sourced by January 2018 report, "What should you deliver by unmanned aerial systems?" (http://www.villagereach.org/wp-content/uploads/2018/02/JSI-UAV-Report.pdf); specifications for Wingcopter sourced from the company's website (https://wingcopter.com)

Initial mapping of UAV technology requirements will be an input into the development of TPPs

TPP attributes that we have partially addressed as part of our mapping of requirements

- **Summary descriptions, including**
  - Target populations
  - Target conditions
- **Potential payloads, including**
  - Weight and volume
  - Specialized handling requirements
- **Flight requirements, including**
  - Range
  - Remote take-off / landing needs
- **Infrastructure requirements, including**
  - Human capital
  - Training
  - Supply chain integration

TPP attributes that we have not yet addressed

- **Target countries**
- **Desired cost**
- **Desired service level**
- **Operating condition requirements in target countries**
- **Safety requirements**
- **Reliability requirements, including**
  - Frequency of replacement of key components (e.g., batteries)

Work in Progress

Differing "Minimum Viable" infrastructure requirements for prioritized use cases

Yellow shading indicates distinct requirement vs. other use cases

Infrastructure requirements		A Delivery in response to medical emergencies	B "Just In Time" resupply to campaigns	C "Just In Time" resupply to health clinics	D 2-way transport of samples / treatments
Physical Infra-structure	UAV support equip.	• Runway/launcher • Power resupply (e.g., batteries) • Spare parts within TBD hours			• Power resupply (e.g., batteries) • Spare parts within TBD hours
	Navigation	• Ideally 1 means of communication, but regulations might require redundancy • Pre-determined flight paths			
Human Capital	Resources	• 1:1 Operator to UAV ratio • TBD Dispatcher to UAV ratio • Health workers at destination	• 1:1 Operator to UAV ratio • TBD Dispatcher to UAV ratio • Workers at dest to retrieve payload	• 1:1 Operator to UAV ratio • TBD Dispatcher to UAV ratio • Workers at dest to retrieve payload	• 1:1 Operator to UAV ratio • TBD Dispatcher to UAV ratio • Health workers at destination
	Training	• Load/unload payloads • Create drop zones at clinics • Administer health interventions	• Load/unload payloads • Create drop zones at field sites • Administer vaccines	• Load/unload payloads • Create drop zones at clinics	• Load/unload payloads • Relaunch UAV for return flight
Supply Chain Integration	Sending	• UAV operates within proximity of stores of relevant medical supplies	• UAV serves defined role in campaign and pre-selected field sites for delivery	• UAV operates within proximity of stores of relevant medical supplies	• Defined laboratory to serve as stop for UAVs • Communications pathway to notify clinic of diagnosis results
	Receiving	• UAV delivers payload to clinic that can store or immediately utilize payload in question			
Process Design	Ordering	• Call-to-order within XX hours notice	• Scheduled vaccine delivery flights at defined cadence (e.g., monthly)	• Call-to-order within XX hours notice	• Scheduled sample pick-up flights at defined cadence (e.g., weekly)

Work in Progress

Differing "Optimal" infrastructure requirements for prioritized use cases

Yellow shading indicates distinct requirement vs. other use cases

Infrastructure requirements		A Delivery in response to medical emergencies	B "Just In Time" resupply to campaigns	C "Just In Time" resupply to campaigns	D 2-way transport of samples / treatments
Physical Infra-structure	UAV support equip.	• Spare parts stored at launch site			
	Navigation	• Single failsafe comms means • Ability to quickly onboard new flight paths			
Human Capital	Resources	• 1:many Operator to UAV ratio • TBD Dispatcher to UAV ratio			
	Training	• N/A			• "Push button return" to enable untrained operators to launch UAV for return flight if landing
Supply Chain Integration	Sending	• "Hub-and-spoke" model to aggregate sufficient demand of discrete emergency cases	• Sufficient inventory to enable true "Just In Time" delivery of inventory as req'd on given day		• Ability to dynamically choose labs for sample delivery based on lab processing capacity
	Receiving	• Cold chain equipment potentially required to store payloads after drop			
Process Design	Ordering	• Seamless ordering interface linked to inventory system; faster response time vs. minimum viable	• Call-to-order system to enable health workers to summon UAV within ~1-2 hours		

Summary: High-level infrastructure requirements across use cases

Evaluation of infrastructure requirements indicates different requirements along the following <u>three</u> dimensions: human capital, supply chain integration, and process design

- **<u>Human capital:</u>** Delivery in response to emergencies and 2-way transport of samples & treatment use cases require trained health workers even on a minimum viable basis
  - Trained health workers need to be available at destination to administer health interventions (e.g., blood for transfusion) and/or package them (e.g., samples)

- **<u>Supply chain integration:</u>** Each use case has different and unique requirements to ensure integration in an existing supply chain, e.g.,
  - Operating within proximity of medical stores
  - Departing and returning from specified laboratories

- **<u>Process design:</u>** Delivery in response to emergencies requires "call-to-order" fulfillment within TBD hours to ensure payloads arrive in time to address emergency

- *Note: Physical infrastructure needs do not drive different requirements across use cases*

Work in Progress

Differing regulatory and policy requirements for prioritized use cases

Orange highlighting indicates distinct requirement vs. other use cases

Regulation and policy requirements		A Delivery in response to medical emergencies	B "Just In Time" resupply to campaigns	C "Just In Time" resupply to health clinics	D 2-way transport of samples / treatments
Regulations	Flight	• Approval from military • Approval for BVLOS flights • Potential approval for **mid-air release of payloads** • Potential approval to **file flight plans ASAP given emergency** • Interaction model with ATC	• Approval from military • Approval for BVLOS flights • Potential approval for **mid-air release of payloads** • Interaction model with ATC	• Approval from military • Approval for BVLOS flights • Potential approval for **mid-air release of payloads** • Interaction model with ATC	• Approval from military • Approval for BVLOS flights • Interaction model with ATC
	Payload	• Potential approval for transport of **human specimens (e.g., blood)** even if not toxic • Potential approval for delivery of **items for which limited medical inventories in country**	• Potential approval for delivery of **items for which limited medical inventories in country**	• Potential approval for transport of **human specimens (e.g., blood)** even if not toxic • Potential approval for delivery of **items for which limited medical inventories in country**	• Approval for transport of samples, in particular for **infectious (IATA Category A and B) samples**
Policies & Guidelines		• Adjustment of **emergency treatment protocols for relevant conditions** to incorporate use of UAVs • Guidelines to import UAVs • Guidelines to contract with foreign organizations • Guidelines for community engagement in target areas	• Adjustment of **treatment and supply protocols for vaccine campaigns** to incorporate use of UAVs • Adjustment of **treatment and supply protocols for outbreak responses** to incorporate use of UAVs • Guidelines to import UAVs • Guidelines to contract with foreign organizations • Guidelines for community engagement in target areas	• Adjustment of **inventory storage guidelines** to reflect ability for UAVs to reduce inventory requirements at clinics by enabling "Just In Time" delivery from hub sites • Guidelines to import UAVs • Guidelines to contract with foreign organizations • Guidelines for community engagement in target areas	• Adjustment of **sample collection protocols for relevant conditions** to incorporate use of UAVs • Adjustment **of treatment delivery protocols for relevant conditions** to incorporate use of UAVs • Guidelines to import UAVs • Guidelines to contract with foreign organizations • Guidelines for community engagement in target areas

