PLAYBOOK FOR ENABLING CIVILIAN DRONE OPERATIONS

02 AFRICAN DRONE FORUM PUBLICATION

WORLD BANK GROUP

02 AFRICAN DRONE FORUM PUBLICATION

PLAYBOOK FOR ENABLING CIVILIAN DRONE OPERATIONS

WORLD BANK GROUP

1818 H Street NW
Washington DC 20433
Telephone: 202-473-1000
Internet: www.worldbank.org

 Cover and interior design: Nik Nikam / World Bank.

Table of Contents

Table of Contents

Boxes, Figures & Tables

Boxes

Boxes, Figures & Tables

Figures

Boxes, Figures & Tables

Tables

Foreword

Emerging economies worldwide are on the rise in terms of both rapidly growing economies and younger populations. The labor force across many countries is also doubling, with millions of young people seeking opportunities. Much of this growth focuses on Metropolitan areas in Africa, with most Africans expected to live in urban areas by 2035. Ensuring this growth is shared broadly will be a crucial challenge, as rural areas, home to most of the world's poor, cannot be left behind. In Africa, only 34% of citizens live within 2km of an all-weather road compared to over 90% in East Asia. The visible results are higher costs for goods and services, long wait times for deliveries, reduced productivity of rural facilities, and fewer opportunities for rural citizens.

Bridging the gap between urban and rural in a way that brings greater reach and resilience to hard-to-reach communities requires us to rethink how to deliver mobility and set up supply chains better. Drones provide an opportunity to overcome persistent infrastructure deficiencies and address the needs and demand for more specialized transport and logistics, digitalization, and other services. They can support delivery operations to smaller airfields and hard-to-reach communities and operations in more hazardous conditions. Enabling safe, efficient and scalable drone operations will require new infrastructure and policy and regulatory reforms, greater engagement with specialized private operators, cross-sectoral and cross-governmental collaboration, and the leveraging of different investment streams to deliver and ensure efficient use of opportunities afforded by drones.

This guidebook brings together experiences and lessons learned from a range of initiatives and operations within the context of the African experience of drone operations. In doing so, it provides detailed guidance and recommendations regarding the needed infrastructure, regulations, and management approaches that underpin the establishment of enabling ecosystems conducive to drone operations anywhere internationally. The World Bank looks forward to working closely with governments, the private sector, and other Development Partners to unlock the lower skies and bring the region's development visions to life.

Nicolas Peltier-Thiberge
Global Director, Transport,
The World Bank

Wendy E. Hughes
Infrastructure Regional
Director, Africa East & South,
The World Bank

Franz Drees-Gross,
Infrastructure Regional
Director, Africa West and
Central, The World Bank

Acknowledgments

This guidebook was prepared under the guidance of Almud Weitz (Practice Manager, Transport—East Africa) by a team led by Edward Anderson (Senior Disaster Risk Management Specialist, Global Facility for Disaster Reduction and Recovery) and Catalina Ochoa (Senior Urban Transport Specialist, Transport—South Asia), who also served as task team leaders for the projects and as members of the book's leadership. This guidebook was produced with financial and technical support from the World Bank's Korea Green Growth Trust Fund (KGGTF) and VillageReach. KGGTF is a partnership between the World Bank Group and the Republic of Korea, established in 2011 to support client countries as they shift to a green development path. Both partners share a common goal to reduce poverty and promote shared economic prosperity in an environmentally responsible and socially inclusive way. Learn more at www.wbgkggtf.org.

The core team was composed of the World Bank consultants Gregor Engelmann, David Guerin, Denise Soesilo, and George Mulamula. Members of the extended team — Ayman A.O. Ali (Senior Transport Specialist, Transport—East Africa), Tautvydas Juškauskas (UNICEF Supply Division, ISG-UAS) and Jonathan Slater (Blue Globe Innovation) — provided invaluable contributions to the book.

The team also benefited at an early stage from consultations on emerging themes with government officials, representatives of civil society organizations, intergovernmental organizations, industry, and researchers who provided their input. Special thanks go to those organizations and individuals who provided written comments and engaged directly with the team, including Alain Mulembwe (AAC / RDC), ANAC MALI, Andy Thurling (Nuair), Ben Savonen (Kijenzi), EAC- CASSOA, Francis Kigen (KCAA), Gabriella Ailstock (UPDWG), Harrison Wolf (World Economic Forum), Helena Samsioe (GLOBHE), Joseph Muhlhausen (WeRobotics), Kim de Boeck (KU Leuven), Klaus Scho (Germandrones GmbH), Jusu Kallon (Sierra Leone CAA), Kofi Konan (ANAC Côte D'Ivoire), Michael Scheibenreif (UNICEF Malawi), Olivier Defawe (VillageReach), Rahul Singh (Global Medic), Sara de la Rosa (AirMap), Susie Truog (VillageReach), Tiamiyou Radji (Senegal Flying Labs), UAV Dach, UK CAAi and Venturi U-Tech.

Peer review was provided by Harsh Gupta (principal investment officer, International Finance Corporation), Christopher J. De Serio (senior transport specialist, Transport—East Africa), Ramtin Amin, (digital development specialist consultant, Digital Development—Global/East Asia and Pacific), Giacomo Rambaldi (independent consultant, Formerly Center for Agriculture and Regional Cooperation (CTA) - Digital Agriculture Lead, African Drone Forum Board Member). Nik Nikam was the principal graphic designer.

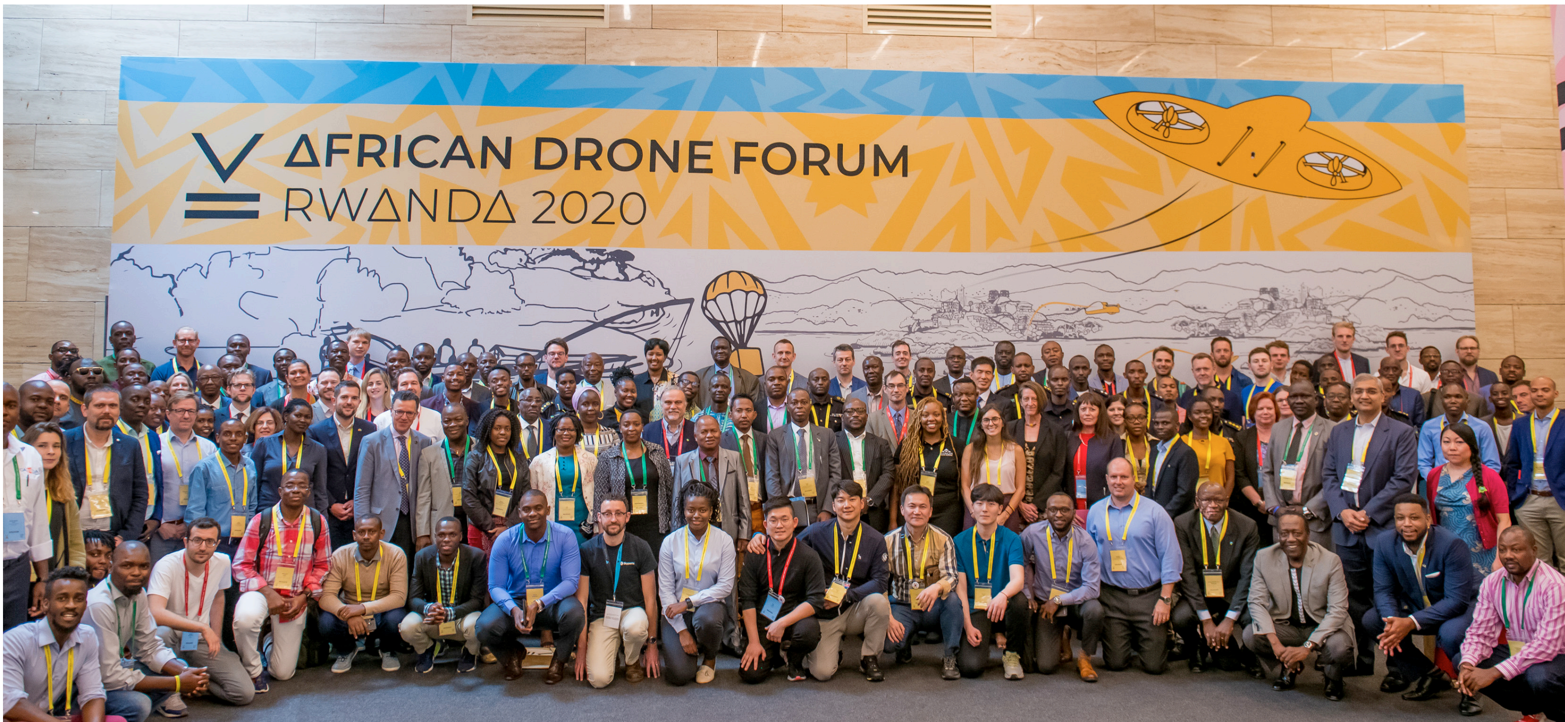
Finally, the team apologizes to any individuals or organizations that contributed to this book but were inadvertently omitted from these acknowledgments.

About the AFRICAN DRONE FORUM (ADF)

The ADF is a multi-stakeholder engagement platform for drone technologies and services that meet the needs of emerging African market opportunities. The program connects the African drone community, curates knowledge relevant to stakeholders, and defines high-frequency drone services' requirements with the potential for significant social and economic benefits. The ADF seeks to demonstrate how a future drone economy will look by showcasing the frontier use cases tailored to African countries' needs and facilitates harmonized rulemaking directions to support African services. The program kicked off in February 2020 as a first-of-its-kind event in Africa, with the potential to evolve into a regular forum on the state of the art and serve as a showcase for system advances with increasing levels of automation that can make a significant difference for isolated and rural communities.


AVY


AFRICAN DRONE FORUM
RWANDA 2020
#ADF2020


AFRICAN DRONE FORUM
RWANDA 2020

Executive Summary

This playbook presents an end-to-end roadmap of elements and activities that underpin ecosystems capable of supporting safe and sustainable high-frequency drone operations.

The focus is on enabling operations using small to medium-size drones or un-crewed aircraft system (UAS) within health, urban land administration, and other sectors. Those are likely to provide significant socio-economic benefits in the near to medium term. The majority of these operations will likely take place within low-level airspace generally shared with helicopters, other UAS, and conventional aviation during take-off and landing and provide the most near-term opportunities to both address deficiencies in current operations and supply chains and to support development in line with the Sustainable Development Goals — including Goal 2 (enhancing food security), 3 (good health and wellbeing), 8 (economic growth and decent job possibilities), and 9 (resilient infrastructure and fostering innovation).

Experiences from the Lake Victoria Challenge (LVC) held in Tanzania and Lake Kivu Challenge (LKC) held in Rwanda were reviewed and analyzed to identify the various elements and activities underpinning successful UAS operations and how they interlink. In addition, we interviewed and surveyed government officials, representatives of intergovernmental organizations, drone manufacturers, drone service providers, end-users, and researchers on their experiences with drones and perceptions on opportunities and barriers to high-frequency drone operations to help inform this playbook. Although the playbook largely builds on African experiences, it is very much region-agnostic and applicable elsewhere. It aims to raise awareness of the complexities of setting up enabling ecosystems and function as a guideline for discussions rather than as a fixed manual.

Our findings and consultations have shown that the most significant barriers to successful UAS operations are:

- **Training and capacity building** on the regulatory and the operations side during *Phase 2: Planning* and *Phase 3: Operations*, respectively;

- **A lack of effective UAS regulations or rules** that regulators should address early on during *Phase 2: Planning*, following training and capacity building;

- **Uncertainty among operators** stemming from the absence of clear and fit-for-purpose regulations or rules, timelines for permits, or long-term contracts to offset potential capital and pre-launch costs and other issues stemming from insufficient planning in *Phase 1: Feasibility* or activities in *Phase 2: Planning*;

- **Insufficient feasibility assessment** in *Phase 1: Feasibility* to identify actual needs and understand the affordability, commercial viability, and ultimately the ongoing monitoring and evaluation during *Phase 4: Sustainability* to ensure operations address needs as circumstances may change; and

- **Airspace integration**, particularly for operations beyond the visual line of sight (VLOS) and ultimately for scaling operations, requires careful considerations on airspace management and traffic management, among others, during *Phase 2: Planning*.

PHASE 1: FEASIBILITY — Whether drones are an appropriate and financially-viable solution capable of delivering transformational value to a particular problem depends on specific needs, the scale of demand, the cost and performance of alternatives, and the given ecosystem's readiness. Although an initial feasibility analysis can be quick and require a very light touch, more rigorous and resource-intensive analyses can identify specific investment needs and contribute to a detailed understanding of baseline costs and affordability.

1.1 Use case needs assessment — Identifying use cases with clear problem statements and addressable needs where drones can have a meaningful impact is the first step when considering the use of UAS[1] or commencing higher-level engagements or tender. Understanding problem statements requires identifying underlying root causes within the existing systems and procedures that create bottlenecks or difficulties. A needs assessment of a use case can help determine its what, how, where, and when and define requirements, settings, objectives, and purpose of envisaged operations[2] while considering the prevailing policies and regulations. It should also consider avenues for mitigating the impact on local distribution networks, economies, and other stakeholders through, for example, creating demand for unusual or new community jobs, such as order taking, maintenance, or droneport management.

1.2 Opportunity cost assessment — An opportunity cost assessment can help determine where and how much money to spend on a particular service. It follows the identification of use cases and operational requirements and analyzes all aspects and associated opportunity costs involved in a particular service to determine costs of alternative systems compared to potential drone operations. Early experiences show that the cost-effectiveness of UAS operations is primarily affected by drone vendor pricing structure, capital costs, ground transportation costs, and the level of demand compared to traditional service provision[3]. Whereas mapping operations are largely cost-effective compared to alternatives, cargo operations with UAS are generally more expensive, especially if examining commodity categories individually and looking exclusively at direct costs of service provision. Combining different programmatic commodities and services, also referred to as product integration or layering, can significantly increase an operation's cost-effectiveness and thus its affordability and commercial viability.

1.3 Stakeholder consultation, community outreach, and sensitization — Ensuring political and social buy-in, wider acceptance, and the alleviation of skepticism and safety and security concerns surrounding drone technology is crucial to increasing the chances for the long-term sustainability of high-frequency operations. Successful stakeholder identification and implementation of a comprehensive and locally tailored engagement and communication strategy often represents an ongoing process and should target different groups within a country, including the national, provincial, regional, or district government, and the general public[4].

1.4 Business models, ownership, and financing — A range of products and services make up the value chain of elements underpinning drone operations, each with its business model archetypes and considerations[5]. Whereas use cases and the products and services to address them are available, financing models covering service provision, beyond an initial setup or pilot phase, often are not. Different funding models and sources exist, such as donor or private funding or Public-Private Partnerships, with later stages of a UAS program potentially utilizing combinations of approaches in a co-financing or blended-financing manner.

1.5 UAS platform considerations — It is crucial to select the right platform to ensure it fits the use case, performs to expectations, and functions safely and as expected in the environment. Other potential considerations include the ease of use, reliability, ongoing operating costs, ease of maintenance and repair, user interface, flight control and navigation, Command and Control (C2) link, and durability. Some UAS are capable of vertical take-off and landing (VTOL), offering additional flexibility and operating capabilities such as flying from small, remote sites with minimal infrastructure. The vast majority of UAS currently used in the commercial sector are small, weighing less than 25kg. Whereas an increasing number of drones rely on electric engines that use lithium batteries, some continue to rely on combustion engines. Depending on the battery size, the logistics of transporting them can become an issue. Another important consideration for platform selection for use cases such as medical cargo is cold-chain capacity. Industry challenges and competitions can be helpful tools to encourage the development and adoption of new technologies and support long-listing of potential UAS service or original equipment manufacturer (OEM) providers.

PHASE 2: PLANNING — Whereas a thorough feasibility analysis can help determine whether drones are the appropriate tool for a given use case, the broader ecosystem incorporating elements of governance, planning, and operations must be capable of supporting that use case. Stakeholders are encouraged to engage with their peers, their regional safety oversight organization, and organizations such as International Civil Aviation Organization (ICAO), European Union Aviation Safety Agency (EASA), and Joint Authorities for Rulemaking on Unmanned Systems (JARUS) to exchange knowledge and strive for harmonization and interoperability of regulations and processes.

2.1 Training and capacity (enabling side) — Understanding technology and its implications is a prerequisite for developing fit-for-purpose regulations. Stakeholders and end-users involved in UAS operations need to understand commercial drones' evolving technology and capabilities, which may be much larger than consumer-oriented commercial-off-the-shelf UAS. Dedicated drone teams within a civil aviation authority (CAA) or another competent authority may be an avenue to ensure that regulations and processes account for the latest developments and specialist requirements. However, establishing a dedicated team dealing with permits, registration, inspections, auditing, airworthiness assessments, and so forth often requires additional funding and support.

2.2 Fit-for-purpose regulations — Similar to most other regulatory regimes, each country has the jurisdiction to adopt, develop, amend, or repeal aviation-related regulations. Whereas regulations are legally binding and prescribe "rules of conduct, standards and other requirements of general applications"[6] that operators must meet, advisory documents set out acceptable means of complying with the "hard law" regulations and focused methods for evaluating the submitted documentation of prospective operators. Each CAA should have a clear structure for publishing its latest regulations, implementing rules, and providing advisory information. Regulators may also want to reduce the burden on oversight and enforcement by determining which UAS and operations impose an insignificant risk to safety, security, and privacy and exempting such from regulatory supervision requirements.

2.3 Harmonization and interoperability — Although the development of regulatory regimes falls under the jurisdiction of each country, certain levels of harmonization, standardization, and ultimately interoperability are desirable. Regulatory harmonization can increase aviation safety and security, reduce administrative burdens for regulators and operators alike, open new markets, and ultimately enable cross-border operations. The alignment of competing interests and national requirements underpinning harmonization processes toward interoperability requires ongoing consultation and stepped or phased approaches[7]. Although ICAO provides standards and recommended practices (SARPs) for international operations or missions certified to a conventional aircraft level, no SARPs for autonomous or low-level UAS operations currently exist.

2.4 Airspace management — UAS can operate outside of conventional aviation's traditional point-to-point model, thus "enabling a more dynamic use of airspace"[8], bringing flexibility to end-users at the same time as complicating considerations for regulators regarding where, when, and how to ensure safety and security when approving operations. Ultimately, most operations will likely follow conventional aviation and occur within predefined air corridors, which may be segregated from or within controlled airspace. Air traffic control will need to either continue to manage or release the airspace to a controlling authority (a temporary flight restriction [TFR]) within controlled airspace. Segregated corridors provide safe environments for testing drone applications, regulatory mechanisms, and operational practices to support decision-making regarding the subsequent scale-up in non-segregated airspace. Such corridors commonly face scalability and funding challenges, however.

2.5 Droneports — Droneports, also known as drone operating centers, represent the interface between earth and sky and are fundamental to safe and sustainable high-frequency UAS operations. Operational requirements identified during the feasibility assessment should determine the number and location of droneports, as they provide information on the performance of the droneport itself and on its broader cost-effectiveness of operations overall. Droneports fulfill essential functions, including power charging or refueling, safe landing and take-off, maintenance, repair, and overhaul. The establishment of droneports generally follows a four-phase approach of 1) site identification and assessment, 2) planning, 3) construction, and 4) operation of droneports.

2.6 Command and control (C2) links and spectrum — C2 links support the actual flight and flight management by connecting the drone and remote pilot station (RPS). The harmonized, standards-based nature of existing mobile networks and technologies makes it a scalable connectivity solution for providing C2 links in Beyond Visual Line of Sight (BVLOS) operations. However, in remote and rural areas, connectivity gaps can prove a significant challenge to the provision of C2 links for BVLOS operations, requiring alternative solutions such as satellite communications. Investments in widening rural connectivity and broadband can address this challenge and provide other ancillary benefits. With few exceptions, most notably the 1090 MHz spectrum band shared among conventional aviation and some UAS operations for the Automatic Dependent Surveillance-Broadcast (ADS-B), and the allocation of 5030-5091 MHz for C2 links[9], there are no global standards for spectrum allocation for UAS operations or C2 links, with rules varying across different regions.

2.7 UTM Services — Effective traffic management is essential to ensure the safe sharing of airspace. One of the primary functions of a UTM system is tracking and monitoring UAS to provide situational awareness and understanding of what a drone is and should be doing. UTM services can also provide the necessary information to support different risk mitigation strategies and overall safety risk management. To this end, it functions as a complementary yet separate tool to air traffic management (ATM) for conventional aviation. UTM software platforms work on the principle of reliable network coverage, cloud access, and interfacing with conventional ATM. Although the ability to track drones as they move through the airspace is at the core of any UTM system, non-cooperative drones, which operate without active tracking technology, may represent a significant challenge.

2.8 Privacy, data management, quality, and transparency — Most drones are equipped with sensors or cameras for data collection, either as part of the mission objective or flight management and safety systems, and potentially represent a significant privacy hazard. Although not all countries' privacy and data protection laws reference UAS technology specifically, attitudes will shift with increasing recognition of UAS in future regulations. Countries may want to require operators to demonstrate their ability to comply with local or regional privacy laws as a condition for obtaining operational approval. Operators involved in data generation need to consider how to handle sensitive areas as part of the operations and seek guidance from national authorities where necessary.

2.9 Logistics and customs — Many operations rely on importing and exporting some or all of the UAS equipment required, including drones, batteries or other fuel technology such as hydrogen cells, and ancillary equipment. Depending on battery size, international dangerous goods regulations may affect battery logistics for cargo and large mapping drones. Additionally, some UAS platforms and other specialist equipment needed to set up operations may be considered dual-use goods and subject to export restrictions.

2.10 Oversight, audits, airworthiness inspections — Many agencies, including ICAO, embody drones in the legal definition for aircraft that evoke certification and airworthiness similar to that in conventional aviation, such that "all aircraft should be reliable, controllable, and safe — no matter how small or large, or whether the crew is onboard the aircraft or piloting it remotely"[10]. There are, however, no standard or even harmonized frameworks for regulating "acceptable" standards of airworthiness, operational conduct, and pilot competency for small UAS. Compared with conventional aviation, the rapid development of UAS technologies further renders traditional approaches of granting airworthiness certification impractical in many cases. Instead, the CAA or another designated airworthiness authority is responsible for authorization, oversight, and granting of operating licenses.

2.11 Insurance — Comprehensive and appropriate insurance coverage is essential to protect UAS operations and reduce liability for operators[11]. Different types of specialist insurance and payment plans exist in addition to basic annual public liability insurance, including hull, physical damage, employer, and product liability insurance. There are two ways of paying for drone insurance: a traditional annual policy with monthly installments or a pay-as-you-fly model covering individual or a daily quota of flights. However, there is little data available to insurers on making predictions for the failure rate with commercial UASs. Nevertheless, an increasing number of insurers are looking to enter the market and provide customized insurance tailored toward drone operations.

2.12 Procurement and service contracts — A good understanding of the use case identified through the initial needs assessment and opportunity cost analysis is essential in informing the procurement process. Procurement usually involves several steps:

- Pre-procurement — involves refining and defining specifications, sourcing interest and identifying potential vendors or service providers, and initial prequalifying. Flying competitions similar to the Lake Victoria and Lake Kivu Challenge or other technology demonstrators in a drone corridor provide a valuable opportunity for assessing vendors' operational, safety, and project management practices and performance, especially in low-connectivity, low-resource, and adverse weather settings.
- Procurement — involves purchasing equipment for in-house operations (insourcing) or procurement of a service provider to service the identified use case(s) (outsourcing).
- Evaluating and Awarding Contracts — involves determining clear evaluation principles and criteria to ensure the quality and capacity to assess proposals and vendors is in place. Some organizations might use insourcing for some drone program elements and outsourcing for others in a hybrid model.

PHASE 3: SETUP — Once enabling elements are in place, the onus falls on the operator to plan operations appropriate to the local operating environment. Developing a robust safety risk management strategy and Concept of Operations (ConOps) is fundamental to applying for operational approval and ensuring the overall safety and security of the drone operations. Stakeholders are encouraged to ensure operations are safe and appropriate to the local operating environment, and involve ongoing community and stakeholder engagement.

3.1 Safety and risk management — Safety risk management is at the core of each management system and helps eliminate or reduce risks to acceptable levels where practical. It includes a four-step process of 1) identification of hazards, 2) risk assessment, 3) mitigations, and 4) determination of acceptable risk levels. In addition to more conventional air risk (i.e., the risk to other airspace users), risk management for UAS operations also requires considerations regarding ground risk because of their relatively short safety track record and levels of sophistication and redundancy. Other potential hazards include cybersecurity hazards; environmental hazards; occupational health, safety, and environment (OHS&E) hazards; privacy and data protection; and reputational damage. The use of heavy or fast platforms raises both air and ground risk significantly, as do operations over populated areas or with complex or busy air traffic. To this end, JARUS has developed a risk-based categorization for UAS operations to account for the increasing complexity of regulatory frameworks and risk management methodologies.

3.2 ConOps — ConOps aims to identify the technical, operational, and human information related to the intended drone operations. Production of a professional operations manual outlining how a UAS operator will conduct its operations is crucial. It should provide users and competent authorities with a structured overview addressing everything they need to know to safely conduct operations described in the proposed ConOps — from a summary of characteristics of the drone platform (i.e., the aircraft operations manual), to the characteristics of the operating environment and operational setup to risk management procedures and other policies and processes.

3.3 Operational approval — Operations should never occur without authorization in the form of permission or a legislated exemption. Depending on the airspace type and risk involved, a CAA may consider categorizing operations and their likeliness of authorization differently, because certain UAS operations may not require any prior operational authorization, which would reduce the administrative burden on operators and authorities such as CAAs. Regardless of operational classification, however, the understanding of airspace, risk, and the platform's capabilities and functions of remote pilots and crew looking to operate UAS remain crucial.

3.4 Training and capacity (operations side) — ICAO identified operators' education and training as fundamental enablers of safe and efficient UAS operations[12]. Key stakeholders and actors requiring training include the flight operations team and local staff, community members, and users using the service. Yet a lack of capable staff is among the most crucial barriers to creating local business opportunities, scaling up, and sustaining operations, and involves three key challenges: finding talent with the right experience, connecting this talent with the right opportunities, and the availability of licensed and certified schools. Inclusively addressing these challenges also provides opportunities for improved gender inclusion in training and recruitment and championing female leaders and entrepreneurs.

PHASE 4: OPERATIONS AND SUSTAINABILITY

— Having determined that operations are feasible, required elements to support safe and efficient scaling of UAS operations are in place, and operators are ready to conduct operations, the final phase of flying and ensuring sustainability may begin.

Beyond the flying itself, ongoing engagement, monitoring, and evaluation should form part of any UAS operation to determine whether an operation was successful, and should strive toward financial and environmental sustainability and overall continuity of knowledge. Operators and end-users are encouraged to collect data on their operations to support education and assist ongoing impact evaluations.

4.1 Flight operations — Flight operations consist of three phases: mission preparation, flight, and post-flight.

- Mission preparation — Flight scheduling, routing, and planning should begin with assessing the operating environment, including potential risks to persons and property near envisaged operations, local weather conditions, and airspace and flight restrictions. Depending on the type of airspace and operation, operators may need to obtain an air traffic control authorization before any flight. The final step of mission preparation should include pre-flight briefings and inspections to assess airworthiness, compliance, and safety.
- Flight operations — Although most flight operations will run under normal procedures as determined during mission preparation, some flights may encounter abnormal situations and call for non-normal (contingency) or emergency response procedures. An emergency response plan should address situations that escalate beyond normal and include contingency conditions to respond to a loss of control of an operation as well as reporting mechanisms to notify authorities.
- Post-flight — Evaluations of individual flights can support the continued monitoring and assessment of overall operations and provide learning opportunities for future flights.

4.2 Sustainability of operations and ecosystem — Continued monitoring and evaluation of operations, financing considerations beyond initial donor-funding, continuity of knowledge, and minimizing environmental impact are crucial to ensuring the sustainability of operations and the broader ecosystem. Monitoring provides insight into how well the operation meets its goals and performance targets, informs suggestions for timely changes to live service provision, and assists with impact assessment and evaluation against alternative technology options. Key performance or impact indicators are fundamental metrics for evaluating the impact of interventions compared with alternative means of service provision. Evaluating cost-effectiveness, cost-benefit or cost-utility, and planning for financial sustainability requires understanding the costs and performance of the UAS operations and alternative systems. From an environmental perspective, operations involving battery-powered drones should consider how spent or damaged batteries are disposed of or recycled to minimize lasting environmental impacts. Operators should also ensure "knowledge and skills transfer and capacity development, such as building local skills in addition to community engagement"[13] both precedes and forms part of the ongoing operations.

Abbreviations

ADDA	African Drone and Data Academy
ADF	African Drone Forum
ADS-B	Automatic Dependent Surveillance – Broadcast
AIP	Aeronautical Information Publication
AltMoC	Alternative Means of Compliance
AMC	Acceptable Means of Compliance
ANSP	Air Navigation Service Provider
ASSURE	Alliance for System Safety of UAS through Research and Excellence
ATC	Air Traffic Control
ATM	Air Traffic Management
BVLOS	Beyond Visual Line of Sight
C2	Command and control
CAA	Civil Aviation Authority
CAAi	CAA International
CAOs	Civil Aviation Orders
CASA	Australian Civil Aviation Safety Authority
CE	Conformité Européenne
ConOps	Concept of Operations
EAC-CASSOA	East African Community - Civil Aviation Safety and Security Oversight Organization
EASA	European Union Aviation Safety Agency
EFTZ	Emergency flight termination zone
EOI	Expression of interest
ERP	Emergency response plan
EUROCAE	European Organisation for Civil Aviation Equipment
FAA	Federal Aviation Administration
FSF	Flight Safety Foundation
GFDRR	Global Facility for Disaster Reduction and Recovery

Abbreviations

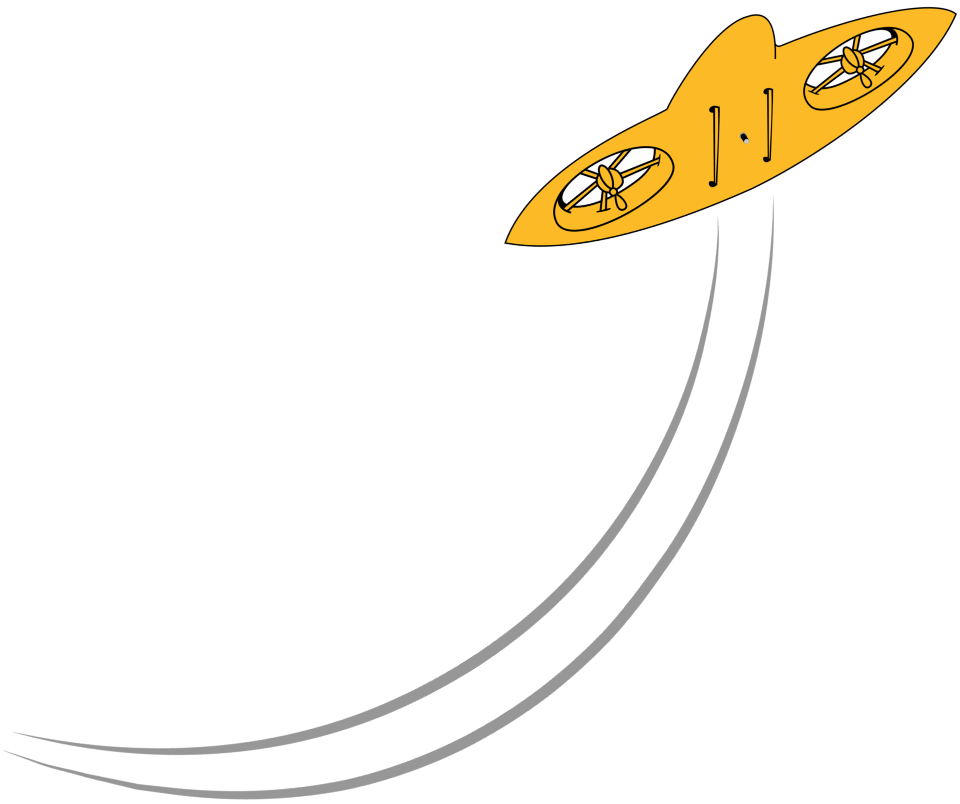
GHSC-PSM	Global Health Supply Chain Program-Procurement and Supply Management
GPS	Global Positioning System
GUTMA	Global UTM Association
HAPS	High Altitude Platform Systems
ICAO	International Civil Aviation Organization
IFR	Instrument flight rules
ISG-UAS	Interagency Supply Chain Group's UAS Coordinating Body
ISM	Industrial, scientific and medical
ISO	International Organization for Standardization
ITB	Invitation to Bid
JARUS	Joint Authorities for Rulemaking on Unmanned Systems
KPI	Key Performance Indicator
LKC	Lake Kivu Challenge
LVC	Lake Victoria Challenge
MOS	Manual of Standards
MoU	Memorandum of Understanding
MTOM	Maximum take-off mass
MUST	Malawi University of Science & Technology
NCRSSH	National Committee on Research in Social Studies & Humanities
NHSRC	National Health Sciences Research Committee
NOTAM	Notice to Airmen
OSHE	Occupational health, safety and environment
OEM	Original equipment manufacturer
OSO	Operation safety objectives
PBO	Performance-based oversight
PDRA	Pre-Defined Risk Assessment
PPP	Public-Private Partnership

Abbreviations

RBO	Risk-Based Oversight
RFI	Request for Information
RFP	Request for Proposal
RFQ	Request for Quotation
RFT	Request for Tender
RPA	Remotely Piloted Aircraft
RPAS	Remotely Piloted Aircraft System
RPS	Remote Pilot Station
RSOO	Regional Safety Oversight Organization
RTCA	Radio Technical Communications for Aeronautics, Inc
SAIL	Specific Assurance and Integrity Level
SARPs	Standards and Recommended Practices
SESAR	Single European Sky ATM Research Joint Undertaking
SMS	Safety Management Systems
SORA	Specific Operations Risk Assessment
STS	Standard scenario
TFR	Temporary Flight Restrictions
TOR	Terms of Reference
UAS	Un-crewed aircraft system
UAS-AG	UAS Advisory Group
UASSG	UAS Study Group
UAV	Un-crewed aerial vehicle
UEMOA	Union Economique et monétaire Ouest Africaine
UK	United Kingdom
UNDRIP	United Nations Declaration on the Rights of Indigenous Peoples
UPDWG	UAV for Payload Delivery Working Group
UPS	Uninterruptible power supply

Abbreviations

URSAC	Unité Régionale de Supervision de la Sécurité et e la Sûreté de l'Aviation Civile de l'UEMOA
UTM	Un-crewed aircraft systems traffic management
VHF	Very high frequency
VLOS	Visual line of sight
VTOL	Vertical take-off and landing
WBG	World Bank Group
WEF	World Economic Forum
WFP	World Food Programme



Introduction

The African Drone Forum (ADF) is a multi-stakeholder engagement platform for drone technologies and services that meet the needs of emerging markets.

Through its work, the ADF seeks to assist countries in Africa and beyond in building enabling drone ecosystems that can make a significant difference for isolated and rural communities, tap into potential new market opportunities, and unlock an additional resource: the lower skies. In Africa, the necessary technologies for Beyond Visual Line of Sight (BVLOS) drone operations and autonomous flights are being tested and proven. “Drone” is a term used mainly by the media and governments when communicating with the public, and although alternative names for a drone exist, such as un-crewed aircraft (UA), un-crewed aerial vehicles (UAV), or remotely piloted aircraft system (RPAS), this guidebook will use the term un-crewed aircraft system (UAS)[14].

The utilization of the lower skies can help overcome existing challenges to service provision, such as topography that makes parts of a country inaccessible. Those accessibility challenges often coincide with infrastructure deficits, creating unsafe driving conditions at night and adverse weather conditions. At the same time, as driving conditions for ground vehicles deteriorate, demand for certain medical and humanitarian use cases does not. As a result, essential goods supply chains across many emerging economies are highly vulnerable and easily disrupted. This fragility provides a strong impetus for introducing alternative transport modalities that can fill gaps in current service provision and strengthen existing supply chains. The use of UASs in the lower skies provides opportunities to support and enhance the resilience of those supply chains, accelerate digitization efforts, and improve service to hard-to-reach or previously unconnected communities. Providing enabling environments can unlock new markets, use cases, and job opportunities and serve

as a crucial downstream enabler to future economic growth, poverty reduction, and shared prosperity in Africa and beyond[15]. Investments in power grids, expanding rural connectivity and broadband access, and boosting education, technological literacy, and other supporting elements will likely yield broader economic and societal benefits.

In 2018, the AU Executive Council recommended that the member states harness the opportunities offered by UAS, with a particular focus on agriculture[16]. Other essential uses include the strengthening of health supply chains, a subject of specific importance in the context of the ongoing COVID-19 pandemic, and mapping and data collection to support land digitalization, cadastral mapping, disaster and risk management, urban planning, and inspection of critical infrastructure from pipelines and powerlines to mining sites and telecommunications. Use cases particularly suited to drones broadly span mapping and data collection, cargo, or hybrid operations.

- **Mapping and data collection** — This use case currently represents the vast majority of UAS operations. These services have proven cost-effective compared with alternatives and are easy to set up, commonly relying on flying within VLOS. In those cases, UAS "cover large surface areas, over a shorter period of time, at a higher resolution, at less cost, greater safety, using fewer resources, than relying only on field personnel and logistics, shortening the time taken to evaluate findings and inform planning"[17].
- **Cargo operations** — This is the most complex use case, relying on flying BVLOS and requiring sophisticated UAS platforms. Despite the demand for UAS applications, few cargo operations make it beyond the limited pilot stage owing to a range of factors, from restrictive regulations affecting permitting and approval to gaps in funding and capacity.

Despite demand across use cases, many UAS operations either fail before the initial pilot stage or do not continue beyond it to a larger scale due to a range of reasons, from challenges with training and capacity building, to unclear UAS regulations or rules, to missing infrastructure and funding gaps. Among the biggest drivers are uncertainty caused by regulations that are "prohibitive, lacking in specificity, or simply nonexistent"[18] and underestimating the complexities and timeframes involved in setting up UAS operations and broader enabling ecosystems.

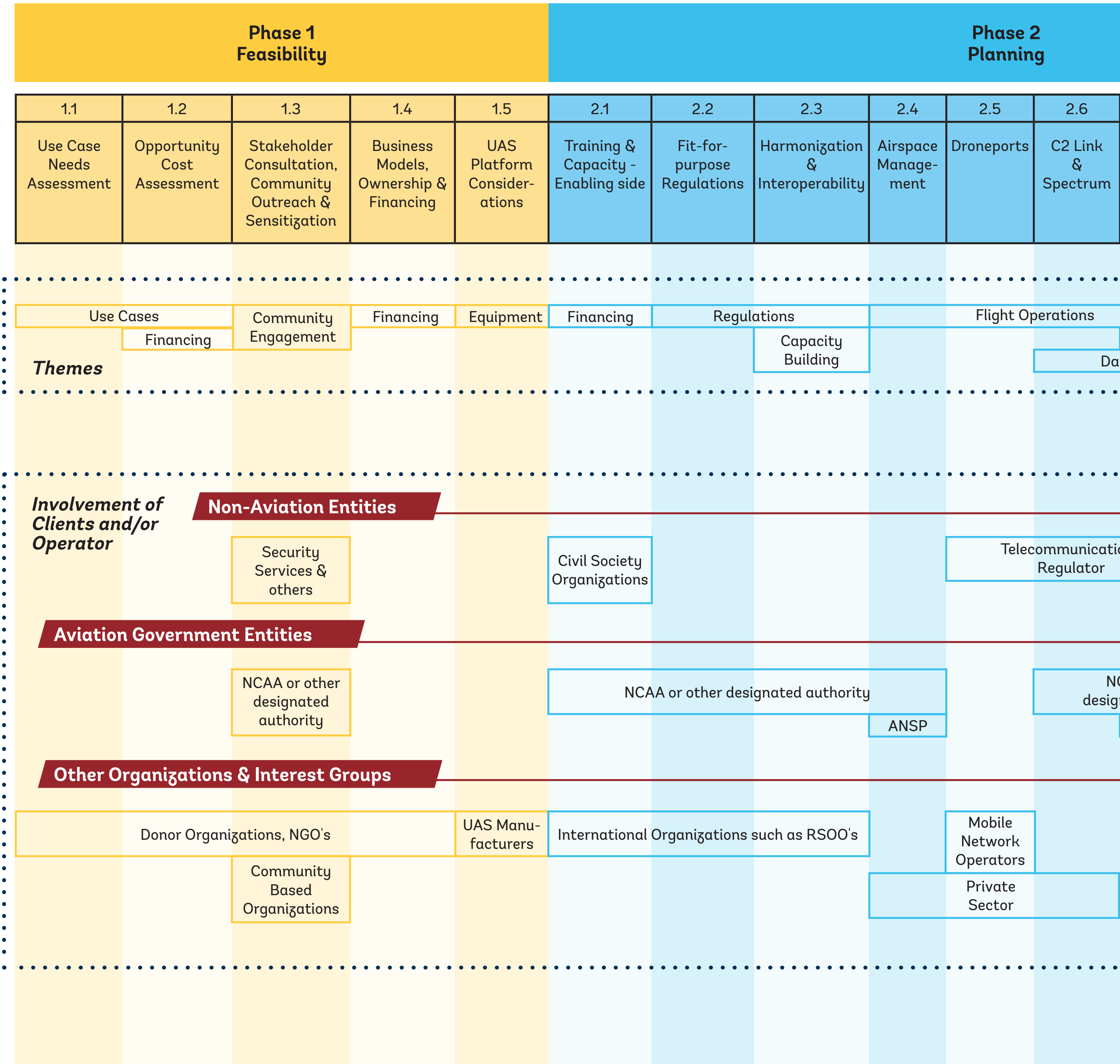
This guidebook identifies elements necessary to unlock the transformational value UASs can bring to a country and set up an environment conducive to safe and sustainable high-frequency drone operations. It achieves this by reflecting on experiences of facilitating the LVC in Tanzania in 2018 and the LKC, under the banner of the ADF, in Rwanda in 2020. It further builds on a review of existing literature, reports, and guidelines regarding the set-up of drone ecosystems and corridors and semi-structured interviews with partners, government representatives, regulators, and UAS service providers and manufacturers. Although the guidebook largely builds on African experiences, it is very much region-agnostic and applicable elsewhere.

The focus is on enabling VLOS and BVLOS operations using small- to medium-size UAS within low-level airspace. These are likely to represent most UAS operations and provide significant socio-economic benefits in the near to medium term. Although there are benefits in providing more in-depth and technical discussions of the individual elements, specifically drone regulations and rules, the focus is instead on raising awareness of the complexities of setting up enabling environments by providing high-level overviews and discussions of all elements that make up a broader enabling environment. Where appropriate, references to pivotal reviews, publications, and studies are included to overcome this limit in scope.

This guidebook covers different elements that form the part of a holistic, enabling environment for safe and sustainable high-frequency UAS operations. Although responsibilities for the various elements rest with a diverse range of stakeholders, we intend to raise awareness of how different elements interlink and form part of a broader enabling environment. Readers should not regard this playbook as a one-size-fits-all approach, but rather as a comprehensive overview of experiences drawn from different operational environments that are not exclusionary to new additions, removals, or changes that naturally occur over time. Each element is associated with at least one of the overarching themes, involves at least one core stakeholder group, and is interconnected with elements across the different phases, as no one element alone "is indicative of the success or failure of a drone programme"[19]. The breakdown for each element is as follows:

1. **Background —** This section endeavors to answer why this particular element matters and what it entails. The background also highlights which stakeholders are traditionally responsible for the implementation. In cases where implementers can make different choices, we have included further explanations and anecdotes. Readers should note that examples generally reflect the experience of a particular deployment and would need to be adjusted and made relevant to a specific country and use case context.
2. **Discussion —** This section raises pertinent questions and discusses particular caveats associated with the element itself or choices related to it.
3. **For more information, see also —** This section highlights in-depth resources regarding a particular element, including a summary of specific relevance. We have strived to include various reports, guidebooks, and academic literature that reflect the progressive and most effective guidance on a particular topic to date.