Summary: High-level requirements on regulation & policies across use cases

Evaluation of regulatory implications indicates that most regulations will apply across use cases, e.g.,

- Approvals from Country CAA (and potentially military) for flight, in particular BVLOS
- Defined interaction model with ATC

Some important differences noted along the following <u>two</u> dimensions

- **<u>Flight:</u>** Mid-air release of payloads for emergency delivery and resupply use cases might require special approval from Country CAA

- **<u>Payload:</u>** Transport of infectious samples is likely subject to existing regulations that follow IATA guidelines regarding packaging; non-infectious human specimens (e.g., blood for transfusion) might also require approval

- *Note: Transport of high-value and limited stock items might require separate approval from relevant administrations given limited availability in country*

Evaluation of policy guidelines indicates need to adjust and/or create guidelines across use cases as follows:

- Incorporate use of UAVs as part of existing treatment, sample collection, and inventory storage guidelines
- Create guidelines to facilitate importing UAVs
- Create guidelines to facilitate contracting of local health organizations with foreign UAV operators
- Create guidelines regarding community engagement

Potential next steps to address in 2019

Opportunities to explore and potentially pursue in 2019 to proceed with the UAVs in Global Health Roadmap

Further analyze use cases

- Respond to questions from use case prioritization

Develop evaluation criteria

- Develop M&E framework (e.g., indicators, data collection tools)
- Provide technical assistance on use of M&E toolkit

Assess business case for UAVs

- Conduct market sizing and landscape assessment for prioritized use cases
- Identify demand bottlenecks
- Assess potential UAV business models
- Develop UAV business case

Conduct country mapping

- Map operating conditions
- Identify regulations of UAVs and payloads
- Map infrastructure available to support UAVs

Conduct technical mapping

- Conduct technical landscape assessment to understand how current UAV technology addresses requirements
- Identify supply bottlenecks

Create Target product profiles

- Create TPP template
- Populate TPPs for prioritized use cases

Help build government capacity

- Outline key considerations for integrating UAVs into health systems
- Document best practices for procurement

Support community engagement

- Develop guidelines for stakeholder and community engagement

Appendix: detailed assessment

Please note before proceeding…

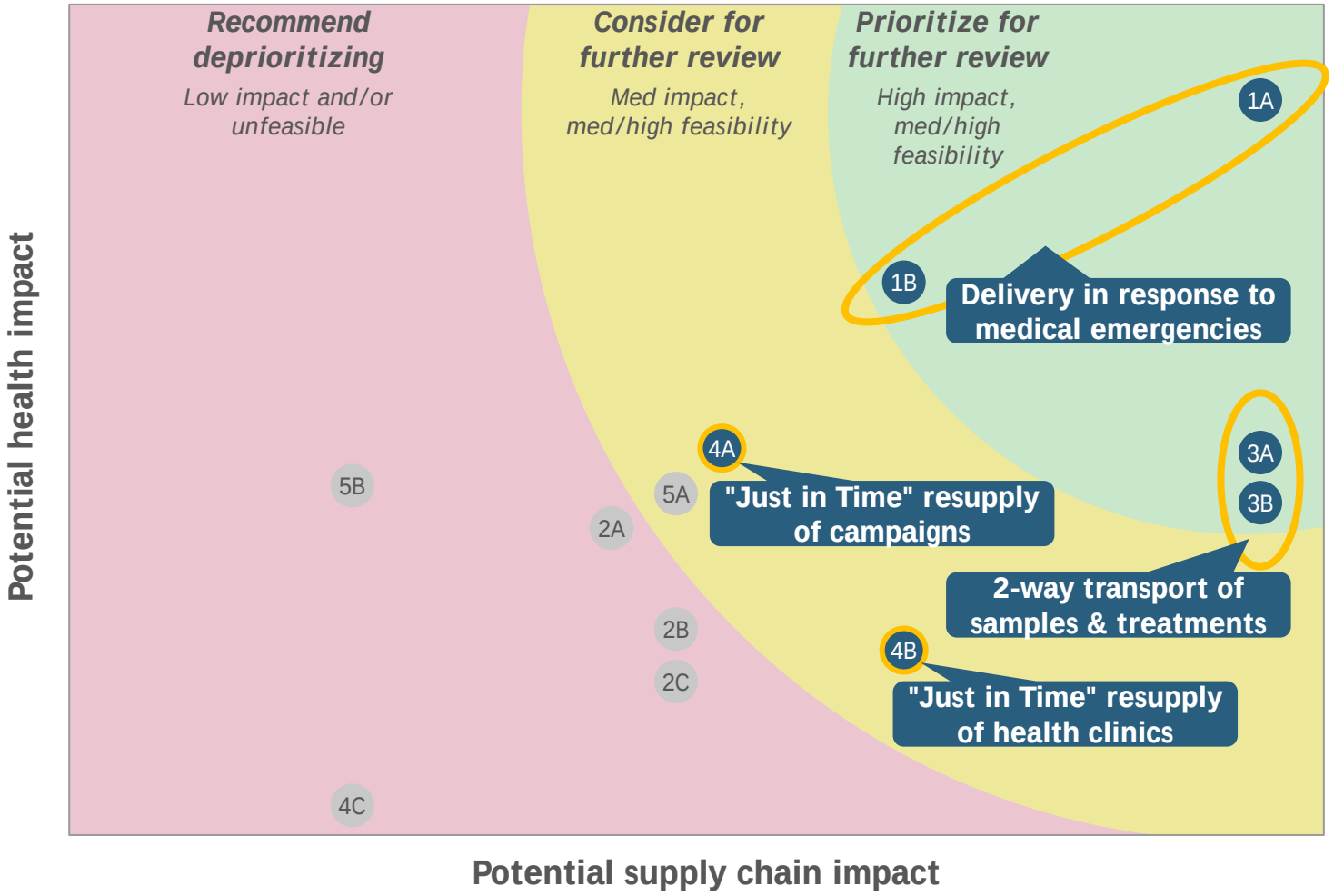
1. These proposed findings are a version 0, as we hope to continue to gather your input.

- We have developed these requirements based on input from ~30 expert interviews as well as findings from desk research.
- We acknowledge that the number of interviews was limited by our timeline and that we may not have captured all points of view.

2. It's important to note that "prioritized" use cases reflect current understanding of impact and feasibility as of 2018 and are intended to help focus efforts on the areas where UAVs are likely to provide the most value in the near term. This is not intended to proscribe investment in other use cases if donors and other stakeholders have a good appreciation of the likely impact and feasibility.