Figure 1.1
Highlighting the themes and stakeholders associated with the different elements and phases



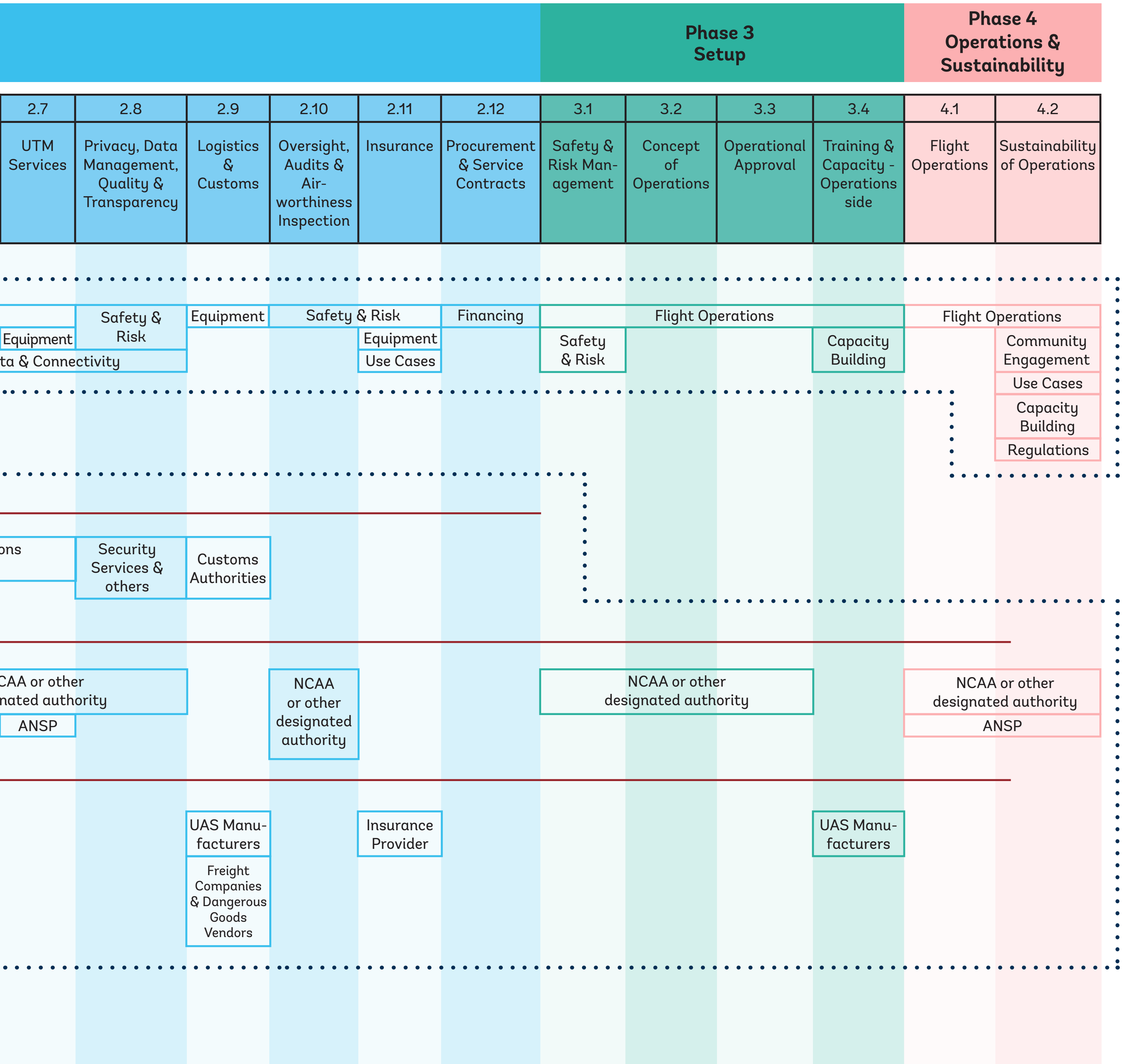
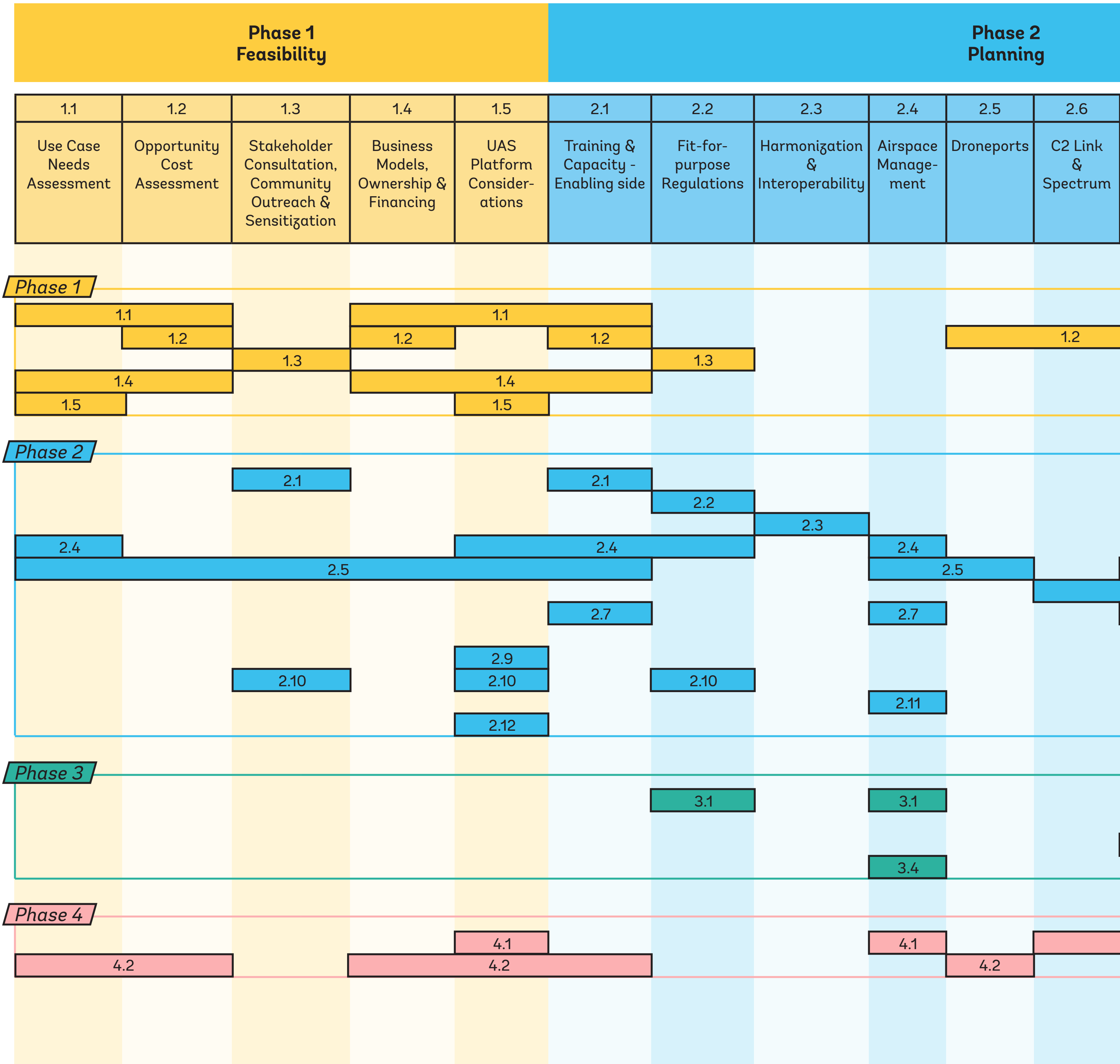
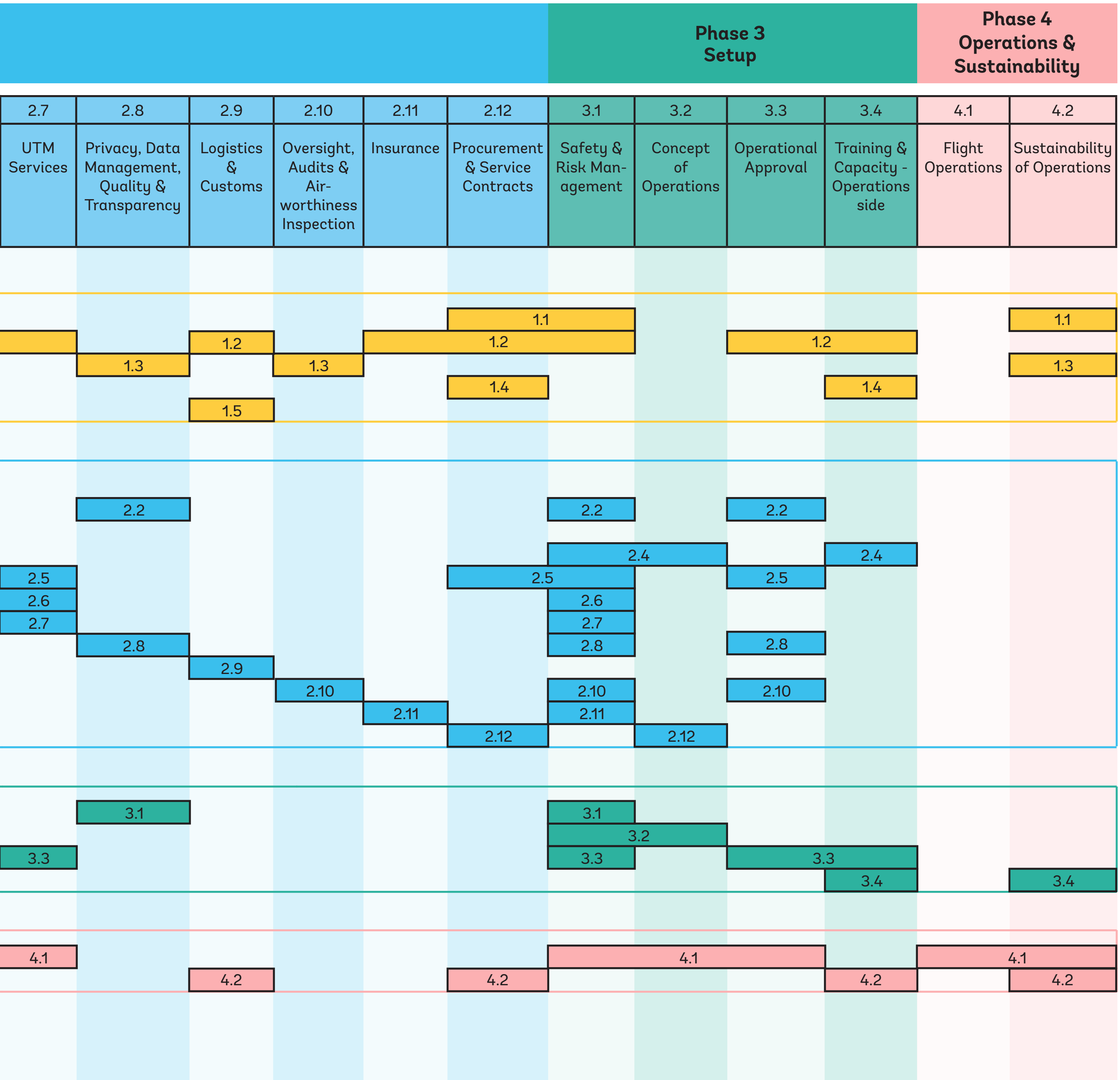

Phase 3
Setup
Phase 4
Operations & Sustainability
2.7
2.8
2.9
2.10
2.11
2.12
3.1
3.2
3.3
3.4
4.1
4.2
UTM Services
Privacy, Data Management, Quality & Transparency
Logistics & Customs
Oversight, Audits & Air-worthiness Inspection
Insurance
Procurement & Service Contracts
Safety & Risk Man-agement
Concept of Operations
Operational Approval
Training & Capacity - Operations side
Flight Operations
Sustainability of Operations
Safety & Risk
Equipment
Safety & Risk
Financing
Flight Operations
Flight Operations
Equipment
Equipment
Safety & Risk
Capacity Building
Community Engagement
ta & Connectivity
Use Cases
Use Cases
Capacity Building
Regulations
ons
Security Services & others
Customs Authorities
CAA or other
nated authority
NCAA or other designated authority
NCAA or other designated authority
NCAA or other designated authority
ANSP
ANSP
UAS Manu-facturers
Insurance Provider
UAS Manu-facturers
Freight Companies & Dangerous Goods Vendors

Figure 1.2
Overview of the different elements across the phases of setting up enabling ecosystems and UAS operations. While each chapter can be read individually, the cells across each line highlight the interconnectedness with other elements and phases.




Phase 3
Setup
Phase 4
Operations & Sustainability
2.7
UTM Services
2.8
Privacy, Data Management, Quality & Transparency
2.9
Logistics & Customs
2.10
Oversight, Audits & Air-worthiness Inspection
2.11
Insurance
2.12
Procurement & Service Contracts
3.1
Safety & Risk Man-agement
3.2
Concept of Operations
3.3
Operational Approval
3.4
Training & Capacity - Operations side
4.1
Flight Operations
4.2
Sustainability of Operations
1.1
1.2
1.3
1.4
1.5
2.2
2.4
2.5
2.6
2.7
2.8
2.9
2.10
2.11
2.12
3.1
3.2
3.3
3.4
4.1
4.2

Phase 1: Feasibility

Drones are a powerful tool capable of providing many benefits — from efficient data collection to safe and timely service provision for medical commodity delivery. Whether UASs are an appropriate solution and capable of delivering transformational value to a particular problem depends on specific needs, the cost and performance of alternatives, and the given ecosystem's readiness. Initial feasibility analysis can range from very light touch and rapid to a very in-depth and resource-intensive study. More rigorous and resource-intensive analyses can highlight specific needs within existing supply chains or operating procedures and contribute to a detailed understanding of baseline costs and affordability for customers, in terms of willingness and ability to pay, compared to alternatives not easily captured by simple analysis. A thorough feasibility analysis should also consider the impact on the broader community and stakeholders, their perceptions, humanitarian needs, and improved quality of life that UAS can bring[20]. Finally, it should also consider potential business models for funding operations, how "success" is measured and monitored, and whether envisioned operations are feasible with available technology.

1.1 USE CASE NEEDS ASSESSMENT AND INTEGRATION INTO EXISTING OPERATIONS AND SUPPLY-CHAINS

Themes: Use cases
Involvement: End-users such as a postal service; Ministries in charge of Agriculture, Infrastructure, Commerce, Land, or Health; local government authorities; donor organizations, NGOs; or UAS service providers looking to conduct or procure services to address specific use cases

Background

The first step in examining the feasibility of drone operations should be the identification of use cases with clear problem statements and addressable needs where drones can have a meaningful impact. Those problems could include large unmapped areas that are difficult to access or high stockout rates in health clinics. The problem statements should, in turn, lead to the identification of clear objectives to frame the envisaged operations. Those objectives both help with the opportunity cost assessment (see 1.2), an informed choice of drone platform (see 1.5), procurement (see 2.12), and ongoing evaluation of operations as part of Phase 4. Undertaking a use case needs assessment will help with this process. Ideally, prospective end-users shall conduct such an assessment in consultation with a wide range of stakeholders and system participants.

Understanding problem statements requires identifying underlying root causes within the existing systems and procedures that create bottlenecks and difficulties. Identifying root causes is necessary to determine whether drones represent a potential solution to address the problem statements. Root causes of stockouts of medical commodities, for example, could be caused by international shipping and procurement challenges rather than challenges in last mile delivery from warehouses to health clinics. Similarly, issues with diagnostic sample analysis could stem from insufficient resources at analysis labs or violation of procedures rather than long transportation times from clinic to laboratories.

Drones can have tremendous potential to generate all kinds of benefits and solve all types of use case problems. Yet a clear understanding of where and how they can have an impact is needed to determine their full potential before any higher-level engagement or tender should occur. A use case needs assessment considers the identified use cases in the context of existing supply chains and procedures to determine whether drones can provide long-term, transformational value rather than a nice-to-have benefit. Integrating drones into existing systems rather than creating new ones will often prove more practical and sustainable. It is a best practice to compare drone solutions with existing solutions to determine whether drones have the potential to provide advantages in efficiency, effectiveness, and cost. Those will vary depending on the chosen drone platform (see 1.5) capabilities and specifications, price, speed, distance, coverage, and overall efficiency and effectiveness.

A needs assessment "defines the operational requirements, conditions, and settings (e.g., population density, and whether in urban or rural context), and would define the operation's objective and purpose" by considering the what, how, where, and when of the use case[21]. An assessment should consider the potential benefits versus the risk of utilizing drones; for example, do the health and service benefits outweigh the risk of adding things to the country's airspace? A needs assessment would consider four different elements:

1. Geography and transport network characteristics (e.g., climate, topography, seasonality, existing transport modalities, quality of the network, density of health facilities, the density of health facilities, and distances between commodity re-supply points);
2. Service demand (i.e., baseline data

summarizing demand for various categories of commodities, including facility-level population, health, and supply chain data);
3. Drone characteristics (i.e., range, payload, delivery mechanism, connectivity requirements)[22];
4. Alternative modes of transport or service provision (e.g., performance, capital expenditure, operating costs, indirect costs such as expired medicines or stockouts, , and comparison with drones);

The analysis should also consider the existing alternatives, local (logistics) partners, and the private sector as well as the current economic structure behind in-country logistics to determine the drones' role within an existing system or structure as a complementary rather than a competitive tool.

Box 1.1 — Steps of a use case needs assessment for UAS operations

Steps of a use case need assessment, which should be carried out in consultation with all stakeholders within the broader ecosystem impacted by drone interventions include[31]:

1. The **identification of gap(s)** in an existing approach to a use case or supply chain;
2. Determining the **root causes of those gap(s)** to understand whether drones and objectives are the right tools to address the identified problem statements sustainably and cost-effectively
3. Understanding the **needs and requirements** of supply chains and operating practices to determine whether drones can have a meaningful impact and provide transformational value
4. The **articulation of requirements** a drone platform needs to be capable of fulfilling

Understanding those elements will help determine whether drones are the right tool for the job, selecting an appropriate platform, informed procurement, engagement, and ultimately success. Approaching donors with a value proposition in the form of clear, long-term plans is also likely to unlock mainstream funding opportunities from the international donor and development community.

Case Study — Urban Land Administration

An early set of use cases in Africa used drones for land administration associated with building surveys, land titling, cadaster, town planning, and infrastructure monitoring. This subset of applications has seen strong demand in cities experiencing rapid and mostly unplanned urbanization — a common challenge across African cities.

The root problem is that the demand for digitalization of urban change currently exceeds either the affordability or pace-mapping of traditional survey methods in these towns and cities. Typically, cities will deploy surveyors for ground-based measurements and collection of plots and building boundaries. Ground-based data collection is costly and, more importantly, time-consuming. Historical alternatives have been the acquisition of very high-resolution aerial imagery from conventional aviation service providers. This option allows for quick city-wide mapping, but is expensive when using aircraft and occurs infrequently (often at five-year intervals), making it ineffective in fast-changing communities with more frequent update needs.

Advantages of drones include reduction in cost and complexity compared with conventional aerial mapping, they are often quicker to deploy, and they usually count on local providers rather than international firms or aircraft. Also, the lower flight level of drone-based photogrammetry versus high-flying aircraft can provide higher resolution images (on the order of 2-3cm needed in cadaster applications) and 3-dimensional data for digital surface models.

The primary operational challenge to consider in urban operations is the ground risk. Surveying buildings necessitates flying over people and houses, as it is impractical to vacate neighbourhoods for the mapping. Furthermore, large-scale urban surveys suggest the need for BVLOS operations within urban areas that are likely to be close to critical infrastructure and populated. Some survey applications, including cadaster, which require very high-resolution measurements, typically involve drones flying very close to the ground; currently, a 2.5cm ground sampling resolution using an eBee Plus drone requires an 80m flight altitude. Low-altitude flying presents a challenge with tall buildings, masts, kites, and so forth.

Many drone regulation regimes forbid flying over people or houses, or BVLOS, within 5km of aerodromes or restrict drones to a maximum or minimum ceiling that may be incompatible with survey requirements. As such, urban surveys are very likely to require extensive consultation with aviation regulators, broad consultation of route and flight planning, and high focus on minimizing ground risk through the use of small, lightweight, frangible aircraft systems. Some professional survey drones weigh less than 2kg, are made of expanded polypropylene foam material, and are designed to break apart on impact.

Urban applications that require heavier drone systems can manage ground risk in alternative ways. In the case of urban river surveys in Dar es Salaam, high-precision river cross-section surveys required the use of drone-mounted Lidar, leading to a total platform weight exceeding 16kg. In this case, the operator managed the ground risk by flying in a tightly controlled and temporarily evacuated river valley, avoiding overflying houses and within the operator and safety officers' line of sight.

Case Study — Disaster Risk Management

Disaster management is a familiar early adopter of new drone-related capabilities — particularly in risk assessment and damage assessment applications. Similar to urban land surveys, these require low-flying, lighter-weight systems operating in complex ground and air risk environments. The challenge statement in this domain differs slightly from urban land administration, as flights are time-sensitive, as is the case with damage assessment or situational awareness where data on impacted areas, buildings, people, and so forth are needed as quickly as possible. Wide-area disasters, such as cyclone damage, flooding, or earthquakes, may also call for BVLOS operations to survey large areas or reach distant communities.

In the context of emergency operations, relief, and response activities, drone services can be a critical enabler of a coordinated and efficient recovery, providing routine situation maps, damage maps, and baselines for reconstruction. The constraining challenge is the lack of time to develop and consult during an emergency, which impedes proper management of permissions, operations manuals, and safety assessments. Therefore, it is highly desirable to have pre-approved service providers operating in coordination with civil protection and humanitarian agencies that are well-versed, trained, and have conducted drills and simulations in advance (see 2.1). Using volunteer drone services deployed for the first time during an emergency is to be avoided where possible, as there is an inherent risk for causing coordination issues stemming from their often-limited experience of working in emergency situations. Instead, ex-ante approvals with local providers or international organizations with the necessary experience is a more pertinent avenue.

An additional consideration is a need for a balanced assessment of risk that considers the consequences of not flying. During an emergency, the understanding of "acceptable risk" may change if the drone application is itself a life-saving objective. These decisions, however, should be discussed and determined ex-ante during disaster preparedness and risk-reduction programs that identify authorized service providers, services, and operating regimes.

Case Study — Health and Layering use cases

Lack of accessibility and poor transportation infrastructure — two supply chain bottlenecks — often lead to the lack of equitable access to health commodities and services. Physical barriers such as topography or terrain, transport infrastructure, weather, or security may prevent governments and organizations from timely delivery of commodities and services. In such instances, drone technology offers a solution to overcome some of those physical barriers. In areas where transportation and accessibility are the root cause of inequities in health service and health commodity coverage, drones have the potential of closing that gap and bringing transformational, leap-frogging value. To maximize the results and impact of drone delivery, it is crucial to clearly define the needs and demands and identify the problem that drones actually can help solve.

Based on several activity reports, drones have demonstrated capability to improve several aspects of health programs, which can potentially contribute to the Sustainable Development Goals[23]:

- The use of drones can lead to a 65% reduction in turnaround times of diagnostic samples (i.e., samples delivered on time, not expiring, effective diagnostics) and up to a 130% increase in diagnostic sample collection, leading to more effective healthcare provision
- Drones can support compliance or adherence with immunization and treatment schedules or campaigns, introducing services that would not be available otherwise
- Drone delivery can help minimize vaccine and other health commodities stockout levels and increase the general availability of health commodities at the health-facility level
- Drones can reduce the health facility dependency on storage capacity and equipment
- Drone delivery bundled with other innovative interventions can offer a cost-effective solution for disease control, based on WHO cost-effectiveness assessment methodologies
- High utilization of drones through frequent usage can decrease transport costs and help recoup both initial capital and ongoing operating costs

Drones represent a promising tool for in-country logistics in access-constrained contexts. They may carry, among other things, life-saving commodities, blood products, vaccines, diagnostic samples, micronutrients, or other small payloads as a part of the routine health supply chain or during emergencies. The quick turnaround time and range of drones allow end-users to use them for emergency orders, regular and just-in-time re-supply of essential commodities, and reverse logistics such as diagnostic sample pick-up to add an on-demand or just-in-time "pull" system to a supply chain[24]. Another emerging use for drones is the delivery of larger payloads that can include humanitarian aid[25].

The delivery solution's selection will depend mainly on the underlying health indicator performance, coupled with transportation and distribution bottlenecks. A Ministry of Health might use drones to improve vaccination coverage; provide timely fulfillment of emergency requests for oxytocin, anti-venom, or blood transfusions; improve turnaround time for infectious diseases diagnostics such as tuberculosis, malaria, or HIV; or increase the overall availability of health commodities and diagnostics services at a health facility level. At the same time, ministries might consider the layering of use cases, such as mapping at the same time as delivering cargo, which can generate efficiencies and cost savings by allocating fixed costs across many flights, thus maximizing utilization in terms of capacity and time[26].

Discussion

Pertinent questions

- Will drones supplement and strengthen existing supply chains, or will they replace existing modes or introduce previously unexplored supply chains?
- What are opportunity costs for lives and impacts on the supply chain—such as, for example, impacts on job opportunities—and how can drones add transformational value?

In cargo operations, UAS can impact different stages of a supply chain, each with different requirements placed on the drone platform.

- First mile—Operations involve transportation from the manufacturer to ports of entry or the highest level in the supply chain, such as a centralized warehouse. These routes are often served by sea, air, or ground transport, as the number of products to be delivered is typically large. At the same time, the first mile generally faces fewer problems and logistics challenges compared with last mile deliveries.
- Middle mile—Operations involve the transport from the highest level of the supply chain to distribution hubs or among such hubs. Drones have the potential to significantly reduce transportation hours and handoff times usually associated with hub and spoke models[27].
- Last mile—Operations involve the transport of payloads to their final destination or in time-sensitive situations such as the delivery of essential commodities, medical aid, and disease outbreak or epidemics management and disaster response supplies.

For cargo operations, drones are likely to have the most significant impact across the last mile because they involve small payloads that are easy to transport, besides being where most access and supply problems within public health systems occur. Some drones support cold-chain transport for temperature-sensitive health products, using active or passive cooling. Companies such as Zipline (for their blood deliveries in Rwanda), for example, use low-tech solutions such as simple ice packs capable of providing cooling for nearly 15 hours. Passive cooling cannot sustain the extreme durations or temperatures necessary for a small number of vaccines and medications, however; such applications require active cooling, which comes at the expense of higher power consumption and more specialist cargo compartments on the drone that cannot be repurposed for other uses as easily. Depending on the type of cargo, considerations for potential risk to public health and safety, property, and the environment may be necessary (see 3.1); this is particularly relevant for goods classified as dangerous, such as biological samples[28].

The introduction of UAS into local operations and supply chains is likely to impact local distribution networks, economies, and logistics partners.
As such, it would be worth considering

the impact of proposed operations and services on the private sector and local communities. A reduction in the volume of goods transported by local drivers, for example, can mean less work and thereby less income, adversely affecting livelihoods. During the process of demands and needs identification, consultations with the local community, local supply chain, logistics, and health stakeholders are critical to ensure that the use cases address local needs (see 1.3). Such an inclusive and consultative process of identifying needs and demands helps shape an accurate problem statement and ensures community acceptance and long-term sustainability of the solution. Ultimately, operations and particularly those involving the last mile will continue to require locals to distribute to local houses or businesses and create demand for unusual or new jobs in communities, such as order taking, maintenance or droneport management.

The analysis also has to consider other aspects of processes and supply chains, including storage and particularly cold-chain capacity (both at the hub and the destination health facility, for example), product and service availability and demand, existing protocols and processes, and available human and organizational resources, including:

- **Managing last mile delivery** — Do remote receiving points have the cellular coverage to provide connectivity, staff available to receive deliveries and reload drones, and in the case of cold-chain cargo, the appropriate storage capacity and electric supply to prevent spoilage?
- **Data management, privacy, and quality** — Does the capability to analyze and understand geospatial or imagery data collected by drones exist in the country? Is there sufficient trust in the data?

Such understanding helps inform cost assessments to determine whether the intervention (i.e., UAS operation) can offer the best value for money or, in other words, whether drone delivery has the potential to yield the most significant improvement in service for the least resources in comparison with alternative interventions. Understanding the existing capabilities, ecosystem, and economic structure can also provide insight into how drone operations can achieve long-term sustainability by applying market-driven approaches.

Finally, the collection of operational, cost, technical, and related data and evidence should be an integral part of drone delivery implementations to ensure that the results are shared, progress is monitored, costs are quantified, and impact is evaluated. Collecting baseline data for evaluations may not always be straightforward, but it is essential for evaluating cost, performance, and impact. Basic information on stock levels across medical facilities, for example, may either be missing entirely or inaccurate due to a range of factors from paper record-keeping with limited information to underreporting (see 4.2)[29]. In order to rigorously generate evidence on drone operations, monitoring and evaluation professionals and financial resources must be identified and budgeted for prior to starting operations[30].

For more information, see also

UN Aviation Safety Section (2017). ***United Nations RPAS Experience: Setting the Stage.*** Presentation delivered at ICAO 2nd Remotely Piloted Aircraft System (RPAS) Symposium — Details UN agency experiences of using drones for various use cases

World Bank Group (2017). ***Guidance Note: Managing the risks of unmanned aircraft operations in development projects.*** — An in-depth overview of possible use cases of UAS.

Use cases — Urban land administration and disaster risk management

GFDRR (2021-a). ***Drones and the 2017 Sierra Leone Mudslide.*** ACP-EU Natural Disaster Risk Reduction Program: Online. — Case study outlining both the approach and key lessons learned.

GFDRR (2021-b). ***Drone Use in Senegal for Flood Control.*** ACP-EU Natural Disaster Risk Reduction Program: Online. — Case study outlining both the approach and key lessons learned.

GFDRR (2021-c). ***Drones and Response to the 2018 Uganda Landslide.*** ACP-EU Natural Disaster Risk Reduction

Box 1.2 — Data scarcity and challenges in quantifying the impact of introducing drones

At present, most UAS operations remain pilots with few at-scale services in existence. Supply chain disruptions and quarantine measures impacting connectivity and service delivery brought about by the COVID-19 pandemic have amplified the interest in utilizing drones to strengthen service provision and resilience. However, considering the inherent complexity of setting up enabling environments, this interest does not yet represent a full gamechanger.

Impacts of introducing drones have primarily materialized among digital applications, which form part of broader digitalization efforts and thus complicate identifying the specific impacts of drones. Although the number of cargo and other operations using UAS have increased in recent years, generating impacts takes significant time, and data does not exist or is not (publically) available yet. In part to address this challenge, the World Bank is conducting a sector-by-sector impact assessment to determine potential environmental, social, and economic impacts of introducing drones for inclusion in a forthcoming report on the harmonization of drone regulations.

Program: Online. — Case study outlining both the approach and key lessons learned.

World Bank Group (2016). ***UAV State of Play for Development: Innovations in Program and Humanitarian Contexts.*** — Note on the use of UAS in development with a specific focus on mapping and how they measure up to other data capturing alternatives

Use cases — Health and delivery

Eichleay, M., Evens, E., Stankevitz, K., Parker, C. (2019) **Using the Unmanned Aerial Vehicle Delivery Decision Tool to Consider Transporting Medical Supplies via Drone.** *Global Health Science Practice*, 7(4), 500-506 — Commentary outlining challenges for integrating UAS into health supply chains

Greve, A., Dubin, S., Triche, R. (2021). ***Assessing Feasibility and Readiness for Cargo Drones in Health Supply Chains. A Guide to Conducting Scoping Trips in Low- and Middle-Income Countries.*** Washington: USAID — Guideline to support planning for cargo operation setup

ISG-UAS (2018, Dec). ***UAVs in Global Health: Use Case Prioritization.*** Presentation delivered at ISG-UAS Group Meeting — Presentation of (1) prioritized use cases for UAS in global health and (2) beginning to detail the requirements to operationalize these use cases.

UNICEF Supply Division (2019, Oct). ***Unmanned Aircraft Systems: Product Profiles and Guidance.*** Kopenhagen: UNICEF Supply Division — Overview of potential considerations in the examination of potential uses for UAS in the transport of health commodities

VillageReach, ISG-UAS (2019, Nov). ***Toolkit for Generating Evidence around the Use of Unmanned Aircraft Systems (UAS) for Medical Commodity Delivery, (Version 2).*** Seattle: VillageReach — Provides guidance and tools to generate evidence around the use of UAS for medical commodity delivery to inform programmatic decision-making

Wright, et al. (2018). ***What should you deliver by unmanned aerial systems? The role of geography, product, and UAS type in prioritizing deliveries by UAS.*** White paper, inSupply — Study considering the cost-effectiveness of different health commodities for delivery via UAS.

Yadav, P., Lydon, P., Oswald, J., Dicko, M., Zaffran, M. (2014). **Integration of vaccine supply chains with other health commodity supply chains: A framework for decision making.** *Vaccine*, 32(50), 6725-6732— Product integration or "layering" of drone services within health supply chains

Yadav, Prashant (2015). **Health Product Supply Chains in Developing Countries: Diagnosis of the Root Causes of Underperformance and an Agenda for Reform, *Health Systems & Reform,* 1(2), pp. 142-154** — Discussion of health supply chains and main challenges and their root causes

1.2 OPPORTUNITY COST ASSESSMENT

Themes: Use cases and financing
Involvement: End-users such as a postal service; Ministries in charge of Agriculture, Infrastructure, Commerce, Land, or Health; local government authorities; donor organizations; NGOs; UAS service providers looking to conduct or procure services to address specific use cases
Timeline: Approximately three months, once a tailored framework to account for UASs is in place. Otherwise it is more likely to take 9-12 months; it is generally more of an iterative process. In the beginning, it will be very high level and would help make a case for government support. As more information becomes available, end-users should refine the cost assessment.

Background

Following the identification of use cases and operational requirements, an opportunity cost assessment can help determine how much money to spend on providing a particular service and what services to spend it on. Such analysis can help resolve uncertainty over the added value of a UAS compared to alternative modalities from trucks and motorbikes for cargo delivery to planes and satellites for mapping purposes. It aims to determine value propositions of different options as a benchmark to inform business model choice (in conjunction with a prior use case needs assessment, see 1.1) and determine whether planned operations are feasible within allocated budgets. It involves the consideration of cost-effectiveness and cost-efficiencies within broader, existing operating practices or supply chains.

It also analyzes all aspects and associated (opportunity) costs needed to provide a particular service to determine baseline costs to compare to potential drone operation costs. A typical approach for exploring the case for using UASs is within the context of the so-called "logistics objectives". The objectives include total operating costs, speed, availability, flexibility, and human or societal objectives. Human and societal objectives are particularly crucial for public-decision makers and international donor organizations who cannot determine the potential cost-effectiveness of UAS "without looking at the public health benefits, which may be substantial"[32]. The opportunity costs of increasing access to healthcare or other services, gender inclusion, lives saved, improved environmental sustainability, or the reduction in waste and stockouts are challenging to quantify. Yet understanding opportunities are crucial to determining the overall cost-benefit of different solutions in the context of affordability, as they will likely counterbalance the intangible benefits.

Drone operations can either be outsourced, running as an external drone-as-a-service model, or insourced, as end-user-run services. (see 1.4 and 2.12)**.** The prior involves paying a company to set up the necessary infrastructure and equipment, provide training, and conduct maintenance and operations. Although accurate data is rarely publicly available (see Box 1.2), cost estimates for external service models for cargo operations range from US$1-2 million in capital expenditure alone, with additional monthly service fees of up to US$100,000 per month for delivery of 500,000 vaccine doses or other supplies to most hard-to-reach areas in a country[33]. If the inevitable inefficiencies of a public sector operation, such as comparatively poorer operating metrics, are included, the overall cost of internal service models may end up significantly higher. External, drone-as-a-service models provide an additional benefit of being "professionalized" operations, alleviating the need for extensive internal capacity building and staffing at the cost to the procuring government or organization. In the case of UAS operations, the opportunity cost assessment should consider a range of elements, particularly if an internal as opposed to an outsourced drone-as-a-service model is chosen, including:

Table 1.1 — Key cost factors in insourcing and outsourcing of UAS operations

Type	Insourced	Outsourced
Capital costs	Procurement — The upfront cost for drones can range from approximately 36,000US$ for multirotor to 100,000US$ for more sophisticated drones capable of Beyond Visual Line of Sight (BVLOS) cargo operations[34]. Little is known about the lifetime of different UAS platforms, with some smaller electric UAS potentially needing replacement after 1000 flight hours making procurement a potentially recurring cost.	
	Infrastructure — Additional investments may be necessary to set up suitable droneports and provide connectivity to support operations (see 2.5), but are highly dependent on the chosen UAS platform.	Infrastructure — Although the UAS service provider will be providing the platform itself, depending on the service arrangement, they may require particular infrastructure such as an airstrip or warehouse to be in place to be able to operate (see 1.4, 2.5).
	Ancillary equipment — Depending on the chosen objectives, computers, mobile phones, and other small equipment may need to be purchased.	
Pre-launch costs	Human resources — This can include hiring additional staff, capacity building with both staff and regulators (see 2.1 and 3.4), and community engagement efforts in the lead-up to the commencement of operations. Training and capacity building often includes the engagement of international staff or consultants'.	
	Operational — This includes travel to potential operating sites for site selection and assessments (see 2.5 and 3.1), applications for operational approval (see 3.3), and potentially very costly shipping and importation of equipment (see 2.9). In some countries, fees for permits and additional costs for permit applications' accelerated approval may also be due.	
Operating costs	Travel — There may be ongoing travel costs for (routine) inspections, audits, mapping, or other scenarios.	
	Maintenance — This is likely to represent the most significant ongoing cost factor and can make up more than half of the ongoing operating budget. Maintenance costs should account for the procurement of spare parts, which may need to be imported from outside the country.	Depending on the chosen business model (see 1.4) and contractual arrangements (see 2.12), UAS service provider fees typically include maintenance, labor and other operating costs.
	Labor costs, meanwhile, might be low when mainly employing local staff.	
	Other costs — This can include data analytics, and ancillary services ranging from Un-crewed Traffic Management (UTM, see 2.7) to insurance (see 2.11) necessary to conduct operations. Assessments should also consider data fees for mobile networks or satellite communications (see 2.6, 2.7), which may be very expensive in some countries, and fuel or electricity.	
Important note	**Unfortunately, it is extremely difficult to obtain this type of information from UAS service providers, with no good or reliable resources to pull data from.** Publishing a request for Information (RFI) or Expression of interest (EOI) may be an avenue for end-users to collect information to aid decision making (see 2.12).	

Discussion

Pertinent questions

- Can the local environment support drone operations without requiring additional costs to set up enabling elements?
- What are the actual benefits of using drones?
- What are the costs of the drone platform or service required for the identified use cases?
- Do drones make sense or not in the specific context and address the identified needs, or is there another more feasible modality?

Although organizations on the ground have experience identifying gaps in health supply chains and data analytics, their financial frameworks are often not tailored to account for aviation, regulations, and drone technology. Ecosystem readiness can introduce significant unforeseen costs that are potentially unaccounted for in traditional cost-benefit analysis models. Depending on the use case needs, sophisticated drones requiring more sophisticated training that is not necessarily available locally may be needed. As a result, pilot studies often reveal that drones are too expensive in a particular instance, do not fit the needs, or do not have the right enabling environment.

Early experience in cost-benefit analysis shows that savings in goods transport using UAS are primarily affected by drone vendor pricing structure, capital costs, ground transportation costs, and the level of demand when compared to traditional transport modes[35]. It is essential to consider that:

- Drone vendors vary significantly in their pricing and drone capabilities.
- Leasing provides a much more cost-competitive option compared to buying.
- Because drones cannot compete in price with cheap or free transportation (including public transit) for cargo operations, site selection is critical for having a cost-effective drone program.
- The reason that drones scale well is because savings add up faster than costs.
- Infrastructure costs can easily prevent drone programs from becoming cost-competitive, regardless of demand levels or drone vendor specifications.

In many countries across Africa, for example, variable costs for alternatives to drones are higher than in many other places "because of (i) high fuel costs; (ii) the age of truck fleets, which leads to much higher fuel consumption; and (iii) road conditions that are among the worst in the world. However, offsetting high variable costs, fixed costs are much lower in Africa than in Europe because of much lower wages and lower capital costs associated with aged trucks"[36].

Most likely, if examining commodity categories individually and looking exclusively at direct costs of service provision, cargo operations with UAS are generally more expensive for most commodities. Instead, drone operations stakeholders should consider them within the broader systems and opportunity costs, such as increased speed and availability of goods and services. Despite being more expensive, studies predict the most cost-effective use case examples would likely be the transport of laboratory samples (associated with the lowest percentage increase in transport costs compared to present), life-saving items, and blood deliveries (associated with the lowest dollar amount increase in transport costs), when accounting for opportunity costs[37].

Cross-subsidization through combining different programmatic commodities and services, also referred to as product integration or layering, can significantly increase the cost-effectiveness and thus affordability and commercial viability[38]. The multi-purpose capabilities of transport and data collection provided by many drone platforms make them an appropriate tool for collecting data for disaster preparedness, humanitarian response, urban planning, infrastructure and environmental monitoring, and agriculture and other use cases during cargo operations. Opening new revenue streams through layering can significantly improve the commercial viability of envisaged drone operations and thus address potential funding concerns, increase financial sustainability, and reduce reliance on donor funding (see 1.4, 4.2). Other avenues for increasing commercial viability and cost-effectiveness include increasing the density of facilities and customers within range of the droneport (see 2.5) and increasing the range and automation of the UAS platform.

For more information, see also

Bahrainwala, L., et al. (2020). **Drones and digital adherence monitoring for community-based tuberculosis control in remote Madagascar: A cost-effectiveness analysis,** PLOSOne — Detailed cost-benefit analysis for the introduction of a tuberculosis treatment program using Drones in Madagascar.

Greve, A., Dubin, S., Triche, R. (2021). ***Assessing Feasibility and Readiness for Cargo Drones in Health Supply Chains. A Guide to Conducting Scoping Trips in Low- and Middle-Income Countries.*** Washington: USAID — Guideline to support planning for cargo operation setup

JSI (n.d.) ***What should you Deliver by What Should You Deliver by Autonomous Aerial Systems? Tool for Determining Cost Effective Use Cases for AAVs***. — Tool for estimating last mile transport and inventory cost implications for UAS operations

McCord, J., Tien, M., Sarley, D. (2013) ***Guide to Public Health Supply Chain Costing: A Basic Methodology***. Arlington, Va.: USAID | DELIVER PROJECT, Task Order 4. — Provides an overview on how to cost supply chains, with Appendix C providing an overview of potential sources of cost information

Ochieng , W., Ye, T., Scheel, C., Lor, A., Saindon, J., Yee, S.L., Meltzer, M., Kapil, V., Karem, K. (2020). **Uncrewed aircraft systems versus motorcycles to deliver laboratory samples in west Africa: a comparative economic study.** *Lancet Global Health,* 8, e143-151— Comparative economic study of the costs and cost-effectiveness of UAS versus motorcycles for laboratory sample delivery.

Stokenberga, A., Ochoa, C. (2021). ***Unlocking the lower skies: The Costs and Benefits of Deploying Drones across Use Cases in East Africa.*** Washington: World Bank — Report analyzing the economic and broader societal rationale for introducing UAS to complement existing supply chains and processes across different use cases from medical cargo and food aid delivery to infrastructure and land mapping in an East African context.

Würbel, H. (2017). ***Framework for the evaluation of cost-effectiveness of drone use for the last-mile delivery of vaccines.*** MSc Thesis, University of Barcelona — Review, comparison and benchmarking of last mile logistics costs for the transport of pharmaceuticals, vaccines and associated commodities using UAS.

1.3 STAKEHOLDER CONSULTATION, COMMUNITY OUTREACH, AND SENSITIZATION

Themes: Community engagement
Involvement: Community engagement should be led by culturally appropriate community-based organizations or within current government systems such as a Ministry of Information or Health, and can further involve end-users, NGOs, donor organizations, or UAS service providers looking to conduct operations. Stakeholder consultation further involves the Civil Aviation Authority (CAA) or other designated authority, security services and other non-aviation government entities, and the private sector.