Based on preliminary assessment and input from key stakeholders, we prioritized four use cases /clusters for further analysis

Qualitative assessment



Long-list of use cases for prioritization

Use case	Use case application
Individual emergency delivery	1A Cold chain products
	1B Non-cold chain products
Humanitarian emergency delivery	2A Products for health interventions for outbreaks
	2B Basic supplies for outbreaks
	2C Food & household essentials
2-way samples / treatment delivery	3A Infectious (IATA CAT A or B) samples
	3B Safe / non-infectious samples
"Just In Time" resupply	4A Scheduled campaigns
	4B Health essentials to 2-3ry clinics
	4C Basic supplies to 2-3ry clinics
Vector Control	5A Releasing sterilized mosquitos
	5B Aerial spraying of pesticides

xx *Prioritized for further analysis*

Note: Representative placements on chart only

Detailed requirements:

A Delivery in response to medical emergencies

Work in Progress

A Delivery for medical emergencies: use case definition

Description	• **Urgent** delivery of **light payloads** of **products for health interventions** for **individuals** suffering from **common emergencies** with **defined treatments** but in situations in which **necessary products are unavailable**								
Function	• 1-way delivery	**Delivery Function**	• Sub-nat'l to field	**Cadence**	• Ad hoc	**Urgency**	• Individual emergency	**Demand**	• Variable

Potential payloads			
Tier 1 **High-value, short shelf-life**	**Tier 2** **Other high-value**	**Tier 3** **Other often out-of-stock**	**Tier 4** **Remaining**
• **Blood for transfusion** – Whole blood – Plasma • **Oxytocin** • **Emergency vaccines, e.g.,** – Rabies vaccine – TIG vaccine	• **AED** • **Anti-venoms** • **Bubble CPAP**	• **Praziquantel** • **Magnesium Sulfate** • **Antibiotics, e.g.,** – Amoxicillin – Flagel • **Bubble CPAP tubing (and other parts)** Note: Items in this tier based on debrief from PATH interviews with health clinics and pharmacists	• **Oral Rehydration Salts (ORS)**

Note: Payloads that fit into multiple tiers would be considered as part of most important tier classification; payloads approximately ranked high-to-low based on unit cost in LMIC countries in each tier based on best available estimates

Work in Progress

A Delivery for medical emergencies: UAV technology requirements (1/2)

Potential payloads	• **Tier 1:** Blood for transfusion, (whole blood, plasma), oxytocin, emergency vaccines (e.g., rabies vaccine, TIG vaccine) • **Tier 2:** AEDs, anti-venoms, Bubble CPAP • **Tier 3:** Praziquantel, Magnesium Sulfate, antibiotics (e.g., amoxicillin, Flagel), Bubble CPAP tubing (and other parts) • **Tier 4:** Oral Rehydration Salts (ORS)

Payload Specifications			Specialized Handling Requirements		
	Minimum Viable	**Optimal**		**Minimum Viable**	**Optimal**
Weight	• **~1-2kg payload** – Blood: 500mL bag is ~0.6kg[1] – Bubble CPAP tubing is TBD – Other drug and vaccine weights TBD, but expect <1kg given individual doses	• **~4-6kg payload** – 4+ units of blood – AED is ~2.0kg[2]	**Cold Chain needs**	• **No cooling or passive cooling as part of payload** – Cooling not required if payload is cold & flight time is short (≤~40min[5]) – Passive cooling possible, but at expense of payload (1 icepack unit is ~0.5kg, number of units TBD)	• **Compatible payload containers with / without active cooling** – Interchangeable containers enables UAV to also operate without cold chain, enabling higher weight / larger size payloads – Active cooling enables longer range flights and delivery to clinics with no cold chain
Size	• **~1.2L (dimensions of at least 105mm)** – 500 mL blood bag is 105x105mm (LxW)[3] – Bubble CPAP tubing is 50-100mmx3-6mm (LxW)[4] – Other drug and vaccine dimensions TBD, but expect small given individual doses	• **~7.0L (dimensions of at least 220x300x105mm)** – AED is 220x300x70mm[2]	**Other storage needs**	• **N/A (healthy blood is classified as an "Except Human Specimen" by IATA)**	

1. https://www.aqua-calc.com/calculate/volume-to-weight 2. http://www.defibtech.com/intl/lifeline/tech-specs 3. https://www.transfusionguidelines.org/red-book/chapter-26-specification-for-blood-pack-base-labels/26-2-specification 4. http://www.junnimed.com/system/download/FP%20Bubble%20CPAP%20System.pdf 5. Based on expert interviews regarding Zipline, which currently delivers blood with no active/passive cooling systems up to 80km away at 128 km/hr in which payload does not exceed 8ºC

Work in Progress

A **Delivery for medical emergencies**: UAV technology requirements (2/2)

Potential payloads	• **Tier 1:** Blood for transfusion, (whole blood, plasma), oxytocin, emergency vaccines (e.g., rabies vaccine, TIG vaccine) • **Tier 2:** AEDs, anti-venoms, Bubble CPAP • **Tier 3:** Praziquantel, Magnesium Sulfate, antibiotics (e.g., amoxicillin, Flagel), Bubble CPAP tubing (and other parts) • **Tier 4:** Oral Rehydration Salts (ORS)

Flight Characteristics			Other Requirements (unique to use case)		
	Minimum Viable	Optimal		Minimum Viable	Optimal
Remote take-off & landing	• No landing required; payloads can be delivered via drop (5x5m drop zone specified by UNICEF Vanuatu in their RFI)	• TBD optimal drop zone dimensions	TBD		
Range	• Beyond-visual-line-of-sight (BVLOS); range likely >50km to justify use of UAVs	• Optimal range TBD pending further country research	TBD		

Work in Progress

A Delivery for medical emergencies: Infrastructure requirements (1/2)

Potential payloads	• **Tier 1:** Blood for transfusion, (whole blood, plasma), oxytocin, emergency vaccines (e.g., rabies vaccine, TIG vaccine) • **Tier 2:** AEDs, anti-venoms, Bubble CPAP • **Tier 3:** Praziquantel, Magnesium Sulfate, antibiotics (e.g., amoxicillin, Flagel), Bubble CPAP tubing (and other parts) • **Tier 4:** Oral Rehydration Salts (ORS)

Physical Infrastructure			Human Capital / Training		
	Minimum Viable	Optimal		Minimum Viable	Optimal
UAV support equip.	• Runway and/or launching apparatuses • Power resupply • Spare parts available for delivery within TBD hours	• Spare parts stored at launch site	Human Capital	• 1:1 Operator to UAV ratio • TBD Dispatcher to UAV ratio • Health workers at destination to administer health interventions • Ad hoc fulfillment teams	• 1:many Operator to UAV ratio • TBD Dispatcher to UAV ratio • Dedicated fulfillment teams (full-time or contracted)
Nav-igation	• Ideally one means of communication (e.g., GSM), but regulations might require redundancy • Pre-determined flight paths and drop zones	• Single failsafe means of communication with ability to operate on lower bandwidth networks (e.g., 3G GSM) • Ability to quickly onboard new flight paths and drop zones	Train-ing	• Training to load / unload payloads • Training to administer health interventions	• N/A

Work in Progress

A Delivery for medical emergencies: Infrastructure requirements (2/2)