Background

Stakeholder and community engagement, management, and sensitization are part of a multi-phase process crucial to getting drone programs off the ground. They are parts of an important activity to ensure political and social buy-in, wider acceptance, and alleviation of skepticism, safety, and security concerns regarding drone technology, and will ultimately increase chances for long-term sustainability high-frequency drone operations. Consultations and engagement should involve aviation and ancillary stakeholders, including ministries, security agencies, regulatory bodies, local communities, and the private sector. Transparency and an early engagement with security agencies is particularly vital as drones are increasingly equipped with cameras to support safe remote take-off and landing, potentially raising privacy and security issues among different stakeholder groups. An engagement and outreach approach usually involves:

1. **Stakeholder identification —** Stakeholders and interest groups critical and relevant for specific drone activity and engaged in a) regulating or facilitating the use of drones, as well as regulations, imports, communications; b) financing or supporting the use of drones; c) analyzing the use of drones; d) utilizing drones and benefiting from them, and e) those providing training and drones or their services to the end-users. Common stakeholders and interest groups include:
    - Academic institutions;
    - Community and district authorities and leaders, including local councils and health facilities, as well as faith and traditional leaders and healers;
    - Development partners including donors, and implementers and civil society organizations;
    - General public in the vicinity of take-off, landing, and operations sites, as well as communities under the flight path of drones;
    - Government Ministries including Agriculture, Defense, Disaster Management and Response, Education, Environment, Health, Information, Internal Affairs, Security, Surveys and Statistics, and Transport;
    - The private sector, including insurance providers, clearing agents, and logistics and manufacturing; and
    - Regulatory authorities, including Civil Aviation, Customs, Revenue and Tax, and Telecommunications.
2. **Stakeholder analysis —** It is vital to understand the needs, rights, interests, concerns, and perceptions of the identified stakeholders and impacted communities to develop a comprehensive and locally tailored engagement strategy. Typical analysis tools include focus group discussions, interviews, and similar quantitative or qualitative methods. The co-design of implementations with stakeholders also presents opportunities to improve project outcomes and create shared value besides aligning interests, which may be competing at times (economic impact versus safety and security, for example).
3. **Communication planning —** This step defines outcomes and supports

engagement and communication strategies tailored to the stakeholder groups and their needs and contributions identified in Step 2. Step 3 can also define media and engagement channels, timetables, and metrics to measure the success of communication strategies.

4. **Stakeholder engagement —** A range of activities, including consultations, drone concept introductions, surveys, workshops, town hall events, demonstrations, discussions, media campaigns, and similar, can be used to implement the engagement strategy. In some cases, discussions and negotiations can occur among project implementers and individual stakeholders, such as landowners in a safe, private setting with translators or trusted intermediaries to negotiate temporary use and access to land or other private assets. Providing stakeholders with the opportunity to question and discuss proposals provides opportunities to strengthen project proposals and foster understanding and buy-in.

Community sensitization and stakeholder roundtable activities must continue throughout the whole operation. Ongoing engagement among stakeholders can support overall ecosystem coordination, including the identification of operational synergies and complementary use cases, quality assurance and compliance monitoring of operations with aviation regulations (see 2.2), privacy and data management (see 2.8), and auditing (see 2.10). Similarly, ongoing engagement and communication efforts with the community and monitoring of public perceptions can help with sustainability and ensure the long-term success of drone programs (see 4.2)[39].

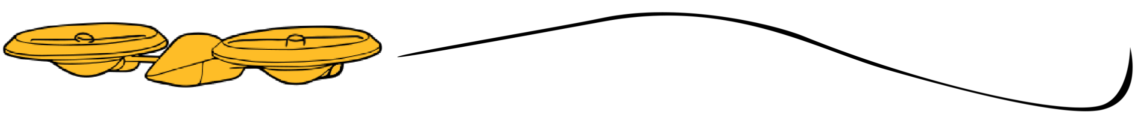
> *"Breaking barriers in communication across ministerial silos helps develop a broader understanding of the opportunities, challenges and solutions government officials face before operations begin. By engaging all relevant government departments early, the opportunity for identifying socially meaningful and economically impactful use cases can ensure buy-in and a shared vision across the government as well as much greater societal adoption from community engagement through existing government channels."* [40]

Community sensitization and stakeholder roundtable activities should also target different groups within a country, including the national, provincial, regional, or district government, and the general public[41]. Across these groups, "support and buy-in must come not only from leadership, but also from those assisting with implementation, such as health facility staff, government officials, and local and traditional leaders who are not connected to the government" [42].

1. **National level —** Engagement often includes institutions and organizations that regulate, support, fund, or utilize drone technology, and contribute to their perspective on the regulations and use of drones. Institutions engaging on the national level include sectoral Ministries, departments, and related institutions that play a central role in ensuring the adoption of drones through high-level policy- and decision-making. Drone activities and programs commonly originate from national-level institutions working closely with development partners to explore the use of innovative technologies to address challenges they face in the completion of their missions and visions.
2. **In-country Provincial, Regional, or District level —** As individual districts may participate in Steering Committee activities, particular importance shall be given to the engagement of relevant authorities and organizations. Those often include authorities such as the central political authority and provincial, regional or district hospitals or disaster response units, or other entities and organizations that ultimately can benefit from the use of drones. Consultations

with stakeholders, thorough needs assessment, scoping visits, interviews, and real-life demonstrations of drone technology are examples of activities employed as a part of a district-level engagement.

3. **Community level —** The local community at the district level is essential in ensuring the social acceptance of drone technology, creating a sense of ownership, and helping dispel misconceptions. They are also crucial in alleviating concerns of families and workers who might be directly affected by loss of income due to reduced demand for traditional service provision. This may involve highlighting ongoing demand for local distribution on the last mile or new opportunities, including order taking, maintenance, or droneport management. Placing the community at the center and enabling them to analyze the technology and co-create technology-driven solutions helps ensure a cultural fit, beyond solving existing challenges. Community sensitization activities often focus on exploring the value of drone technology by ultimate beneficiaries (i.e., community, community health office, community education institution, community leadership), addressing and answering the critical questions about the risk, safety, duration, and scope of the drone operations, as well as looking at how the technology fits into the larger societal ecosystem. Methods of sensitization and engagement include (but are not limited to) consultations, focus group interviews, large-scale technology demonstrations, presentations, question and answer sessions, and other innovative communication for development tools. The culmination of the sensitization activities is often an official approval by the traditional leadership of a community, which the district leadership might also consult. District- and community-level outreach can occur in parallel to ensure close coordination and consultation between the two.
4. **General Public** — Raising awareness of drone technology and its benefits is essential for general public perception and acceptance[43]. Highlighting the enabling role of drones for the creation of markets and job opportunities in addition to faster access to goods locally can help to increase the social acceptance of drones. Implementing partners might choose various media channels to reach a large national audience. Sensitization activities at a community level can help create a common message for sharing with the general public. National campaigns often focus on balancing safety and privacy concerns and conveying the key benefits of drone technology.



Box 1.3 — National Steering Committee and community outreach in Malawi

One successful example of engagement and consultation was framed around activities in the Humanitarian Drone Corridor near Kasungu, Malawi. A National Remotely Piloted Aircraft Steering Committee has been created as a platform for inclusive engagement, information and experience sharing, consultation, and collective decision-making in the area of drones[44]. The committee convenes interested and relevant organizations, institutions, and entities. UNICEF, in collaboration with the Department of Civil Aviation, Ministry of Health, and Ministry of Information, further supported an extensive community sensitization and outreach campaign. The campaign aimed at sourcing community feedback and concerns about the use of drones in supply chain delivery, alongside demonstrations of the real-life drone use to community members and leaders through “drone days”. This approach helped ensure the common understanding as well as acceptance of this technology among communities. The latter is particularly crucial, as witch doctors are an integral component of many African cultures, including Sierra Leone and Malawi, potentially raising fears of drones and medical facilities besides inhibiting the transport of blood over people's houses and communities[45]. Community sensitization and information campaigns can help alleviate those fears and concerns.

Discussion

Pertinent questions

- Can all stakeholders and the local community identify with the benefits, and are their concerns taken seriously and into account?
- How can engagement work when it is too risky, such as in the middle of a civil war or unrest?
- Who is best suited to directly engage with communities, considering the historical context of colonialism, systemic power imbalances, and cultural norms and preferences?

Projects should apply principles of ethics and considerations over privacy and data protection when designing the implementation and operation and conduct an ethics review as part of their ongoing engagement, planning, and operations efforts. Development organizations such as UNICEF have developed and embraced a set of principles to guide their technology projects[46]. Researchers at Delft have instead proposed the following principles[47], which are focused more on the design of the technology itself (see Table 1.2).

Table 1.2 — Ethics principles	
UNICEF principles	Delft principles
Design with the user	Inclusion
Build for sustainability	Sustainability
Be data-driven	Accountability
Use open standards, open data, open-source, and open innovation	Transparency
Reuse and improve	Responsibility
Do no harm	Safety
Be collaborative	Democracy
Understand the existing ecosystem	Privacy
Design for scale	Security

The United Nations Declaration on the Rights of Indigenous Peoples (UNDRIP) recognizes the right of indigenous communities to Free, Prior, and Informed Consent (see 2.8). This normative framework protects the inherent right Indigenous communities have to decide on mining, forestry, oil, gas, water, or other proposed external activities that would affect their lands, territories, or natural resources.

For more information, see also

Eichleay, M., Mercer, S., Murashani, J., Evens, E. (2016). ***Using Unmanned Aerial Vehicles for Development: Perspectives from Citizens and Government Officials in Tanzania.*** **10.13140/RG.2.1.3834.8560—** Summarising initial perceptions of UAS safety, purpose, use cases, and regulations among government officials and the general public, stressing the importance of holistic community engagement.

Fabian, C. and Fabricant, R. (2014). The Ethics of innovation. ***Stanford Social Innovation Review*** — Ethical Framework for the introduction of novel technology solutions in international development

FAA (2016, Feb). ***Community Involvement Manual*****. Washington: FAA —** Covering good practices and techniques for community engagement, including project lifecycles

Greve, A., Dubin, S., Triche, R. (2021). ***Assessing Feasibility and Readiness for Cargo Drones in Health Supply Chains. A Guide to Conducting Scoping Trips in Low- and Middle-Income Countries.*** **Washington: USAID** — Guideline to support planning for cargo operation setup

Mauluka, Chancy (2019). When the Drone Flies! Rethinking Communication Models in the Context of Innovations. ***The Journal of Development Communication*****, 30(2)** — Study of UNICEF's approach for community sensitization to drone operations in the Kasungu drone corridor

Truog, et al. (2020). Insights Before Flights: How Community Perceptions Can Make or Break Medical Drone Deliveries. ***Drones*****, 4(3)** — Study on the similarities and differences in community perceptions to UAS for medical cargo delivery in Malawi, Mozambique, the Democratic Republic of the Congo, and the Dominican Republic.

Van den Hoven, J., et al. (eds.) (2015). ***Handbook of Ethics, Values and Technological Design*****. Springer: Dordrecht** — A detailed survey of how technological and institutional design should reflect an awareness of ethical factors ranging across sustainability, human well-being, privacy, democracy and justice, inclusivity, trust, accountability, and social and environmental responsibility.

1.4 BUSINESS MODELS, OWNERSHIP, AND FINANCING

Themes: Financing
Involvement: End-users such as a postal service; Ministries in charge of Agriculture, Infrastructure, Commerce, Land, or Health; local government authorities; donor organizations; or UAS service providers looking to conduct or procure services to address specific use cases

Background

A range of products and services make up the value chain of elements underpinning drone operations, each with its own business model archetypes and considerations[48]. The value chain begins with specialized sub-tier suppliers providing components, software, and sensors necessary for manufacturers to produce UAS platforms. Manufacturers can subsequently opt to focus on the production of UASs alone, acting under an Original Equipment Manufacturer (OEM) business model, or cover elements of service provision under a drone-as-a-service model in addition to manufacturing[49].

- **OEM model —** Involves the manufacturing and sale of UAS platforms, components, sensors, or software solutions to operators (outsourcing) or end-users (insourcing). Those would, in turn, need to obtain regulatory approval, provide training and capacity building and operate flights before engaging data analytics and support services (see 2.12).
- **Drone-as-a-service model (outsourcing)** — Here, the service provider would provide and source or manufacture the UAS platform, data analytics, and ancillary services ranging from Un-crewed Aircraft Systems Traffic Management (UTM) to insurance necessary to conduct operations. Most drone-as-a-service cargo operations require operators to partner with the customer to manage operations, as is the case with Wingcopter, Aerial Metric, and others. In many medical cargo operations, the Ministry of Health sources commodities and manages warehousing and ordering, whereas the drone service provider executes the distribution. Other services such as Zipline provide warehousing, sourcing of commodities, distribution, and order management within their offerings.
- **Vertically integrated model or outright ownership (insourcing)** — Here, operations run in-house with the model either relying on a UAS platform purchased from an OEM manufacturer or one designed and built in-house. This model can potentially cover all elements of the value chain from manufacturing the UAS platform to capacity building, flight operations, data analytics, running of support services, and sourcing of commodities.

Many cargo UAS operations use drone-as-a-service models instead of outright ownership due to increased flexibility to change UAS platforms (see 1.5) as technology evolves and needs change[50].

Whereas use cases and the products and services to address them are available, financing models covering service provision beyond an initial setup or pilot phase often are not. Continued funding beyond the initial pilot period of a few months is one of the biggest and most common inhibitors for attracting operators and setting up operations. Considerations for continued service should therefore be made from the very beginning. In certain circumstances, funding may be diminished "due to changes in administration, priorities or overall funding availability. Securing initial funding is often easier than securing continued funding in subsequent years" [51]. Business models, funding, and financing proposals should include clear outlines of how proposed drone activities fit into existing processes and supply chains and address proven needs and quantified demand (see 1.1) in a cost-effective manner (see 1.2). Quantified demand stems from an analysis of the addressable market and an understanding of the potential

Box 1.4 — Example options for outsourced, drone-as-a-service UAS operations

The most common include gig models or commercial franchises depending on the identified need and chosen business focus:

- Gig-model — Sweden-based GLOBHE recognized that for certain types of operations such as mapping, which are often quick to complete and do not rely on established droneports such as cargo operations, gig models might be more applicable. They noticed that local drone pilots often have a hard time getting customers and identifying business opportunities. Based on this epiphany, they chose to develop a platform to connect local drone pilots with business opportunities in a gig-model to utilize the local capacity that is already in place. It strengthens the local community and entrepreneurs, addresses local use cases, reduces the cost for bringing in personnel and equipment from outside the country, and reduces administrative hurdles.
- Full drone-as-a-service provision — Zipline, an American healthcare logistics start-up founded in 2014, designs drones to deliver medical products. To improve the medical supply chain in disconnected areas, Zipline, in contract with the Rwandan government, launched the world's first automated blood delivery system operating at a nationwide scale in partnership with the UPS Foundation and Gavi. The company uses autonomous electric drones to deliver medicines to hospitals, clinics, and health centers as and when required. Different third-party logistics services, including warehousing, and distribution, are performed by Zipline. "When Zipline's flight operations began in 2016, the company had contracts with 21 hospitals in Rwanda and only delivered blood. It has since expanded to 160 different medical products and is contracted to serve close to 2,500 hospitals and health facilities across Rwanda and Ghana" [53]. The creation of Zipline is an excellent example of government and private enterprise working seamlessly.

for commercial and sustainability of the proposed operations. Demonstrating understanding and clearly identifying needs and objectives significantly increases the likelihood of unlocking funding for services from both the private and public sectors and lays the foundation for long-term sustainability. The use of offtake contracts, in particular, can help attract commercial funding and address potential concerns of uncertainty beyond initial pilots. A longer term commitment would enable amortization of the upfront capital expenditure over a longer time frame, thus reducing annual outgo. Different funding models and sources exist, with later stages of a UAS program potentially utilizing combinations of approaches in a co-financing or blended financing manner:

- **Donor-funded** — Underpins the vast majority of UAS projects so far. Options exist to cross-subsidize projects through parallel use cases (see 1.2). In the past, donors have helped provide funding for infrastructure investments (for example, Ghana) or provided funds to support the operations side (for example, Tanzania, Malawi, or the Democratic Republic of Congo).
- **Public-Private Partnership (PPP)** —

Can help reduce reliance on direct-foreign (donor) investment and provide the next step to sustainability for such projects. The government's role in such partnerships may be determined by the public benefits derived from financed operations — niche business opportunities versus public goods that support wider communities. A PPP model could allow several operators to use the same UAS platform, droneports, and other infrastructures, such as a district medical warehouse, for fixed or ad hoc services on a contractual basis or per-use basis.
- **Private or commercial funding** — There is increasing interest from UAS operators, venture capitalists, and commercial banks to finance high-frequency UAS operations. Such operations are likely to involve privately owned infrastructure, such as a dedicated distribution center that is operator-specific and managed by a single company, with Zipline serving as a prominent example.

Discussion

Pertinent questions

- What should requirements for capacity building among the local community and economy be?
- Will payout obligations occur in a lump sum or installments, based on operators meeting milestones?
- How long would governments or end users be willing to commit upfront through offtake contacts?
- Who will cover the initial seed costs for setup and equipment purchases?
- What will happen once the donor money runs out?

Training and capacity building can represent an additional business model for OEM operators and pure operators. In insourcing, end-users should consider the procurement of training and capacity-building services alongside the platform purchase (see 2.1 and 3.4). Such training can range from basic operations, piloting, and maintenance of UAS platforms to safety risk management, drone network design, drone service network management, scheduling and dispatching, network service monitoring, and operations reviews. At the same time, PPPs, such as the one between the Rwandan government and Carnegie Mellon University, provide opportunities to accelerate domestic manufacturing to reduce shipping costs and time for platforms and spare parts (see 1.5) and create high-skilled job opportunities.[52]

Some drone manufacturers may opt to set up their own delivery companies under a drones-as-a-service business model to create their own demand for the manufacturing of drones. Uncertainty can be challenging, as there is often an unknown demand from the client side, making investments tricky. It requires massive investments to go out there and provide deliveries at scale as a drone manufacturer. Although we are finally seeing some companies succeeding in that field, many have either changed business models, gone out of business, or relied on other income sources such as Google Wing or Amazon.

For more information, see also

Cohn, P., Green, A., Langstaff, M., Roller, M. (2017, Dec 5). *Commercial drones are here: The future of unmanned aerial systems*. McKinsey & Company — Explores the UAS value chain and different business models and opportunities applicable to different elements within it.

Stokenberga, A., Ochoa, C. (2021). *Unlocking the lower skies: The Costs and Benefits of Deploying Drones across Use Cases in East Africa.* Washington: World Bank — Value assessment of different UAS use cases including medical commodity and food aid delivery, land mapping, agriculture and infrastructure inspections, and their policy and operational implications.

1.5 UAS PLATFORM CONSIDERATIONS

Themes: Equipment
Involvement: End-users such as a postal service; Ministries in charge of Agriculture, Infrastructure, Commerce, Land, or Health; local government authorities; donor organizations, or UAS service providers or manufacturers looking to purchase UAS platforms or procure services to address specific use cases

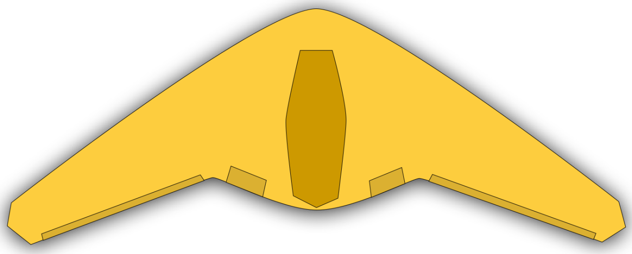
Background

Appropriately selecting the right technology to ensure it fits the use case, performs to expectations, and can function appropriately in the environment is crucial. Factors that can affect this choice include, but are not limited to:

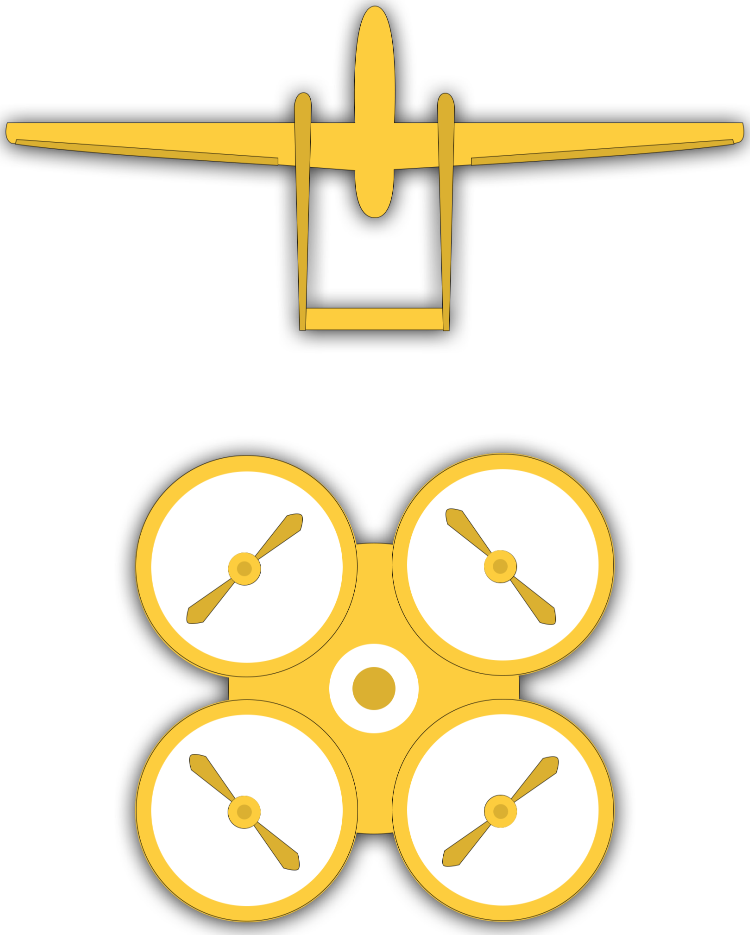
- Distance for envisaged operations
- The use case itself
- Size and weight of the payload in the case of cargo operations
- Local network connectivity
- Operating altitude and weather patterns

The understanding of operational requirements and factors should underpin the definition of minimum requirements and specifications that a UAS needs to fulfill. Among the most basic are range (i.e., distance and flight time) and speed, which are crucial to determining the value proposition for adding an on-demand just-in-time or “pull” system to supply chains (see 1.1), payload capacity (i.e., volume and weight), and specificity (for example, cold-chain)[54]. It is important to note that battery-powered UAS are likely to have more limited range and payload capabilities than gasoline-powered drones in the short to medium term.

Figure 1.3 — Overview of main UAS platform configuration



Fixed-wing drone capable of one-way logistics (deliver-only)



VTOL fixed-wing (top) and **VTOL rotocraft** (bottom) drones that are capable of reverse logistics (delivery and pick-up)

Box 1.5 — Main UAS platform configurations

UAS have three main platform configurations — Fixed-wing, vertical take-off and landing (VTOL) fixed-wing, or VTOL rotorcraft, with the vast majority of drones currently used in the commercial sector being small UAS, weighing less than 20-25kg.

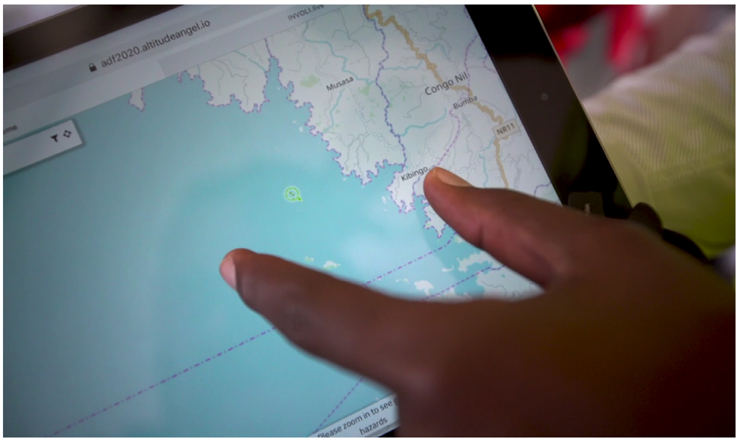
Fixed-wing – Configured like a traditional fixed-wing aircraft, such UAS require landing and take-off profiles with a bigger footprint. Their flight profile means that they are more aerodynamically efficient and typically have a more extended range and greater flight endurance, however. The fixed-wing platforms mostly use parachute airdrop mechanisms to deliver commodities and goods without landing at a delivery site, as this would require specialist landing infrastructure in each destination (runway or a catapult and retrieval system). Fixed-wing drones capable of only delivering commodities one-way can fly longer distances and serve the larger geographical areas. However, they have the limitation of not being capable of picking up packages.

VTOL fixed-wing or rotorcraft — Such "platforms fly using the same principles as manned helicopters, although the vast majority often have four, six, or eight rotors. Consequently, the platforms have a VTOL capability that makes them more operationally versatile" [55]. VTOL capable drones can support reverse logistics (landing at the delivery site) in addition to parachute-dropping (a package to the delivery site) of commodities. Their agility and flexibility allow them to support diagnostic sample pickup from remote health clinics, for example. The distribution facility does not need specific take-off and retrieval mechanisms or runways, which might otherwise require high set-up costs and might not be feasible in some areas. VTOL drone systems can land in small spaces to deliver a package or pick up a package. Several such systems also offer a possibility of delivery without landing. In such cases, a drone uses a string to lower the payload, and after it reaches the ground, the string is retracted, and the drone returns to the home base. VTOL fixed-wing drones offer a more extended range compared to VTOL rotorcraft.

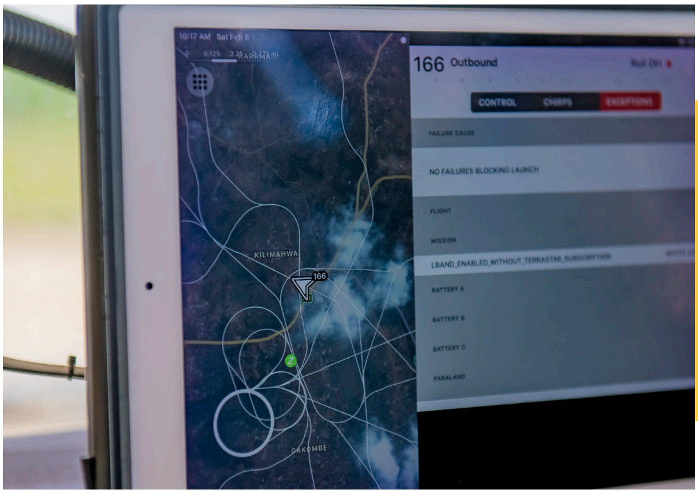
There are many other considerations, including ease of use, reliability, and ongoing operating costs:

a. Maintenance and repairs — When UASs are damaged through wear and tear, a crash, or other reasons, facilities, spare parts, and know-how for repairing and maintaining need to be in place to reduce service outages as much as possible. Given the overall supply chain problems common to resource-constrained environments, it might take a very long time to obtain spare parts for drones from outside a country. Some issues with more complex drones may only be fixable by the manufacturer itself. Therefore, UAS with low-maintenance requirements, low operational footprint, and spare parts readily or potentially available, via 3D-printing on-site, have huge advantages. Maintenance can make up a large part of operating costs, with some operators spending upwards of half their operating budget on maintenance of components. It is also crucial to check whether a drone service provider has a robust training program for repairs and maintenance to ensure that the local staff has the necessary training to maintain it efficiently. Ultimately, many operators are unlikely to have enough experience to have service or retirement schedules based on actual operational experience and information on the lifetime of the UAS owing to limited long-term experience.

b. User interface — The difficulty of operating drone platforms varies. Platforms with built-in fail-safe features and easy-to-use user interfaces and controls have significant advantages, ensuring that local staff can quickly learn how to operate them safely.



c. Flight control and navigation — A drone must have robust and redundant navigation and other flight control systems (Global Positioning System [GPS], Inertial Measurement Unit, or other) to ensure that it can maintain its orientation even under frequency jamming or other technical abnormalities. Flight control software should be easy to use, the same as the overall user interface.



d. **Command and control (C2) link** — C2 is the data link between a drone and a remote pilot station and used to manage the flight. There are various possible architectures and considerations in the design, security, and management of the C2 link. Because of the limitation of regular and extended-range radio links, more and more platforms rely on cellular and satellite links instead. The quality of a link in such a situation heavily depends on cellular network coverage; satellite connection is still more expensive and is usually used as a stable backup. The drone platforms that consider low-connectivity, low-resource settings and redundant C2 link solutions have an advantage.

e. **Durability and reliability** — It is crucial to consider a platform's ability to withstand harsh weather conditions, such as the capability to operate in light rain, high wind, high altitudes, dust, sub-zero temperatures, or extreme heat and humidity. There are no specific studies of various drone platforms and their tolerance for different weather conditions. Evaluating the provider's flight safety records and total flight hours for the specific model is crucial to determine both durability and reliability.

Discussion

Pertinent questions

- Which propulsion method is most suited considering local infrastructure?
- What are the operational requirements (for example, long-duration cold-chain for vaccine transport), and can the drone operate within the environment (for example, altitude or weather)?

Whereas an increasing number of drones rely on electric engines that use lithium batteries, some continue to rely on combustion engines that use various types of fuel. There is an increasing trend to use hydrogen fuel or other alternative sources of power to extend drone flight time and operational range.

- **Gasoline-powered** drones generally provide a greater range making them potentially more suitable for certain use cases than battery-powered UAS. However, higher platform cost, noise, pollution, and consistent fuel supply and quality have to be considered when choosing such a platform[56]. A growing number of manufacturers do not believe in gasoline-powered drones as they are afraid they might be associated with military drones.

- **Battery-powered** drones are more environmentally friendly; however, they have limitations in terms of range owing to battery capacity. Additionally, stable electricity supply, battery charging capabilities, and battery swapping at different destinations (for example, health facilities or distribution centers) are important considerations to ensure that drones can operate uninterrupted. As the energy density of batteries is improving, one can expect that the range gap between battery-powered and gasoline-powered drones will be closed in the future.

Depending on the lithium batteries' size, the logistics of transporting them can become an issue. Most commercial airlines are unwilling to transport lithium batteries above a specific size as they may be classified as dangerous goods (see 2.9), requiring alternative approaches for handling or transporting.

Another important consideration during platform selection for temperature-sensitive product distribution and some other use cases is cold-chain capacity. The majority of drone pilot projects for health use cases to date used passive cooling (e.g., insulated cargo boxes that use ice-packs or cool water packs) to maintain vaccine temperatures (2-8 degrees of Celsius) during flights. Evidence shows that passive cooling was sufficient to maintain the cold-chain within acceptable limits. Active cooling systems could also be used as a cold-chain solution and could be particularly important in ultra-cold-chain scenarios. They provide longer storage times (14.9+ hours) at the expense of increased power consumption and reduced versatility of repurposing the drone.

Industry challenges and competitions can be a helpful tool to encourage the development and adoption of new technologies and support long-listing of potential UAS service or OEM providers. They also make sense if there is a cutting-edge element to be achieved that is not commonly implemented. The ADF, for example, focuses on safe and scalable electric VTOL cargo operations, which to date have never been scaled into national-level programs in Africa. Before opening a request for proposal (RFP) (see 2.12) for the ADF, the organizing team conducted market research to understand how many technology providers globally offer electric VTOL, fixed-wing UASs to assess the feasibility of narrowing technology requirements.

However, some larger organizations and companies may be hesitant to invest in cargo drone technologies due to regulatory barriers. Cargo use cases rely on BVLOS operations and, in some cases, dropping cargo, transporting dangerous goods, and other aspects governed by national regulations. Uncertain regulations or approval processes can prohibit operations at scale, making investments in technology development and manufacturing a risky endeavor in many cases and leading to manufacturers adopting a wait-and-see approach instead. Costs associated with certification through the US Federal Aviation Administration (FAA) or similar bodies in the EU can further exacerbate such concerns. On the flipside, there is a risk that large manufacturers may end up dictating certain standards within the industry, resulting in an uneven playing field for start-ups.

For more information, see also

Coban, S., Oktay, T. (2018). Unmanned Aerial Vehicles (UAVs) According to Engine Type. *Journal of Aviation,* 2(2), 177-184 — Classifications of drone designs according to different metrics

Dronethusiast (2018). Travelling with LiPo Batteries and your Drone — Advice on transporting of lithium batteries

USAID GHSC-PSM (2018, Jul 9). *Unmanned Aerial Vehicle Procurement Guide*. Washington: Chemonics International Inc. — Covering recommended specifications and questions for offerors with a specific focus on cargo operations

VillageReach (2020, Jun). *How to Select a Drone Service Provider for Transport of Health Products. Lessons Learned*. Seattle: VillageReach — Tool outlining a range of requirements to consider as part of UAS service provider selection with a specific focus on the transport of health commodities

Phase 2: Planning

Whereas a thorough feasibility analysis can help determine whether drones are the appropriate tool for a given use case, the broader ecosystem needs to be capable of supporting them. Sufficient knowledge and capacity, regulations, network connectivity, equipment, and infrastructure will need to be developed or put in place across broader ecosystem-supporting and operation-specific elements for UAS operations to be successful. Regulators and legislators need to have sufficient capacity to develop fit-for-purpose UAS regulations before striving toward harmonization with other countries and, ultimately, interoperability. Airspace is a scarce resource, and its management impacts where and what scale of operations are possible. Similarly, the location and sophistication of droneports should be proportional to the envisioned operations. Safe and efficient scaling of drone operations also requires reliable and secure connectivity and tracking capabilities to allow for “the dynamic, integrated management of air traffic and airspace” [57] via UTM. Ancillary elements such as privacy considerations, data management, data quality, and transparency should underpin data collection efforts, and operators should ensure sufficient insurance coverage for all operations. Straightforward logistics and customs procedures can help alleviate potential set-up bottlenecks, at the same time as auditing and airworthiness inspection mechanisms can support due diligence processes. Only once these enabling elements are in place and the feasibility analysis has shown the viability of conducting UAS operations should considerations turn toward thorough and transparent vendor selection, procurement, and service contract modalities.


LAKE KIVU
CHALLENGE
Operations

2.1 TRAINING AND CAPACITY - ENABLING SIDE

For operators: refer to section 3.4 training and capacity - operations side
Themes: Capacity building and financing
Involvement: CAA or other designated authority looking to improve capacity, civil society and international organizations such as a Regional Safety Oversight Organization (RSOO) looking to support capacity building

Background

Stakeholders and end-users involved in drone operations need to understand the technology and capabilities of commercial drones, which may be much larger than consumer-oriented commercial-off-the-shelf UAS. Introducing Air Traffic Control (ATC) and CAA staff to the concepts, benefits and altruistic intentions of UAS (see 1.3) will increase the likelihood they will support drone operations and design enabling regulations. For CAAs, the need for understanding stems from a need to assess safety, maintain control of the airspace, fulfill their oversight responsibility, and check compliance with regulations. End-users need to understand capabilities to determine whether drones are the right tool, which ones are appropriate, and how to get the most out of them during operations.

> *"In our ministry, we have been looking forward to these technologies. We have a budget for drones and software, but no one knew how to operate them. We will use the technology to monitor the growth of corn, beans and basic grains during the drought. We can use sensors [attached to the drones] to analyze the soil, to avoid planting crops that won't thrive. We might have to diversify the crops [for a better yield]."* [58]
>
> Mey Riveiro, Ministry of Agriculture in Honduras

Understanding drones and their implications on traditional aviation risk management is also a prerequisite for developing fit-for-purpose regulations to manage a country's airspace "safely, economically and efficiently" [59]. There is a distinct lack of training on regulations and rules and, more importantly, safety and traffic management specific knowledge inherent to UAS among many CAAs. This often extends to a limited understanding of drone-specific Operations Risk Assessments and their evaluation (see 3.1). Drone technology is rapidly evolving, bringing with it widespread ramifications on existing operating procedures, processes, and arrangements. It affects, among others:

- **Airspace management** — As most drones can take-off and land outside of closely regulated and controlled traditional take-off and landing infrastructure;
- **Security —** Protocols for airdropping of cargo;
- **Privacy** — As most drones are equipped with cameras to assist with remote take-off and landing;
- **Risk management —** As drones can potentially pose significant risks to people and objects on the ground; and
- **Certification —** Owing to rapidly evolving technology.

Box 2.1 — Example training opportunities for national stakeholders and regulators

- National stakeholders, the World Food Programme (WFP) UAS training for emergency operations — Building in-country capacity for rapid deployment and the practice of emergency scenarios is critical for the safe, effective, and timely use of drones in emergency settings60. In 2018 and 2019, WFP and its local partners delivered a series of UAS training exercises in nine countries: Bolivia, Colombia, Cuba, El Salvador, Ethiopia, Haiti, Madagascar, Mozambique, and Nepal, strengthening the capacity of 400 representatives from more than 100 organizations. WFP has designed a 2-week complete UAS training course divided into three modules:
  1. Let's COORDINATE — a workshop on strengthening cooperation among national stakeholders with theoretical sessions on safety procedures, privacy and data management, and lessons learned from a range of case studies;
  2. Let's FLY — a series of hands-on training exercises in how to operate drones safely;
  3. Let's MAP — a practical course on processing data obtained from drones using different software platforms.

  Participants found flight security, route and flight planning, and the introduction to drones' technical features and capabilities to be among the most valuable components of the program. Further regional training sought to foster collaboration and consider regional applications through the collaborative development of a Concept of Operations (ConOps) for different use cases.
- Government regulators, the UK-CAA International (CAAi) and Sierra Leone CAA — The International Civil Aviation Organization (ICAO) and others have appointed the UK-based CAAi to provide CAAs with training and technical support on aviation safety, security, and regulation in the past. This process includes root and branch assessments to understand authorities' capabilities and challenges and reviews of legal and regulatory frameworks. Based on identified gaps and shortcomings, CAAi develops tailored training programs and recommendations and implementation deliverables to address those. In Sierra Leone, for example, the collaboration between CAAi and Sierra Leone CAA "helped establish an autonomous CAA organisational structure covering the scope of the State's safety oversight responsibilities"[61]

Discussion

Pertinent questions

- Would a specialized full-time employee be more cost-effective than engaging consultants on an ad hoc basis?
- Who will conduct audits and evaluate maintenance schedules, regulations, and permit paperwork, and what does it take to assess this?
- What are the required levels of training, cost, and complexities?

Dedicated drone teams within a CAA may be an avenue to ensure that regulations and processes account for drones' latest developments and specialist requirements. For example, India's Civil Aviation Requirements (CAR) called for establishing "a Drone Directorate within the Directorate General of Civil Aviation. The Drone Directorate may issue necessary guidelines, which may be updated faster, as the needs of a nascent drone industry differ from those of the mature Civil Aviation Industry"[62] to account for the rapid development inherent to the drone sector. During our interview and survey outreach some CAAs in Africa reported that they have two or three dedicated people working on drones alongside an intern or placement student from the Morocco aviation school, where drone content is covered. The development of such teams and undertaking of broader activities also represent an opportunity for promoting gender inclusion.

Establishing a dedicated team dealing with permits, registration, inspections, auditing, airworthiness assessments, and so forth often requires additional funding and support, however. For many CAAs, inspections and other elements unique to approvals for drones are not part of the core business of CAA inspectors. It raises concerns over who will pay for CAA staff to review documentation, manage permits, and conduct audits. RSOOs have a mandate to support member states "in providing safety oversight and resolving their safety deficiencies due to insufficient financial, technical and/or qualified human resources"[63].

For more information, see also

WFP (2019) ***Unmanned Aircraft Systems (UAS) Training. Report on the Regional Drone Training for Central America*****. Rome: WFP** — Overview of WFP's Let's FLY, Let's MAP, and Let's COORDINATE training program and lessons learned from its implementation with officials from six Central American countries

2.2 FIT-FOR-PURPOSE REGULATIONS

Themes: Regulations
Involvement: CAA or other designated authority looking to develop fit for purpose regulations and international organizations such as a RSOO to support CAAs
Timeline: The development and refinement of fit-for-purpose regulations is an ongoing process that can occur in parallel with other activities and may start as early as initial considerations to allow the operation of UAS within a country's airspace.

Background

Similar to most other regulatory regimes, each country has the jurisdiction to adopt, develop, amend, or repeal aviation-related regulations. The goal of regulations is to set legal "frameworks that enable socially and economically important use cases, while mitigating negative impacts, securing the skies from unlawful actors and enforcing the policies they do create"[64]. Regulations, rules, and guidance, when promulgated, can relate either directly to UAS or UTM or be indistinctly associated with ancillary ones, from privacy and data protection to liability, insurance, security, environmental protection, dangerous goods transport, radio frequency spectrum, and so forth. Table 2.1 highlights common elements governing the use of UAS. The responsibility for developing regulations, rules, and guidance and administering and controlling civil aviation within a country typically falls on a national aviation authority. Additionally, service providers for aerodromes, air navigation, and so forth can further support their work and that of the department of Ministry for Aviation. The ICAO supports national governments in developing their regulations by facilitating alignment through the publishing of Standards and Recommended Practices (SARPs).

"The civil aviation authority is responsible for, inter alia, ensuring aviation safety and protecting the public from aviation hazards. Operators of aircraft, whether manned or unmanned, are likewise responsible for operating safely. The rapid rise of UAS raises new challenges that were not considered in historic aviation regulatory frameworks. Before devising any regulatory framework for UAS operations, the regulator should understand and assess the UAS situation in his or her State." [65]

Table 2.1 — Common elements of UAS regulations[66]

Type	Element	Importance to UAS operations
Operations	Beyond Visual Line of Sight (BVLOS)	Enables cargo and large-scale mapping and surveillance operations besides representing a step toward urban area operations
	Autonomous Flight	Allow for increasingly automated operations, from scheduled and repetitive surveying of pipelines to routine surveillance missions
	Altitude restrictions	Mitigation of air risk and supporting BVLOS operations in uncontrolled airspace Flights near or above (groups of) people. It is integral to urban and public safety use cases and certain surveillance applications
	Airspace integration	Enables UAS operations in controlled airspaces and interaction with conventional Air Traffic Management (ATM) and aviation.
Operator	Operator certification	Increase safety through ensuring operators are trained and comply with regulations, maintenance requirements, and so forth through regular auditing.
UAS platform	Remote identification	Enable law enforcement and ATC to remotely identify and track UAS during operations for increased safety, compliance and to enable UTM
	Propulsion certification	Create certification standards for UAS looking to operate using battery-powered or hydrogen propulsion and opportunity to promote green technologies.
	Airworthiness certification	Create airworthiness standards for UAS platforms, such as weight restrictions.

The inherent complexity of aviation necessitates the use of a leveled approach in its regulation. The need for a balanced approach to aviation regulations is universally recognized. It has been implemented or recommended as a three-level approach for UAS regulation by the European Union, European Union Aviation Safety Agency (EASA), and the ICAO UAS Model Regulations. This approach ranges from "hard law" with binding rules (i.e., regulations) to "soft law" (i.e., non-binding standards) to afford certain flexibility[67].

Level 1 (Basic or primary regulations)

Outlining "**basic principles**"[73] defining a CAAs competencies and essential requirements.

Level 2 (Implementing acts, rules to Level 1)

Outlining **Civil Aviation Regulations**, defining airspace rules and **Safety Regulations,** defining standards underpinning airworthiness, licenses, and ratings of personnel involved in operations, ATC, dangerous goods regulations, and other safety topics. Level 2 also involves both **Manuals of Standards (MOSs)**, outlining uniform specifications and standards applications, and **Civil Aviation Orders (CAOs)**, and outlining technical details and requirements to complement requirements set in the regulations.

Level 3 (Advisory documents)

Including **Acceptable Means of Compliance (AMC)** outlining how to comply with specific implementing rules and associated **Guidance Material**. Advisory documents may also include other advisory publications to be read in conjunction with the referenced regulations to explain their intent and provide context for the regulation and how operators may apply it. These may include **Advisory Circulars** associated with MOSs or Safety Regulations; **Civil Aviation Advisory Publications** associated with CAOs or Civil Aviation Regulations; and **Airworthiness Advisory Circulars** as guidance to CAOs.