Potential payloads	• **Tier 1:** Blood for transfusion, (whole blood, plasma), oxytocin, emergency vaccines (e.g., rabies vaccine, TIG vaccine) • **Tier 2:** AEDs, anti-venoms, Bubble CPAP • **Tier 3:** Praziquantel, Magnesium Sulfate, antibiotics (e.g., amoxicillin, Flagel), Bubble CPAP tubing (and other parts) • **Tier 4:** Oral Rehydration Salts (ORS)

Supply Chain Integration			Process Design		
	Minimum Viable	Optimal		Minimum Viable	Optimal
Send-ing	• UAV operates within reasonable proximity of stores of relevant medical supplies	• "Hub-and-spoke" model to aggregate sufficient demand of discrete emergency cases • Hub sites have sufficient inventory of relevant payloads • Operations are conducted in partnership with relevant national bodies, e.g., National Blood Service or equivalent	Order-ing	• Call-to-order within XX hours notice	• Seamless ordering system (e.g., integrated LMIS, online order management tool) to ensure payloads are loaded and dispatched quickly given emergency nature of use case • Ordering system integrated with inventory management tools to ensure inventory accuracy
Receiv-ing	• UAV delivers payload to a clinic that can immediately utilize the payload in question	• UAV delivers payload to a clinic that can also store the payload in question (e.g., cold chain equipment available)	Other		

Work in Progress

A **Delivery for medical emergencies**: Regulation and policy implications

Potential payloads	• **Tier 1:** Blood for transfusion, (whole blood, plasma), oxytocin, emergency vaccines (e.g., rabies vaccine, TIG vaccine) • **Tier 2:** AEDs, anti-venoms, Bubble CPAP • **Tier 3:** Praziquantel, Magnesium Sulfate, antibiotics (e.g., amoxicillin, Flagel), Bubble CPAP tubing (and other parts) • **Tier 4:** Oral Rehydration Salts (ORS)

	Regulations	Policies & Guidelines
Flight	• Approval from Military may be required for flight operations depending on air space in question • Approval required from CAA for Beyond-Visual-Line-of-Sight flights • Approval potentially required from CAA for mid-air release of payloads • Approval potentially required from CAA to file flight plans on ASAP basis given emergency nature of use case • Depending on air space, defined interaction model required with existing country air traffic control management system	• Adjustment of treatment protocols for relevant conditions (e.g., post-partum hemorrhage, (pre-)eclampsia) to incorporate use of UAVs when relevant • Adjustment of storage protocols to reflect ability of UAVs to quickly deliver payloads from centralized hubs (e.g., protocols directing storage of blood for transfusion as set by National Blood Service or equivalent body) • Creation of guidelines to expedite import of UAVs and supporting equipment in coordination with relevant country authorities • Creation of guidelines for local companies and organizations (e.g., hospitals) to contract with foreign organizations to operate UAVs or provide support services • Creation of community engagement guidelines to publicize and normalize use of UAVs in target areas
Payload	• Approval from MoH potentially required for transport of human specimens (e.g., blood) even if not toxic substance • Approval from MoH potentially required for delivery of items for which limited medical inventories available in country (e.g., specialized antibiotics)	

A **Delivery for medical emergencies**: Backup list of interviewees that provided input regarding this use case

- **Andrew Schroeder, WeRobotics**
- **Ansgar Kadura, Wingcopter**
- **Brittany Hume Charm, Zipline**
- **Dan Singer, CDC**
- **Denise Soesilo, FSD**
- **Edward Anderson, World Bank**
- **Katie Qutub, USAID**
- **Kevin Etter, UPS**
- **Marga Eichleay, FHI360**
- **Martin Ellis, Global Fund**
- **Matiko Machagge, JSI**

Note: Interviewees listed in alphabetical order by first name; some interviewees provided input regarding multiple use cases and therefore appear on multiple lists

Detailed requirements:

B "Just In Time" resupply to campaigns

Work in Progress

B "Just In Time" resupply of campaigns: use case definition

Description	• Delivery of **multiple vaccine doses** on an **as-needed basis** to **field sites** for **scheduled campaigns** like EPI and for **semi-scheduled campaigns** as needed for outbreak response								
Function	• 1-way delivery	**Delivery Function**	• Sub-nat'l to field	**Cadence**	• Semi-scheduled	**Urgency**	• Non-emergency	**Demand**	• Regular

Potential payloads			
Tier 1 **Vaccines for outbreaks**	**Tier 2** **EPI vaccines for campaigns**	**Tier 3** **Other vaccines for periodic campaigns**	**Tier 4** **Remaining**
• **Cholera vaccine** • **Ebola vaccine** • **Polio vaccine (oral)**	• **Diphtheria / Tetanus / Pertussis (DTP) vaccine** • **Tuberculosis vaccine** • **Hepatitis B vaccine** • **Measles, Mumps, and Rubella (MMR) vaccine** • **Polio vaccine (inactivated)**	• **Rotavirus vaccine** • **Hepatitis A vaccine** • **Typhoid vaccine** • **Influenza vaccine**	• **N/A**

Note: Payloads that fit into multiple tiers would be considered as part of most important tier classification; payloads approximately ranked high-to-low based on unit cost in LMIC countries in each tier based on best available estimates

Work in Progress

B "Just In Time" resupply of campaigns: UAV technology requirements (1/2)

Potential payloads	• **Tier 1:** Outbreak vaccines, e.g., Cholera, Ebola, Polio (oral) • **Tier 2:** EPI campaign vaccines, e.g., DTP, TB, Hep B, MMR, Polio (inactivated) • **Tier 3:** Other campaign vaccines, e.g., Rotavirus, Hepatitis A, Typhoid, Influenza • **Tier 4:** N/A

Payload Specifications			Specialized Handling Requirements		
	Minimum Viable	Optimal		Minimum Viable	Optimal
Weight	• **~1-2.5kg payload** – Based on specifications from UNICEF Vanuatu for monthly shipment of sufficient vaccines for 50 children (<1 years) and a small ice pack (4 units)	• **~2.5-4kg payload** – Optimal payload would enable transport of more vaccines as well as equipment like syringes	**Cold Chain needs**	• **No cooling or passive cooling as part of payload** – Passive cooling possible, but at expense of payload (1 icepack unit is ~0.5kg, specs from UNICEF Vanuatu specified 4 units at ~1.8kg) – To be validated if cooling not required if payload is cold & flight time is short	• **Compatible payload containers with / without active cooling** – Interchangeable containers enables UAV to also operate without cold chain, enabling higher weight / larger size payloads – Active cooling enables longer range flights
Size	• **~1-2.5L** – Based on specifications from UNICEF Vanuatu for monthly shipment of sufficient vaccines for 50 children (<1 years) and a small ice pack (4 units)	• **TBD** – Optimal payload would enable transport of more vaccines as well as equipment like syringes	**Other storage needs**	• **N/A (vaccines are likely exempt from mandated packaging requirements as per IATA classifications, but dependent on country-specific regulations)**	

Work in Progress

B "Just In Time" resupply of campaigns: UAV technology requirements (2/2)