Whereas regulations are legally binding and prescribe "rules of conduct, standards and other requirements of general applications" that operators must meet, advisory documents set out acceptable means of complying with the hard law regulations[68] and associated implementing rules. EASA, for example, provides operators with the opportunity to propose **Alternative Means of Compliance (AltMoC)** to showcase abidance with the implementing rules or with regulations in cases in which no associated AMC exists[69]. AltMoCs may also include the proposition of new standard scenarios (STSs) (see 3.1) as alternatives to those published by EASA.

Aviation safety regulations should provide focused methods for evaluating the submitted documentation by prospective operators to grant or reject flight and operation proposals. The methods for safety regulation fall under two categories: Prescriptive or performance-based (see Box 2.2). Although performance-based regulations do not specify specific means of achieving compliance, they set goals that allow alternative ways of achieving compliance — for example, "something shall prevent people from falling over the edge of the cliff." With prescriptive regulations, the specific means of achieving compliance are mandated, for example, "you shall install a 1 meter high rail at the edge of the cliff"[70].

The Joint Authorities for Rulemaking on Unmanned Systems (JARUS) has developed a risk-based categorization for UAS operations to account for the increasing complexity of regulatory frameworks and risk management methodologies (see 3.3)**.** The risk-based oversight (RBO) approach applies rules proportionate to the risk profile of an operation and the safety performance of the operator[71]. The profile depends on the specific nature and complexities of the operation and proposed UAS platform. The RBO approach stipulates that low-risk operations such as a light quadcopter flying within VLOS, close to the ground but away from other people, should attract less oversight than higher-risk operations such as those above people (see 3.1). Safety performance considers traditional aviation safety methods, including Safety Management Systems (SMS), Emergency Response Plan (ERP), ConOps paperwork by prospective operators, and past certification or oversight. The risk-based framework provides regulatory strategies for all UAS and all operational environments, with considerations ranging from aircraft design, production, maintenance, operational approval, pilot competency, regulatory enforcement, and safety promotion. According to EASA, performance-based oversight (PBO) and RBO converge in the use of performance indicators as a way to evaluate risks of operations:

> *"The concept of "performance" conveys the idea of tangibly measuring the health of the system under scrutiny and ultimately assessing its overall performance. Performance indicators, as a means to measure, may specifically help to either identify risks within that system or measure safety risks or monitoring actions mitigating these risks. This means that a PBO can also support the identification of areas of greater risk and serve the risk assessment and mitigation exercise. This is where PBO meets RBO."*[72]

Box 2.2 — Prescriptive and performance-based UAS regulations

Regulations can represent "prescriptive rules that specify what needs to be done and how, or performance-based rules that specify what the outcome should be instead of how to achieve it"[74].

Prescriptive regulations	**Performance-based regulations**
Description	
Provides detailed, rigid requirements such as the weight, size, or speed of the UAS, making them more applicable to regulating technical systems. They may also prescribe the operation's altitude or geographical limitations that an operator cannot exceed without exemptions.	Provides a comprehensive process or framework of goals focussed on risk-based trade-offs. Such a framework helps identify "general characteristics for low-risk flights that can be easily approved, while also defining a framework for approval that leverages rapidly evolving and data-driven safety analysis"[75] and risk management. The modes of performance-based rules "adopted in the EU are a combination of objective-based rules (only the objective is defined, not the means to achieve it) and process-based rules (specific organizational requirements and/or processes are prescribed as enablers of the desired outcome). Objective-based rules relate closely to the operational environment and procedures"[76].

Prescriptive regulations	Performance-based regulations
Advantage	
Providing exact specifications for compliance makes it easy for CAAs or other designated authorities to identify whether an "operator meets all requirements within a particular type of proposal"[77].	The flexibility afforded by setting goals allows for evaluating all types of UAS operations regardless of platform characteristics and operational parameters resulting in support for applications that would be extremely difficult to approve under a prescriptive regime.
Disadvantage	
Considering the rapid technological development of UAS platforms, prescriptive approaches may stifle innovation, limit the scope for approval of medium- or higher-risk applications, cause uncertainty for "accessing airspace beyond the specifically authorized operational parameters"[78] and potentially reduce the "the traceability between the prescriptive regulation and the contextual factors [...], which may lead to misleading compliance demonstration"[79] over time.	Potential uncertainty in how to comply with objective requirements and account for inconsistencies in implementation can slow down the approval of lower-risk operations that are easy to approve under a prescriptive regime[80].

Ultimately,

"Most regulations apply a mix of performance-based and prescriptive approaches, and often lean towards prescriptive practices. [...]. The EU has adopted a generally performance-based approach for operations in the Specific operations category. In Africa, only Ghana and Rwanda currently accept the SORA, a performance-based risk assessment procedure developed by JARUS as an acceptable means of compliance for certain operations types. Generally speaking, prescriptive approaches seem to be more common across African countries."[81]

Discussion

Pertinent questions

- How will CAAs ensure dissemination and awareness of the latest regulations, implementing rules, and advisory information?
- Can CAAs identify UAS operations that pose low enough risk to safety, security, and privacy so as not to require approvals?

Each CAA should have a clear structure for publishing its latest regulations, implementing rules, and advisory information regardless of approach. Furthermore, clear guidance on registering, applying for permits, dealing with customs procedures, spectrum bands, and so forth should be available for international UAS service providers looking to fly in a designated country or for local drone startups and operators. In reality, however, many websites, email addresses, or phone contacts are out of date. Similarly, language barriers for multilingual engagement may persist, making it challenging to obtain the latest information and find correct contact points within government agencies. An up-to-date, national register of UAS pilots, their certification, and recertification could improve oversight capabilities for CAAs or other designated authorities and provide them with an easy avenue for disseminating the latest information on regulations or implementing rules and advisory information.

Regulators may also want to determine which UAS and operations impose too insignificant a risk to safety, security, and privacy to regulate them and burden oversight and enforcement. Studies have demonstrated that UAS with a maximum take-off mass (MTOM) of less than 250g, often classified as "nano", might pose no risk of severe or long-term injury in case of a crash and have no present risks to security[82]. Although studies are ongoing, preliminary findings suggest that a platform's overall ability to absorb and dissipate energy in a non-destructive manner rather than platform weight alone affects the impact severity of a UAS. In any case, "harmless" operations with nano platforms are not generally considered aviation. Aside from the point of sale education via do's and don't's on leaflets, the basic principle of "No person may operate an aircraft in a careless or reckless manner so as to endanger the life or property of another"[83] applies. In some cases, pilots need to observe additional local restrictions such as maximum operating heights, remaining within VLOS, or minimum age. Beyond impact damage, regulators should consider the potential security and privacy implications of small platforms. In Europe, for example, UAS operators need to register themselves if their UAS platform is "equipped with a sensor able to capture personal data"[84] (see 2.8, 3.3).

Whereas ICAO provides SARPs for international operations or missions certified to a conventional aircraft level, no SARPs for autonomous or low-level UAS operations currently exist[85]. The development or the amendment of SARPs can take as much as five to seven years, with global implementation and harmonization taking even longer. There is an increasing demand for ICAO to consider such low-level airspace operations, however. In 2007, ICAO established the UAS study group (UASSG) to support regulation and guidance development; in 2014, the ICAO RPAS Panel replaced the UASSG. Its scope is to facilitate "safe, secure and efficient integration of [UAS ...] into non-segregated airspace and aerodromes"[86] at the same time as maintaining existing safety levels for conventional aviation. The ICAO UAS model regulations stemming from the group's work "are meant to offer model language for States to facilitate the establishment of UAS regulations," with states having the option to "adapt the model regulations, as appropriate, to meet their specific needs"[87].

Yet most UAS platforms are unable to comply with the Convention on International Civil Aviation[88]. The inability to comply highlighted the need for ICAO to address the increasing number of UAS operating in low-level airspace that could conflict with conventional aviation as a matter of urgency. Thus, member states and the aviation industry asked ICAO to go beyond the conventional international instrument flight rules (IFR) framework and develop a global baseline of provisions and guidance material for the proper harmonization of UAS regulations. In their UTM principles, ICAO stipulates that:

> *"UAS operators must prove compliance with a minimum set of safety standards and be operationally and legally accountable if routine operations are to be accepted by the public. Each of these issues depends on the harmonization of risk- and performance-based regulations and oversight, and should include consideration of emerging technological solutions"[89].*

Compared with conventional aviation, the rapid development of UAS technologies further renders traditional approaches of granting airworthiness certification impractical, in many cases. Instead, certification processes for UAS "will demand suitably flexible and responsive regulatory approval models that are performance-based, supportive of innovation and which can develop the knowledge and skill sets of both regulators and industry in parallel with the technology changes"[90]. Such processes may include CAAs proposing airworthiness criteria that manufacturers must meet to prove their designs' reliability, controllability, and safety. Potential principles to guide design include but are not limited to[91]:

- Safety by Design — All aspects from initial design and manufacturing to refurbishment and repair follow safety and manufacturing principles prescribed within aviation regulations.
- Security by Design — The design of hardware (i.e., physical aspects of a UAS) and software reflect end-to-end security considerations to ensure "continuous monitoring, tracking, tamper proofing, trusted hardware design, sense and avoid capabilities, and standardized emergency responses"[92].
- Privacy by Design — The UAS has features that aid in protecting privacy, which are enabled by default.

In addition to meeting airworthiness criteria,

> *"each UAS should have specifications for the environmental conditions that are applicable to its operation. The manufacturer shall determine the limitations for operating in varied weather conditions and include the information in the manufacturer's instructions and limitations. UAS built for testing or home-built models must likewise possess documentation that specify environmental conditions or limitations."*[93]

For more information, see also

ADF (2021a). ***A systematic review of UAS regulations and rules in African Union Member States***. — Review of regulations across African Union member states as there are discrepancies in the availability and design of regulations across countries and regions globally

Droneregulations.info (2021). ***Global Drone Regulations Database.*** **—** Summary of current UA regulations across the globe

Greve, A., Dubin, S., Triche, R. (2021). ***Assessing Feasibility and Readiness for Cargo Drones in Health Supply Chains. A Guide to Conducting Scoping Trips in Low- and Middle-Income Countries.*** **Washington: USAID** — Guideline to support planning for cargo operation setup

ICAO (2016, Dec 7). ***The ICAO UAS Toolkit. Helpful tools to assist States in realizing effective UAS operational guidance and safe domestic operations.*** **ICAO: Montreal**

ICAO (2020, Jun 23). ***ICAO Model UAS Regulations*****. ICAO: Montreal** — It provides a model text for the regulation of UAS, that states are free to adapt to their own needs and choice of regulatory level (primary, secondary, and so on). *Note: Model regulations do not supersede or replace Annexes to the Chicago convention.*

Ministry of Civil Aviation Government of India (2019, Jan). ***Drone Ecosystem Policy Roadmap*****.** — Highlights elements and considerations for the airworthiness assessment of UAS platforms.

Union Economique et monétaire Ouest Africaine (UEMOA) (2019). ***Annexe Au Reglement D'Execution Relatif A l'Exploitation Des Aeronefs Telepilotes*** **—** Model text for UAS regulations for french speaking CAAs across Africa (although it does not align with ICAO UAS Model Regulations)

WEF (2018, Dec). ***Advanced Drone Operations toolkit: Accelerating the Drone Revolution.*** **Geneva: WEF** — Comparing real-world approaches to enable drone regulations

2.3 HARMONIZATION AND INTEROPERABILITY

Themes: Regulations and capacity building
Involvement: CAAs or other designated authority and International organizations such as a RSOO looking to harmonize fit for purpose regulations toward achieving interoperability

Background

Although the development of regulatory regimes falls under the jurisdiction of each country, certain levels of harmonization are necessary to support international operations and movement. Global interoperability through harmonized frameworks is essential to support international aviation, as non-harmonized certifications, training, and other aspects would likely ground global travel and trade by air. Solutions for ATM and communications, navigations and surveillance should be adaptable and compatible to support seamless operations and deployment across different regions. Similarly, harmonized training and certification requirements would allow operators to conduct operations in different regions without facing regulatory approval bottlenecks. In reality, however, there is a general lack of standards and harmonization across regulatory frameworks for UASs in Africa and elsewhere[94].

The conceptual goal of the International Civil Aviation Organization (ICAO) is to achieve global harmonization and interoperability through the provision of SARPs[95]. This vision extends to an integrated, harmonized, and globally "interoperable ATM system for all users during all phases of flight, that meets agreed levels of safety, provides for optimum economic operations, is environmentally sustainable and meets national security requirements"[96]. Harmonization and interoperability are broadly considered as:

- **Harmonization** — A process resulting in a similarity of approaches to the design of regulatory frameworks, requirements for certification and training, and so forth to enable interoperability.
- **Interoperability** — The ability "of two or more networks, systems, components or applications working together through exchanges of information between them, without any restriction, and with the ability to use the exchanged information for technical or operational purposes without any restriction"[97].

Discussion over the use of standardization versus harmonization remains ongoing, however. Whereas standardization implies uniformity, harmonization means a move toward choice from similar approaches. When considering rapidly evolving technology such as UAS, harmonization has the benefit of providing member states with an opportunity to adopt recommended practices appropriate to their circumstances without placing undue constraints on local regulations and practices[98].

> *"The isolated development of legislation and rules could result in a situation allowing one UAS operation while preventing it in an adjacent country, even using the same UAS for the same concept of operation. Research in the EU shows that incompatibility hampers the growing civilian UAS business, as numerous different technical requirements need to be followed depending on the location, and UAS rules can vary between states within a country. Operators and manufacturers of the largest number of platforms, generally smaller UA under 25 kg, but specifically those less than 4 kg, have petitioned for consistency across UAS/drone regulations. Commercial off-the-shelf products can then be sold worldwide"*[99].

At the same time as standardization is vital to ensure international aviation safety and security, which relies on cross-border interoperability, harmonization is the key to opening new markets for UAS operations. Despite the demand for UAS operators to serve multiple markets, opportunities for training are scarce, and differing regulations across countries serve as administrative bottlenecks.

- Harmonized training and certification requirements would allow training facilities to develop standard curriculums and allow pilots to apply their skills internationally — assuming harmonization of labor laws for such skillsets.
- Harmonization of regulations, training, and certification can make it easier for operators to service different regions while also addressing safety,

Box 2.3 — The European Union Aviation Safety Agency (EASA) approach to harmonization

The European Commission promulgated rules to harmonize national UAS regulations across all European Union member states to ensure safe and efficient scaling of UAS operations and traffic across the region. This harmonization was designed as a stepped-approach:

1. Oct. 2019 — Implementing rules (947) and Delegated Acts (945) define the subdivision of UAS operations into three categories: Open, Specific, and Certified, and the associated thresholds among these categories. Their publication set in motion a transitional period that, although initially delayed by the COVID-19 pandemic, entered into force on December 31, 2020101.
2. Nov 2019 — Release of advisory documents including Guidance Material and Acceptable Means of Compliance, allowing the use of the Specific Operations Risk Assessment (SORA) and Standard Scenarios (STS's) as harmonized approaches to safety risk management for UAS operations.
3. Mar. 2020 — Publishing of an opinion on U-Space, the single European Un-crewed Aircraft Systems Traffic Management (UTM).
4. April 2020 — Publishing of rules for safe drone operations in Europe's cities by EASA followed by proposed standards for light drone certification in July. Certification of larger UAS had previously been prescriptive, relying on detailed technical specifications derived from conventional aircraft with special provisions for UAS specific aspects.

Compliance with basic technical requirements is demonstrated by affixing the Conformité Européenne (CE) marking and UAS class to each product at the point of sale and platform in operation. Each manufacturer that demonstrates conformity with the assessment procedures thus safely reduces the burden on CAAs and enforcement agencies to conduct case-by-case approval processes for every flight.

These steps allow lower-risk operations to occur with free movement of pilots and UAS platforms among member states for domestic operations. However, it does not permit cross-border operations as those are highly complex international operations, attracting ICAO SARPs, considering UAS operating similar to conventional aircraft, and invoking customs considerations. The UAS industry and others initially assumed that cargo UAS over urban areas would not be classed as certified operations. However, EASA changed direction in 2020 before publishing final drafts of STS's, instead deferring to certification through airworthiness.

accountability, and sustainability concerns due to a reduction in the complexity of diverse sets of regulations, implementing rules, and guidance material.

- The improved coordination of spectrum bands for UAS operations would further alleviate concerns over spectrum interference in border areas or across international borders (see Annex C).

The European Experience (see Box 2.3) provides an example of a harmonized approach to regulating UAS. Although the European experience and the ICAO Model UAS Regulations[100] provide a starting point for consideration, they may not reflect the needs of individual states or regions.

The alignment of competing interests and national requirements underpinning harmonization processes toward interoperability requires consultation and stepped or phased approaches. A stepped approach to harmonization would involve increasing harmonization in targeted areas, regionally, continent-wide, and then with other large trading blocs such as EASA in the European Union or the FAA in the United States. A phased approach to harmonizing regulations would provide participating countries with a roadmap of parts they can adapt when they are ready. Incorporating drones into master plans for transport or aviation can improve efforts to integrate diverse airspace users and ensure roadmaps consider adequate support through the allocation of resources for the development and the deployment of a diverse range of operational environments and UAS use-cases[102]. Harmonization could involve a roadmap for increasing the complexity of permitted operations at the same time as retaining acceptable levels of risk:

1. VLOS requests

Fly UAS including one-off applications, minor training for agency staff, and the application of STS operations only.

2. BVLOS requests

One-off applications in segregated airspace or areas with low ground risk, reliable connectivity, and test corridors.

3. Concurrent VLOS and BVLOS flights

Increase complexity at the same time as retaining adequate spacing and segregation between them.

4. Considerations over lower-risk operations

Legislate the exemption of lower-risk operations from the overarching regulatory approach based on operator declaration to reduce the burden on CAAs and industry. Continued assessment of all higher-risk operations, including heavier cargo, flights over populated areas, and so forth, using the SORA methodology or similar safety and risk management approaches.

5. Complex, segregated operations

Considerations over approval of UAS operations nearer to urban areas or controlled aerodromes, cross-border flights, transport of dangerous goods, increased number of flights in close proximity, and some automated flights and more than one UAS per remote pilot.

6. Full integration, interoperability, and harmonization

Two-way movement of operations, full cross-border compatibility, Urban or Advanced Air Mobility, operations over urban areas, full integration of conventional and un-crewed operations in the same airspace, at the same time as allowing all complexities of operations.

Discussion

Pertinent Questions

- Which elements of regulations can be harmonized, and what should be left to participating states?
- Who will oversee harmonization efforts in different regions?

Standard aviation English phraseology is crucial to effective verbal communication and reducing ambiguity in aviation and should be complemented by plain-language communications in English when necessary. Difficulties in plain language communications between ATC and flight crew have caused serious incidents and accidents in the past, prompting ICAO to introduce a language proficiency system for communications among operational personnel, including ATC or Flight Information System and pilots[103]. Outside of those communications, it is up to policymakers to decide which language to use. In Africa, 22 African Union member states are Francophone, five are Portuguese speaking, and the remainder Anglophone with some Arabic. Within ICAO, the Language and Publications Services is responsible for producing ICAO documents and publications in all UN official languages (i.e., Arabic, Chinese, English, French, Russian, and Spanish) per the requisite quality standards. As of March 2021, the *"ICAO UAS Model regulations"*[104] is only available in English. The *"ICAO UAS Toolkit"*[105] and *"U-Aid. UAS for Humanitarian Aid and Emergency Response Guidance"*[106] are only available in English, whereas the ICAO RPAS Manual[107] was translated into all six languages on initial publication in 2015.

For more information, see also

EASA (2018). ***Introduction of a regulatory framework for the operation of unmanned aircraft systems in the 'open' and 'specific' categories*** **(Opinion No 01/2018).** — EASA rules for the open and specific UAS operations (see 3.2)

EC (2016, June 1). ***Commission takes steps to modernise EU's standardisation policy*** **(MEMO/16/1963)** — Provides background, context, and explanation to the European approach to harmonizing regulations.

2.4 AIRSPACE MANAGEMENT

Themes: Flight Operations
Involvement: CAA or other designated authority and Air Navigation Service Provider (ANSP) to manage national airspace

Background

UAS can operate outside of conventional aviation's traditional point-to-point model, thus "enabling a more dynamic use of airspace"[108] and complicating considerations of where, when, and how to approve operations. This flexibility stems from reduced requirements for take-off and landing infrastructure and operations in lower levels of airspace that introduce additional considerations over ground risk (see 3.1).