Potential payloads	• **Tier 1:** Outbreak vaccines, e.g., Cholera, Ebola, Polio (oral) • **Tier 2:** EPI campaign vaccines, e.g., DTP, TB, Hep B, MMR, Polio (inactivated) • **Tier 3:** Other campaign vaccines, e.g., Rotavirus, Hepatitis A, Typhoid, Influenza • **Tier 4:** N/A

Flight Characteristics			Other Requirements (unique to use case)		
	Minimum Viable	Optimal		Minimum Viable	Optimal
Remote take-off & Landing	• No landing required; payloads can be delivered via drop (5x5m drop zone specified by UNICEF Vanuatu in their RFI) • Ability to clear sufficient space at field sites to serve as drop zones	• TBD optimal drop zone dimensions	Decon-tamin-ation	• UAV not deployed in situations requiring decontamination (e.g., Ebola outbreak)	• UAV designed to enable rapid decontamination (e.g., removable parts to facilitate cleaning)
Range	• Beyond-visual-line-of-sight (BVLOS); range likely >50km	• Optimal range TBD pending further country research	TBD		

Work in Progress

B "Just In Time" resupply of campaigns: Infrastructure requirements (1/2)

Potential payloads	• **Tier 1:** Outbreak vaccines, e.g., Cholera, Ebola, Polio (oral) • **Tier 2:** EPI campaign vaccines, e.g., DTP, TB, Hep B, MMR, Polio (inactivated) • **Tier 3:** Other campaign vaccines, e.g., Rotavirus, Hepatitis A, Typhoid, Influenza • **Tier 4:** N/A

Physical Infrastructure			Human Capital / Training		
	Minimum Viable	Optimal		Minimum Viable	Optimal
UAV support equip.	• Runway and/or launching apparatuses • Power resupply • Spare parts available for delivery within XX hours	• Spare parts stored at launch site	Human Capital	• 1:1 Operator to UAV ratio • TBD Dispatcher to UAV ratio • Ad hoc fulfillment teams • Workers at destination to create drop zones and recover payloads • Health workers at destination to administer vaccines	• 1:many Operator to UAV ratio • TBD Dispatcher to UAV ratio • Dedicated fulfillment teams (full-time or contracted)
Nav-igation	• Ideally one means of communication (e.g., GSM), but regulations might require redundancy • Pre-determined flight paths and drop zones	• Single failsafe means of communication with ability to operate on lower bandwidth networks (e.g., 3G GSM) • Ability to quickly onboard new flight paths and drop zones	Train-ing	• Training to load / unload payloads • Training to clear sufficient space to serve as drop zones • Training to administer vaccines	• N/A

Work in Progress

B "Just In Time" resupply of campaigns: Infrastructure requirements (2/2)

Potential payloads	• **Tier 1:** Outbreak vaccines, e.g., Cholera, Ebola, Polio (oral) • **Tier 2:** EPI campaign vaccines, e.g., DTP, TB, Hep B, MMR, Polio (inactivated) • **Tier 3:** Other campaign vaccines, e.g., Rotavirus, Hepatitis A, Typhoid, Influenza • **Tier 4:** N/A

Supply Chain Integration			Process Design		
	Minimum Viable	Optimal		Minimum Viable	Optimal
Send-ing	• Pre-determined role as part of specific campaign to ensure inventory availability and pre-selected field sites for delivery	• Sufficient inventory of vaccines to enable true "Just In Time" delivery of exact vaccine inventory as required at a field site on a given day	Order-ing	• Scheduled vaccine delivery at defined cadence (e.g., monthly)	• Call-to-order system to enable health workers to summon UAV within ~1-2 hours
N/A			Other		

Work in Progress

B "Just In Time" resupply of campaigns: Regulation and policy implications

Potential payloads	• **Tier 1:** Outbreak vaccines, e.g., Cholera, Ebola, Polio (oral) • **Tier 2:** EPI campaign vaccines, e.g., DTP, TB, Hep B, MMR, Polio (inactivated) • **Tier 3:** Other campaign vaccines, e.g., Rotavirus, Hepatitis A, Typhoid, Influenza • **Tier 4:** N/A

	Regulations	Policies & Guidelines
Flight	• Approval from Military may be required for flight operations depending on air space in question • Approval required from CAA for Beyond-Visual-Line-of-Sight flights • Approval potentially required from CAA for mid-air release of payloads • Depending on air space, defined interaction model required with existing country air traffic control management system	• Adjustment of treatment and supply protocols for vaccine campaigns to incorporate use of UAVs • Adjustment of treatment and supply protocols for outbreak responses to incorporate use of UAVs • Creation of guidelines to expedite import of UAVs and supporting equipment in coordination with relevant country authorities • Creation of guidelines for local companies and organizations (e.g., hospitals) to contract with foreign organizations to operate UAVs or provide support services • Creation of community engagement guidelines to publicize and normalize use of UAVs in target areas
Payload	• Approval from MoH potentially required for delivery of vaccines for which limited medical inventories available in country	

Work in Progress

B "Just In Time" resupply of campaigns: Backup list of interviewees that provided input regarding this use case

- **Amy Lehman, Lake Tanganyika Floating Health Clinic**
- **Ansgar Kadura, Wingcopter**
- **Barry Koperberg, Wings for Aid**
- **Christian Vazquez Paez, UNICEF Vanuatu**

Note: Interviewees listed in alphabetical order by first name; some interviewees provided input regarding multiple use cases and therefore appear on multiple lists

Detailed requirements:

C "Just In Time" resupply to health clinics

Work in Progress

c "Just In Time" resupply of health clinics: use case definition

Description	• Delivery of **moderate payloads** of **medical supplies** on an **as-needed basis** to **2ry-3ry health clinics** (and not field sites) as required to **maintain pre-determined inventory levels**								
Function	• 1-way delivery	**Delivery Function**	• Nat'l to sub, sub to field	**Cadence**	• Scheduled	**Urgency**	• Non-emergency	**Demand**	• Regular

Potential payloads			
Tier 1 **High-value, short shelf-life**	**Tier 2** **Other high-value**	**Tier 3** **Other often out-of-stock**	**Tier 4** **Other sundry**
• **Blood for transfusion** – Whole blood – Plasma • **Oxytocin** • **Vaccines, e.g.,** – EPI vaccines	• **Anti-malarials** • **Drugs to treat hypertension, e.g., thiazide diuretics**	• **Praziquantel** • **Magnesium Sulfate** • **Antibiotics, e.g.,** – Amoxicillin – Flagel • **Iron supplements** • **Paracetamol and other antipyretics** Note: Items in this tier based on debrief from PATH interviews with health clinics and pharmacists	• **Oral Rehydration Salts (ORS)** • **Adhesives** • **Bandages** • **Gauzes** • **Syringes** • **Tourniquets**

Note: Payloads that fit into multiple tiers would be considered as part of most important tier classification; payloads approximately ranked high-to-low based on unit cost in LMIC countries in each tier based on best available estimates

Work in Progress

c "Just In Time" resupply of health clinics: UAV technology requirements (1/2)

Potential payloads	• **Tier 1:** Blood for transfusion, (whole blood, plasma), oxytocin, emergency vaccines (e.g., rabies vaccine, TIG vaccine) • **Tier 2:** Anti-malarials, drugs to treat hypertension, e.g., thiazide diuretics • **Tier 3:** Praziquantel, Magnesium Sulfate, antibiotics (e.g., amoxicillin, Flagel), iron supplements, paracetamol and other antipyretics • **Tier 4:** Oral Rehydration Salts (ORS), adhesives, bandages, gauzes, syringes, tourniquets

Payload Specifications			Specialized Handling Requirements		
	Minimum Viable	**Optimal**		**Minimum Viable**	**Optimal**
Weight	• **1-2kg payload** – Blood: 500mL bag is ~0.6kg[1] – Other drug and vaccine weights TBD, but expect <1kg given individual doses	• **4-6kg payload** – 4+ units of blood	**Cold Chain needs**	• **No cooling or passive cooling as part of payload** – Cooling not required if payload is cold & flight time is short (≤~40min) – Passive cooling possible, but at expense of payload (1 icepack unit is ~0.5kg, number of units TBD)	• **Compatible payload containers with / without active cooling** – Interchangeable containers enables UAV to also operate without cold chain, enabling higher weight / larger size payloads – Active cooling enables longer range flights and delivery to clinics with no cold chain
Size	• **~1.2L (dimensions of at least 105mm)** – 500 mL blood bag is 105x105mm (LxW)[3] – Bubble CPAP tubing is 50-100mmx3-6mm (LxW)[4] – Other drug / vaccine dimensions TBD, but expect small given individual doses	• TBD	**Other storage needs**	• **N/A (healthy blood is classified as an "Except Human Specimen" by IATA)**	

Work in Progress

c "Just In Time" resupply of health clinics: UAV technology requirements (2/2)

Potential payloads	• **Tier 1:** Blood for transfusion, (whole blood, plasma), oxytocin, emergency vaccines (e.g., rabies vaccine, TIG vaccine) • **Tier 2:** Anti-malarials, drugs to treat hypertension, e.g., thiazide diuretics • **Tier 3:** Praziquantel, Magnesium Sulfate, antibiotics (e.g., amoxicillin, Flagel), iron supplements, paracetamol and other antipyretics • **Tier 4:** Oral Rehydration Salts (ORS), adhesives, bandages, gauzes, syringes, tourniquets

Flight Characteristics			Other Requirements (unique to use case)		
	Minimum Viable	Optimal		Minimum Viable	Optimal
Remote take-off & Landing	• **No landing required; payloads can be delivered via drop**	• **Landing possible if necessary to enable delivery of larger payloads (that might be damaged via drop); TBD optimal drop zone dimensions**	TBD		
Range	• **Beyond-visual-line-of-sight (BVLOS); range likely >50km**	• **Optimal range TBD pending further country research**	TBD		

Work in Progress

c "Just In Time" resupply of health clinics: Infrastructure requirements (1/2)

Potential payloads	• **Tier 1:** Blood for transfusion, (whole blood, plasma), oxytocin, emergency vaccines (e.g., rabies vaccine, TIG vaccine) • **Tier 2:** Anti-malarials, drugs to treat hypertension, e.g., thiazide diuretics • **Tier 3:** Praziquantel, Magnesium Sulfate, antibiotics (e.g., amoxicillin, Flagel), iron supplements, paracetamol and other antipyretics • **Tier 4:** Oral Rehydration Salts (ORS), adhesives, bandages, gauzes, syringes, tourniquets

Physical Infrastructure			Human Capital / Training		
	Minimum Viable	Optimal		Minimum Viable	Optimal
UAV support equip.	• Runway and/or launching apparatuses (definitely if fixed wing and likely even if VTOL to limit vertical flight time) • Power resupply • Spare parts (available within XX hours)	• Spare parts (stored at launch site)	Human Capital	• 1:1 Operator to UAV ratio • TBD Dispatcher to UAV ratio (subject to local regulations) • Workers at destination to recover payload drops	• 1:many Operator to UAV ratio • TBD Dispatcher to UAV ratio
Nav-igation	• Ideally one means of communication (e.g., GSM), but regulations might require redundancy • Pre-determined flight paths and drop zones	• Single failsafe means of communication with ability to operate on lower bandwidth networks (e.g., 3G GSM) • Ability to quickly onboard new flight paths and drop zones	Train-ing	• Training to load / unload payloads	• N/A

Work in Progress

c "Just In Time" resupply of health clinics: Infrastructure requirements (2/2)

Potential payloads	• **Tier 1:** Blood for transfusion, (whole blood, plasma), oxytocin, emergency vaccines (e.g., rabies vaccine, TIG vaccine) • **Tier 2:** Anti-malarials, drugs to treat hypertension, e.g., thiazide diuretics • **Tier 3:** Praziquantel, Magnesium Sulfate, antibiotics (e.g., amoxicillin, Flagel), iron supplements, paracetamol and other antipyretics • **Tier 4:** Oral Rehydration Salts (ORS), adhesives, bandages, gauzes, syringes, tourniquets

Supply Chain Integration			Process Design		
	Minimum Viable	Optimal		Minimum Viable	Optimal
Send-ing	• UAV launches within reasonable proximity of known stores of relevant medical supplies	• "Hub-and-spoke" model to aggregate sufficient demand to justify inventory stores at hub site • Hub sites have sufficient inventory of relevant payloads to enable "Just In Time" nature of use case	Order-ing	• Call-to-order within XX hours notice	• Seamless ordering system (e.g., integrated LMIS, online order management tool) to ensure payloads are loaded and dispatched quickly to fulfill "Just In Time" nature of use case
Receiv-ing	• UAV delivers payload to a clinic that can store the payload in question	• Cold chain equipment available at destination to store payloads that require cooling	Other		

Work in Progress

C "Just In Time" resupply of health clinics: Regulation and policy implications

Potential payloads	• **Tier 1:** Blood for transfusion, (whole blood, plasma), oxytocin, emergency vaccines (e.g., rabies vaccine, TIG vaccine) • **Tier 2:** Anti-malarials, drugs to treat hypertension, e.g., thiazide diuretics • **Tier 3:** Praziquantel, Magnesium Sulfate, antibiotics (e.g., amoxicillin, Flagel), iron supplements, paracetamol and other antipyretics • **Tier 4:** Oral Rehydration Salts (ORS), adhesives, bandages, gauzes, syringes, tourniquets

	Regulations	Policies & Guidelines
Flight	• Approval from Military may be required for flight operations depending on air space in question • Approval required from CAA for Beyond-Visual-Line-of-Sight flights • Approval potentially required from CAA for mid-air release of payloads • Depending on air space, defined interaction model required with existing country air traffic control management system	• Adjustment of inventory store guidelines to reflect ability for UAVs to reduce inventory requirements at clinics by enabling "Just In Time" delivery from hub sites • Creation of guidelines to expedite import of UAVs and supporting equipment in coordination with relevant country authorities • Creation of guidelines for local companies and organizations (e.g., hospitals) to contract with foreign organizations to operate UAVs or provide support services • Creation of community engagement guidelines to publicize and normalize use of UAVs in target areas
Payload	• Approval from MoH potentially required for transport of human specimens (e.g., blood) even if not toxic substance • Approval from MoH potentially required for delivery of items for which limited medical inventories available in country (e.g., specialized antibiotics)	

c "Just In Time" resupply of health clinics: Backup list of interviewees that provided input regarding this use case

- **Amy Lehman, Lake Tanganyika Floating Health Clinic**
- **Ansgar Kadura, Wingcopter**
- **Dirk Rabien, GIZ**
- **Edward Anderson, World Bank**
- **Katie Qutub, USAID**
- **Kevin Etter, UPS**
- **Joanie Robertson, PATH**
- **Matiko Machagge, JSI**

Note: Interviewees listed in alphabetical order by first name; some interviewees provided input regarding multiple use cases and therefore appear on multiple lists

Detailed requirements:

D 2-way transport of samples / treatments

Work in Progress

D 2-way transport of samples / treatment: use case definition

Description	• **Collection of medical samples** for diagnosis for **individuals or groups of individuals** and **delivery of treatment** for diagnosed conditions								
Function	• 2-way delivery	**Delivery Function**	• Sub-nat'l to field	**Cadence**	• Varies	**Urgency**	• Varies	**Demand**	• Varies

Potential payloads							
Tier 1 **Samples that quickly degrade / urgent treatments**		**Tier 2** **Other samples do not degrade as quickly / less-urgent treatments**		**Tier 3** **Other often out-of-stock medical supplies**		**Tier 4** **Remaining**	
Samples	**Treatment**	**Samples**	**Treatment**	**Samples**	**Treatment**	**Samples**	**Treatment**
• **Live blood** (for diagnosis of conditions & testing of blood for transfusion) • **Sputum** • **Stool**	• N/A	• **Dried blood spots**	• **Anti-retrovirals (ARV)** – First-line – Second-line – Pediatric • **Antibiotics**	• **Test collection kits**	• **N/A**	• **N/A**	• **N/A**

Note: Payloads that fit into multiple tiers would be considered as part of most important tier classification; payloads approximately ranked high-to-low based on unit cost in LMIC countries in each tier based on best available estimates

Work in Progress

D 2-way transport of samples / treatment: UAV technology requirements (1/2)

Potential payloads	• **Tier 1:** Live blood samples, sputum samples, and stool samples; ARVs (first-line, second-line, pediatric-specific) to treat HIV • **Tier 2:** Dried blood spot samples; antibiotics • **Tier 3:** Test collection kits • **Tier 4:** N/A

Payload Specifications			Specialized Handling Requirements		
	Minimum Viable	Optimal		Minimum Viable	Optimal
Weight	• **~1-2kg payload** – Sample weights vary, but UNICEF-JSI study in Malawi indicate sample load of ~2 DBS samples, ~10 sputum samples, and 33 whole blood samples would be ~0.6kg; ARV and antibiotics weights TBD, but expect to be <1kg for individual doses	• **~2-4kg payload** – Many (TBD) samples	**Cold Chain needs**	• **DBS samples** – No cooling required for dried blood spot samples – Note: passive cooling (e.g., ice packs) potentially sufficient to transport live blood, sputum, and stool samples; 1 icepack unit is ~0.5kg, number of units TBD	• **Compatible payload containers with / without active cooling** – Interchangeable containers enables UAV to also operate without cold chain, enabling higher weight / larger size payloads – Active cooling enables longer range flights
Size	• **~1.0L (dimensions of at least 100mm)** – IATA guidelines for Cat A payloads is smallest dimension must be 100mm[1] – Sample dimensions TBD, but UNICEF-JSI study in Malawi indicates sample load of ~120 DBS samples & ~10 TB samples is ~0.5L in volume	• **TBD** – Dimensions for carrying multiple samples of different types TBD	**Other storage needs**	• **DBS samples** – DBS samples are not infectious cargo as per IATA classifications	• **Live blood, sputum, and stool samples that are being tested for HIV and/or TB (classified as Category A cargo as per IATA classifications)** – Sample should be placed in rigid 1st receptacle placed in rigid 2nd receptacle placed in package of at least 100m in dimension[1]

1. https://www.uccs.edu/pusafety/sites/pusafety/files/inline-files/IATA_guide_doc.pdf

Work in Progress

D 2-way transport of samples / treatment: UAV technology requirements (2/2)

Potential payloads	• **Tier 1:** Live blood samples, sputum samples, and stool samples; ARVs (first-line, second-line, pediatric-specific) to treat HIV • **Tier 2:** Dried blood spot samples; antibiotics • **Tier 3:** Test collection kits • **Tier 4:** N/A

Flight Characteristics			Other Requirements (unique to use case)		
	Minimum Viable	Optimal		Minimum Viable	Optimal
Remote take-off & landing	• Landing required to collect samples (likely with VTOL operations to maximize operational flexibility)	• Landing required with ability to make multiple stops if necessary (complete VTOL operations)	Decon-tamin-ation	• UAV not deployed in situations requiring decontamination (e.g., Ebola outbreak)	• UAV designed to facilitate rapid decontamination (e.g., removable parts to enable easy cleaning)
Range	• Beyond-visual-line-of-sight (BVLOS); range likely >20km to justify use of UAVs	• Optimal range TBD pending further country research	TBD		

Work in Progress

D 2-way transport of samples / treatment: Infrastructure requirements (1/2)

Potential payloads	• **Tier 1:** Live blood samples, sputum samples, and stool samples; ARVs (first-line, second-line, pediatric-specific) to treat HIV • **Tier 2:** Dried blood spot samples; antibiotics • **Tier 3:** Test collection kits • **Tier 4:** N/A

Physical Infrastructure			Human Capital / Training		
	Minimum Viable	Optimal		Minimum Viable	Optimal
UAV support equip.	• Potentially runway and/or launching apparatuses even if VTOL to limit vertical flight time • Power resupply • Spare parts available for delivery within XX hours	• Spare parts stored at launch site	Human Capital	• 1:1 Operator to UAV ratio • TBD Dispatcher to UAV ratio • Health workers required at destination to collect diagnostic samples and potentially administer treatments	• 1:many Operator to UAV ratio • TBD Dispatcher to UAV ratio
Nav-igation	• Ideally one means of communication (e.g., GSM), but regulations might require redundancy • Pre-determined flight paths and drop zones	• Single failsafe means of communication with ability to operate on lower bandwidth networks (e.g., 3G GSM) • Ability to quickly onboard new flight paths and drop zones	Train-ing	• Training to load / unload payloads • Training relaunch UAV for return flight if landing • Training to collect diagnostic samples and potentially administer treatments	• "Push button" return functionality to enable untrained operators to relaunch UAV for return flight if landing

Work in Progress

D 2-way transport of samples / treatment: Infrastructure requirements (2/2)

Potential payloads	• **Tier 1:** Live blood samples, sputum samples, and stool samples; ARVs (first-line, second-line, pediatric-specific) to treat HIV • **Tier 2:** Dried blood spot samples; antibiotics • **Tier 3:** Test collection kits • **Tier 4:** N/A

	Supply Chain Integration			Process Design		
	Minimum Viable	Optimal		Minimum Viable	Optimal
Sample trans-port	• Defined laboratory to serve as base for UAVs	• Ability to dynamically choose laboratories for sample delivery based on required testing and lab processing capacity	Order-ing	• Scheduled sample pick-up flights at defined cadence (e.g., weekly)	• Call-to-order system to enable health workers to summon UAV within XX hours as needed for sample transport
Treat-ment deliv-ery	• Communications pathway to notify clinic of diagnosis results	• Communications pathway to <u>immediately</u> notify clinic of diagnosis results	Other		

Work in Progress

D 2-way transport of samples / treatment: Regulation and policy implications

Potential payloads	• **Tier 1:** Live blood samples, sputum samples, and stool samples; ARVs (first-line, second-line, pediatric-specific) to treat HIV • **Tier 2:** Dried blood spot samples; antibiotics • **Tier 3:** Test collection kits • **Tier 4:** N/A

	Regulations	Policies & Guidelines
Flight	• Approval from Military may be required for flight operations depending on air space in question • Approval required from CAA for Beyond-Visual-Line-of-Sight flight • Approval potentially required from CAA for mid-air release of payloads • Depending on air space, defined interaction model required with existing country air traffic control management system	• Adjustment of sample collection protocols for relevant conditions (e.g., HIV, TB, Cholera) to incorporate use of UAVs when relevant • Adjustment of treatment delivery protocols for relevant conditions (e.g., HIV, TB, Cholera) to incorporate use of UAVs when relevant • Creation of guidelines to expedite import of UAVs and supporting equipment in coordination with relevant country authorities • Creation of guidelines for local companies and organizations (e.g., hospitals) to contract with foreign organizations to operate UAVs or provide support services • Creation of community engagement guidelines to publicize and normalize use of UAVs in target areas
Payload	• Approval from MoH required for transport of samples, in particular for infectious (IATA Category A and B) samples	

D **2-way transport of samples / treatment**: Backup list of interviewees that provided input regarding this use case

- **Andrew Schroeder, WeRobotics**
- **Astrid Knoblauch, Stony Brook University**
- **Christian Vazquez Paez, UNICEF Vanuatu**
- **Dirk Rabien, GIZ**
- **Enrique Paz, UNICEF Madagascar**
- **Helena Samsioe, GLOBHE**
- **Judith Sherman, UNICEF Malawi**
- **Julia Bem, USAID**
- **Kameko Nichols, The Nichols Group**
- **Katie Qutub, USAID**
- **Marga Eichleay, FHI360**
- **May Chu, Office for Science and Technology Policy (OSTP), formerly CDC**
- **Matiko Machagge, JSI**
- **Scott Dubin, Chemonics**
- **Simon Grandjean Lapierre, Stony Brook University**
- **Timothy Amukele, Johns Hopkins University**
- **Xavier Tomsej, USAID**

Note: Interviewees listed in alphabetical order by first name; some interviewees provided input regarding multiple use cases and therefore appear on multiple lists

Country-level assessment framework

Overview of country-level assessment framework

This section contains a summary of our proposed framework to evaluate use cases on a country-level

The purpose of this framework is to create a common approach that can be applied <u>in and across</u> countries by a variety of stakeholders to ensure consistent and comparable assessments of use cases

Underlying this framework is an Excel-based tool that lists the detailed questions that constitute each component

- At its core, this tool is a checklist of questions by which to evaluate use cases
- The tool characterizes the type of output for each question (e.g., qualitative vs. quantitative) as well as likely sources to answer these questions (e.g., public databases, interviews)

We anticipate that users will utilize this framework iteratively, populating the most obtainable data first and then deciding on what additional data is required to inform decision making on a case-by-case basis

- We expect that some components of this framework will need to be estimated on a back-of-the-envelope basis, and that some components might not be knowable in a particular country

This framework is an input to, and not a replacement for, the Monitoring & Evaluation (M&E) framework that VillageReach will be developing over the coming months

We hope for this framework to become a living document with other stakeholders adding to it to reflect the lessons they have learned by applying it in their country.

Work in Progress

Assessment framework evaluates use cases across three dimensions

Health assessment vs. status quo

What are the health impacts of utilizing UAVs vs. current alternatives?

Financial assessment vs. status quo

What investment is required?

How do operating costs compare to current alternatives?

What financial benefits will use case create vs. current alternatives?

Feasibility

How possible and practical would it be launch a successful UAV operation?

Work in Progress

Approach to comparatively assessing health impact at a country-level

High-level approach to be utilized across health conditions to assess use case in a specific country

Incremental health impact of utilizing UAVs

Country-specific burden of addressable health conditions	×	% pop that does not receive products for care (at all or in timely manner)	×	% pop that is addressable by UAVs	×	Impact of product delivered by UAV
• Incidence • Current outcomes • Other population risk vectors (e.g., % pop vaccinated)		• Patients without products for: – Prevention – Diagnosis – Treatment		• Population that lives within UAV range of health facility / medical supply warehouse		• Incremental improvement in health outcomes due to availability of health product

Health benefits derived from <u>increasing access</u> and <u>improving timeliness</u> in delivering health products for populations that need them

Work in Progress

Approach to comparatively assessing financial impact at a country-level

High-level approach to assess use case in a specific country

Net investment

Initial, upfront investment

- Capital to procure UAVs / set up ground infrastructure (vs. equivalent investment for current vehicles)

+

Ongoing investment

- Expansion capital, replacement capital (vs. equivalent investment for current vehicles)

Investment costs incurred in the first year

Investment costs incurred after the first year

−

Net operating costs

Operating costs if utilizing UAVs

- Includes costs of flights and support costs such as labor
- Driven by number of required flights

−

Operating costs for current best alternative

- Includes costs of transport and support costs such as labor

Net operating costs takes into account not only differences in per trip operating costs but also in number of required trips for given mode of transportation

+

Incremental benefits

Financial benefits of utilizing UAVs vs. current best alternative

- Reductions in
  - Holding costs
  - Cold chain equipment
  - Spoilage / wastage
  - Etc.

Note: Net operating costs could indicate savings vs. alternative and would therefore be negative

Work in Progress

Approach to assessing feasibility at a country-level

High-level approach to assess use case in a specific country

UAV Technology

- What are the operating conditions (e.g., climate) that UAV design must take into account?

Infrastructure

- Is required support infrastructure available, e.g., runways, power supplies, spare parts?
- Is required communications coverage available, e.g., 3G/4G networks?
- Is required talent available or can it be easily trained?
- What experience does <country> have with UAVs?
- What experience does <country> have in insourcing vs. outsourcing different supply chain solutions?
- Are the other country dynamics that should be considered, e.g., political stability?

Regulations / Policy

- Are there formal regulations regarding UAVs?
- Are there formal regulations regarding transport of payloads in question?
- What policies would need to be modified to reflect the use of UAVs?

Interest / Experience

- How much political interest is there to
  - address health conditions in question?
  - utilize UAVs?
- How much funder interest is there?
  - address health conditions in question?
  - utilize UAVs?
- Does the country have prior experience regarding the operation of drones (commercially or in the context of public health)?
- Is there community acceptance regarding the use of UAVs?