Ultimately, most UAS operations will likely follow conventional aviation and occur within predefined air corridors, which may be segregated from or integrated into controlled airspace. A Drone Corridor is "a segregated airspace defined by the appropriate authorities in consultation with the airspace designers to keep commercial UAS operations out of the non-segregated airspace in which manned aircrafts operate."[109] It forms a standard UAS route depicted on charts, Notice to Airmen (NOTAM), and so on to create awareness of operations among other airspace users. A CAA can introduce drone operations into existing airspace and airway management through:

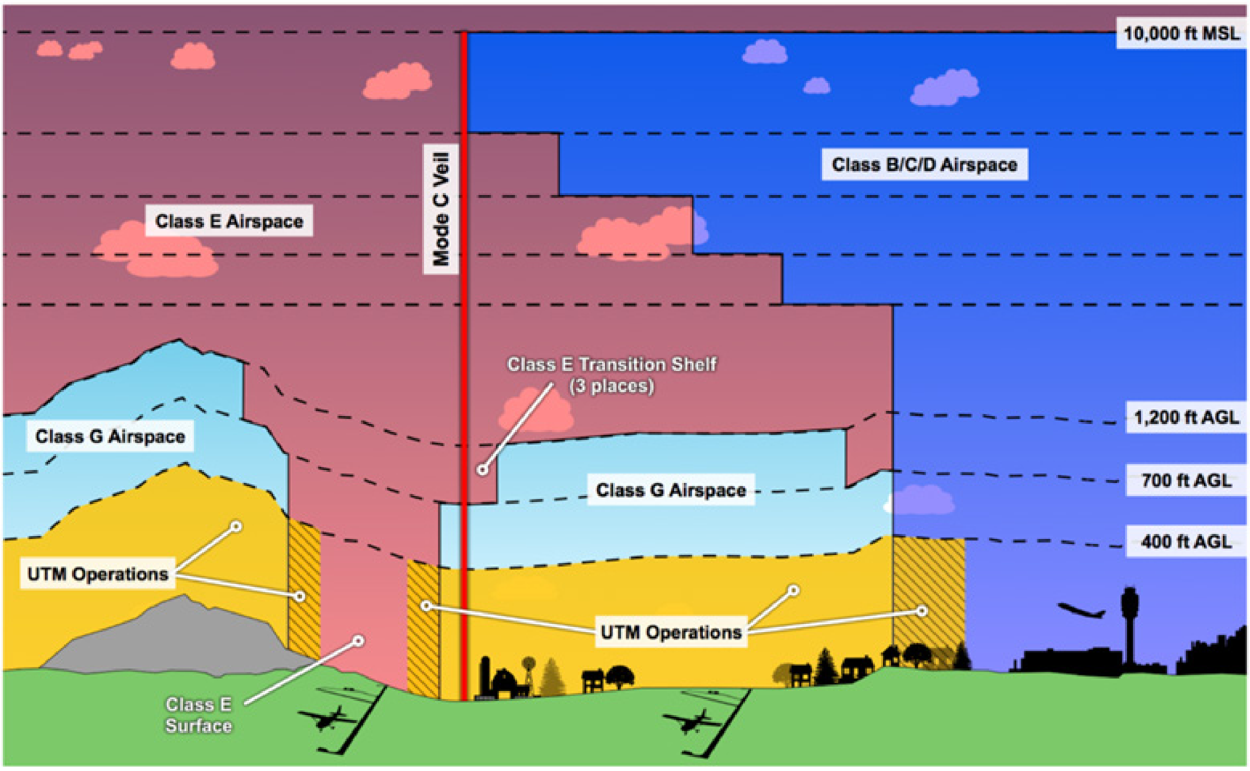
a. **Segregation —** Airspace is designated for operations with access restrictions for other airspace users known as restricted or atypical airspace[110]. It requires operations to remain within the assigned airspace and safety buffers surrounding it. Procedures are needed in an airspace violation by another party entering or the operation escaping the segregated airspace.
b. **Integration —** UAS operations take place in the same airspace as other (conventional) operations. ICAO asserts that this approach should in no way

increase safety risks; however, no separation minima or segregation guidelines exist among UAS and other operations. Instead, the extent of separation or segregation depends on the level of risk of the UAS operation — it is generally lower for VLOS, yet challenging for BVLOS operations and represents a work in progress.

The ADF assessed both airspace options: integration during the LVC in Tanzania and segregation at the LKC in Rwanda. Regulatory support for integration was not available at the LVC, with flights taking place in natural air traffic gaps. At the LKC, extensive work with the CAA precipitated the setup of restricted airspace based on the JARUS semantic model (see Annex B and Section 3.2 for further discussions on the role of airspace in safety risk management).

ATC will need to either continue to manage or release the airspace to a controlling authority in the case of integrating (a TFR) within controlled airspace (see Figure 2.1 for an overview of airspace types). Regardless of the approach, NOTAMs, which can be supported with Aeronautical Information Publication (AIP) supplements if needed, should be published to inform other airspace users of potential drone activity in the specified airspace. Such NOTAMs should cover airspace dimensions, hours of activation, activity heights and altitudes, and contact details such as phone number or Very High Frequency (VHF), alongside ATC procedures for activation and deactivation. In controlled airspace, the CAA should broadcast the activation and deactivation of temporary airspace restrictions via the area VHF frequency to allow involved parties to monitor this during operations. An alternative exists in temporary airspace releases; here, an agreement is made between the airspace custodian to allow an individual (one-off) BVLOS flight under agreed-upon procedures and away from other airspace users by flying only during gaps in conventional air traffic. This airspace is then temporarily restricted to other airspace users, such as other UAS operations and conventional aviation.

Figure 2.1: Operations in the context of airspace classes[111]



Segregated corridors represent opportunities for testing and to support decision-making across various areas relating to drone operations.

1. **Use-case testing** — Corridors have played an essential role in testing the feasibility and scalability of safely conducting different drone applications, including mapping and medical commodity delivery, by providing a real-world environment and challenges (see 1.1).
2. **Sensitization and community acceptance** — Drone tests in corridors can help identify the best strategies and approaches for local community sensitization and stakeholder management (see 1.3).
3. **Operational testing and technology demonstration** — Drone manufacturers, service providers, and researchers benefit from stress-testing their platforms, evaluating drone compliance with regulatory requirements, and exploring various technological and operational aspects of their solutions. Drone corridors have proven helpful for technical tests (flight performance) and operating aspects, including BVLOS ConOps, standard operating and emergency procedures, UTM, and similar. Corridors can also support vendor or service provider prequalification, testing, and technical demonstrations (see 1.5).
4. **Regulation** — It enables regulators to test their regulatory procedures and coordination mechanisms within segregated airspace and ensure that regulations are fit-for-purpose in both theory and practice (see 2.2).

The benefits of segregated drone corridors are undeniable, as they offer a safe environment to evaluate drone applications, regulatory mechanisms, and operational practices for the subsequent scale-up in non-segregated airspace. Similar corridors to Malawi (see Box 2.4) exist in Sierra Leone, Kazakhstan, and elsewhere.

Discussion

Pertinent questions

- What is the more appropriate airspace management option, open (integrated) or closed (segregated)?
- How will test corridors be funded, and what is the incentive for potential users?

Such corridors commonly face scalability and funding challenges, however. As tests are often limited in duration, it is hard to generate a long-lasting impact from activities within a corridor. Because drone corridors are usually located in remote areas to address ground risk challenges, they have difficulties demonstrating urban land administration use cases (see 1.1), for example. Increasing market opportunities such as the potential for progressive scale-up of operations outside dedicated corridors is likely to increase the chance of attracting genuine agencies and customers. Most corridor users are likely to be international companies, which will need to raise considerable funds to support logistics and operations. They may be dismayed by potential fees charged for corridor access. However, potential revenue streams for training exist in corridor usage, as institutions might settle within the corridor to set up training centers (see 2.1, 3.4).

For more information, see also

Department of Civil Aviation Malawi, MACRA, VillageReach, GIZ, and UNICEF (2019, Dec). *Malawi Remotely Piloted Aircraft (RPA) Toolkit: A Guideline for Drone Service Providers, Humanitarian and Research Fields.* — Summary of the Humanitarian Drone Corridor in Kasungu, Malawi for drone service providers looking to operate there.

FAA (n.d.). *ALC-42: Airspace, Special Use Airspace and TFRs.* — A basic introduction to airspace classification and types of Controlled Airspace

UPDWG (2019, May 22). *Technical and Logistical Challenges Encountered During Test Flights in Malawi.* Presentation — Details lessons learned from the implementation of the Humanitarian Drone Corridor in Kasungu, Malawi

Box 2.4 — Segregated Airspace, The Malawi Humanitarian Drone Testing Corridor

UA Established in early 2017, Malawi's Humanitarian Drone Testing Corridor is the first of its kind on the continent. It serves as an experimental technological "sandbox" and open to companies, academic entities, and other drone industry participants — enabling them to test specific drone solutions within a humanitarian and development context. This testing helps the Malawian government, UNICEF, and other development partners gather the evidence and learn how they can use UAS technology safely and at scale to benefit the people of Malawi. The Corridor is located two hours drive from Malawi's capital Lilongwe and covers around 5000km2 of the Kasungu district. The corridor is a circular shape with a 40km radius (80km diameter) and a permitted altitude of 1312 feet (400m) above ground level. Kasungu aerodrome, with its 1200m long tarmac runway, is at the center of the corridor.

Kasungu district is home to several communities, villages, and towns with a total population of ~800,000, the majority of which resides in rural areas. Before establishing the Corridor in Kasungu, UNICEF undertook an extensive community sensitization campaign to help familiarize local people and authorities with the use of drones (see 1.3). That campaign has helped provide information about the risks and benefits of using drones for medical delivery, mapping, environmental monitoring and other applications.

Communities, health facilities, terrain, obstacles, critical infrastructures such as dams, power stations, high-power transmission, and mobile network coverage has been extensively mapped to provide crucial risk management data to prospective corridor users. The understanding of network coverage and provision (see 2.6) alongside knowledge on community and facilities locations on the ground is crucial to enable adequate safety and risk management (see 3.1) and mission planning (see 4.1). Prospective corridor users looking to conduct long-range BVLOS testing requires Department of Civil Aviation approval (see 3.3), possession of a valid UAS pilots license, 3rd party liability insurance (see 2.11), a detailed safety and risk management (see 3.1) and ConOps (see 3.2), and needs to adhere to UNICEF innovation principles and address one or more UNICEF Global Goals for Every Child.

2.5 DRONEPORTS

Themes: Flight operations
Involvement: UAS service provider, end-users such as a postal service or Ministries in charge of Agriculture, Infrastructure, Commerce, Land, or Health, or local government authorities and the private sector using the droneport for flight operations and ancillary services; telecommunications regulator and mobile network operators to provide connectivity

Background

Droneports (sometimes synonymous to Drone Operating Centers) represent the interface between earth and sky and are fundamental to safe and sustainable high-frequency UAS operations. Their fixed locations enable transport and mobility services and provide a convening location for training, testing, and raising community awareness as a civic space[112]. Given established demand and if well designed and executed, a network of droneports can be profitable, create employment opportunities, share value and provide iconic and futuristic civic buildings in communities that lack significant architecture. As the concept is new and implementation depends on local contexts, there is no template of a "perfect" droneport. Nonetheless, droneports need to provide some universal key features, regardless of an operations scale.

> Long haul deliveries *"would require drone ports being built as public infrastructure, and development initiatives being embedded into regional infrastructure — in the same way we are currently benefiting from public roads, private telephone connections and internet service providers in remote places. Corporate interests would have to take the fiduciary risk: governments/ NGOs would then only have to purchase (or rent) the drones"* Jonathan Ledgard[113]

Operational requirements should determine the number and location of droneports, as they have implications on the performance of the droneport itself and broader cost-effectiveness of operations overall. Depending on the size of the service area, droneports can be set up in a centralized or decentralized manner. In a centralized approach, one droneport would serve the entire area, reducing capital cost for droneports, but requiring more powerful drones capable of long-range flights at high speeds. In a decentralized approach, operations would be split across multiple droneports serving as distribution hubs for flight operations and allowing for quicker service times and the use of lower-range UAS. Identified needs, scale of demand, and the combination of capital cost, operating, and other costs (see 1.2) heavily drive decisions over a centralized versus decentralized approach (see 1.1). Regardless of the chosen model, the operation of droneports near populated areas and critical infrastructure necessitate considerations over ground risk mitigations. Safe operations of droneports require adequate physical space on the ground and three-dimensional airspace surrounding them as safety buffers to reduce air and ground risk (see 3.1).

At a minimum, droneports should allow for essential functions, including power charging or refueling, safe landing and take-off, maintenance, repair, and overhaul. Depending on the length of the operation, they can either be set up as temporary or permanent bases and utilize existing infrastructure such as buildings or airstrips. At a minimum, droneports should have:

- **Accessibility** to the businesses or communities it is looking to serve may be crucial for resupplying a distribution center. In addition to accessibility from an infrastructure point, sites in the middle of a jungle or on beaches, for example, may prove inaccessible during specific weather scenarios.
- **Space for take-off and landing** should be free from sand and excess dust where

possible. The LKC flying operations, for example, have shown that too smooth a surface can lead to false pressure and altitude reading when the UAS lands.

- **A building with basic facilities** such as electricity, fresh water, and a washroom are necessary for full-time operations. It can also provide shelter during rainy seasons, provide space for storing equipment, and repair or maintenance work.
- **A consistent power supply and reliable power grids** is essential for UAS operations with battery-powered UAS (see 1.5) and to power an UTM system (see 2.7). Generators or solar panels can be appropriate solutions in areas with frequent power cuts, whereas Uninterruptible Power Supply (UPS) units can prevent damages from sudden power outages.
- **Connectivity and reliable internet access** are necessary to remotely pilot aircraft, download location maps, make software updates to UAS platforms, and reliably run UTM systems.
- **Security** and perimeter fences reduce the ground risk of potential harm to individuals while providing safe storage for equipment at the droneport. Community sensitization (see 1.3) can help reduce risks of theft and malicious damage to the operations, reducing the need for private security to help guard equipment at night.
- **A clear view** of the surrounding airspace to detect potential hazards such as birds, helicopters, or non-cooperative drones, which could collide with a drone (see air risk in 3.1) and may not show up on the UTM system used for situational awareness and risk mitigation.
- **Warehousing and logistics facilities** if distributing and receiving medical commodities such as blood, vaccines, or lab samples, pharmacy supplies, which may also require additional refrigeration.

In addition to these features, it is an absolute necessity that droneports contain the tools and resources necessary for repairing and maintaining drones on-site, especially in case of particularly remote or hard-to-reach droneports, as damaged drones reaching these facilities may depend on such services for continued operation. These facilities would need to include tools for basic mechanical and electrical repair and some digital fabrication capabilities, such as the on-site 3D printing of spare drone parts. The inclusion of such equipment within droneports could then have the bonus of giving community members access to these revolutionary technologies in a public setting and offer opportunities for expanding local maintenance and manufacturing capabilities.

Discussion

The establishment of droneports will generally follow a four-phase approach of 1) site identification and assessment, 2) planning, 3) construction, and 4) operation of droneports[114].

1. **Site identification and assessment —** This phase helps determine suitable locations for the droneport setup and should include an environmental and safety assessment of the site. Droneports can be set up in urban, peri-urban, or rural areas depending on the underlying use case and its associated service requirements, goals, and aims. Rural, urban and peri-urban areas each come with their caveats, from accessibility and ease of access to facilities such as power grids and network connectivity, to implications on operational approval (see 3.3) owing to increases in ground risk to people and infrastructure (see 3.1).
2. **Planning —** Local surveyors and drones flown VLOS can help render accurate models and map sites with exact GPS coordinates. Drone service providers will need this information for route and planning and safe BVLOS operations with remote take-off and landing. The necessary level of sophistication beyond the chosen distribution system's requirements, technology, and use case (such

as cold-chain) is largely personal preference. A droneport could range from a simple tarp to a futuristic-looking structure, such as the Norman Foster Foundation's vision.

3. **Construction —** Depending on accessibility and plans for the droneport extensive work may be required. This would include bringing in equipment and materials from outside the area or even outside the country, including some specialist equipment such as solar panels, USPs, weather stations, or relay antennas.
4. **Operation —** Depending on whether insourcing or outsourcing is the business model chosen (see 1.4, 2.12), the droneport and operations management may fall within the drone service provider's remit. Routine site surveys can help identify potential risks as surrounding areas develop further.

For more information, see also

Norman Foster Foundation (n.d.). ***Droneport***.
— Summary of Norman Foster's Imagination of a droneport as a central civic structure in Rwanda

2.6 C2 LINKS AND SPECTRUM

Themes: Flight operations, data, and connectivity
Involvement: UAS service provider coordinates with the CAA or other designated authority to request frequencies for and avoid interference issues during drone operations. Telecommunications regulator will allocate and manage radio frequencies.

Background

C2 links support flight and flight management by connecting the drone and remote pilot station (RPS). In addition to providing a means to control the drone, they provide data links for sending mission-critical information, navigation, and communication needs from identification and authentication to positioning throughout the flight. Link performance, the health of the C2 link can be affected by signal strength and interference issues, among others. Operations commonly rely on unlicensed spectrum in industrial, scientific and medical (ISM) radio bands with the option to extend the radio line of sight via relay stations when within VLOS.

BVLOS operations instead require the C2 link to be relayed through alternative means of connection, such as mobile networks such as GSM or 4G or LTE, or via satellite communications.

The harmonized, standards-based nature of existing mobile networks and technologies makes it a scalable connectivity solution for the provision of C2 links in BVLOS operations. Mobile networks can increase link performance and provide direct communication for remote identification, detect-and-avoid, and other risk mitigation and collision avoidance measures (see 2.7, 3.1). Owing to the globally harmonized nature of the dedicated licensed spectrum underpinning the provision of mobile network services, it can provide safe, secure, and efficient connectivity options for BVLOS and high-risk environment operations above urban and peri-urban areas with reliable network coverage. Some location services can also support positioning based on signal triangulation from cell towers using a similar concept to GPS via satellites. Greater bandwidths afforded by the increasing rollout of 4G and 5G services will provide even more security, quicker transmission speeds, and better reliability of C2 links.

Discussion

Pertinent questions

- Will operations in border areas cause interference issues with neighboring countries?
- What happens during a C2 link failure or other issues with data link performance?

Operators should consider how and where UAS can broadcast location information to avoid interference, particularly for operations in border areas. In some cases, operators may need to request access to specific spectrum bands before setting up an UTM and commencing flight operations. The clear communication of frequency plans highlighting network strength, network coverage, spectrum-related regulations, and a plan of available spectrum bands can assist with the planning of operations and reduce the risk of interference. Historically, a lack of frequency spectrum allocation to support C2 links has been a significant inhibitor to achieving the required C2 link performance for BVLOS operations. In addition, receivers also need to be available and within range to interact with the UTM system, which may be difficult in some areas due to connectivity gaps.

In remote and rural areas, connectivity gaps can prove a significant challenge to the provision of C2 links for BVLOS operations. Working with the telecommunications regulator and mobile network operators in the country could result in installing new towers to address those gaps and provide additional coverage. In areas without backhaul or power to support mobile towers, satellite links may prove one of the only viable connectivity solutions despite their relatively high costs. Combining terrestrial links (that is, 3G, 4G, and 5G) with solar-powered HAPS, such as balloons or solar-powered stratospheric aircraft, and satellite communications provides opportunities to overcome connectivity gaps and provide redundancy while opening opportunities to engage with the local space industry.
In addition to enabling UAS operations, investments in rural and affordable connectivity can further help create economic activity and access to services.

With few exceptions — most notably the 1090 MHz spectrum band shared among conventional aviation and some UAS operations for the ADS-B, and the allocation of 5030-5091 MHz for C2 link[115] — there are no global standards for spectrum allocation for UAS operations, with rules varying across different regions. Instead, the national telecommunications regulator is responsible for managing spectrum allocation, which would include C2 links, and prevent interference across the licensed spectrum. In the case of Automatic Dependent Surveillance - Broadcast (ADS-B) usage, the telecommunications regulator should perform radio frequency spectrum analysis to identify potential congestion of the 1090 mhz spectrum to consider the impact of spectrum crowding on the performance of the ANSP surveillance system. The risk of overcrowding of the 1090 mhz spectrum is prompting discussions on whether to limit the use of ADS-B on small UAS operations in low-level airspace. Such ADS-B overcrowding is likely to be less of an issue in countries with relatively low levels of conventional aviation.

For more information, see also

GSMA (2018). ***Using Mobile Networks to Coordinate Unmanned Aircraft Traffic*. London: GSMA** — Guidance note highlighting the role that mobile networks can play in providing C2 Link, support UTM operations, and other aspects of connectivity essential for safe and sustainable high-frequency drone operations with a specific focus on 5G.

ITU (2012-a) ***Examples of technical characteristics for unmanned aircraft control and non-payload communications links (Report ITU-R M.2233).*** **Geneva:ITU** — Discussion of achievable C2 link performances ahead of passing of WRC-12 RES153[116]

UPDWG (2019, May 22). ***Technical and Logistical Challenges Encountered During Test Flights in Malawi.*** **Presentation** — Discussion on connectivity challenges encountered in the Humanitarian Drone Corridor in Kasungu, Malawi

Vaughn, M. (2019). ***Considerations on the use of 1090 MHz and 24-bit aircraft addresses.*** **Presentation delivered at ICAO Drone Enable/3.** — Discussion on the risks of overcrowding of Aviation specific 1090MHz spectrum and the future of 24-bit aircraft addresses in the face of massive increases in demand through UAS operations.

2.7 UTM

Themes: Flight operations, equipment, data and connectivity
Involvement: CAA or other designated authority, ANSP and UTM service provider, in some cases in collaboration with the telecommunications regulator

Background

Low-level airspace, home to most UAS operations, is commonly shared with helicopters, other UASs, and conventional aviation during take-off and landing, making effective traffic management essential to ensure safe sharing of airspace. The introduction of UAS into this airspace gives rise to concerns over traditional ATM capacity to handle authorization, appropriate use by operators, safety and security, and how to coordinate their use[117]. UTM can assist with this need and increase airspace access and integration through awareness while it enhances operations safety and security.

The primary function of a UTM system is tracking and monitoring UAS to provide situational awareness and understanding of what a drone is and should be doing. It can help facilitate safe and efficient scaling of drone operations, making it an essential element for states safety oversight approach and airspace management in the face of scaling a national drone program. Common capabilities include[118]:

- **Situational awareness** — Provides an overview of where UAS are operating and checks whether UAS are what they claim to be on their preplanned and approved route(s)
- **Deconfliction** — Different options for managing mitigation measures to prevent collisions between UAS's and conventional aviation, and thus avoid air risk or ground risk scenarios
- **Notification —** Notifies airspace users in an emergency or abnormal situation such as through the inclusion of AIP, an aeronautical information circular, or

NOTAM notifications within the platform

- **Compliance —** Options to monitor the compliance of airspace users with environmental, security, and privacy requirements

If linked in with an existing Flight Information System, the UTM system can be a source of valid, current, and accurate information to support drone operations — from aeronautical, geospatial, weather, flight and flow, security, and other information.

> *"UAS Traffic Management, or UTM, is a digital air traffic management system made up of technologies and services designed to maintain safe integration and separation of drones and other aircraft and objects in low-altitude airspace. UTM works by connecting drones and their control systems, drone operators, and enterprise fleet managers to airspace authorities for the exchange of mission-critical information and services related to remote identification, situational awareness, operations planning, notification, airspace authorization, traffic deconfliction, conformance monitoring, and emergency management. UTM differs from classical ATM in that it is digital and predominantly self-managed, relying primarily on automation and autonomous capabilities for safety at scale. UTM involves minimal human interaction, giving rise to a variety of business models that vary from traditional ATM both economically and financially."*[119]

UTM services can provide the necessary information to support different risk mitigation strategies and overall safety risk management (see 3.1)**.** Among the most common mitigation strategies for collision avoidance and reduction of air and ground risk are:

- **Geo-fencing** — A feature within the flight control software that triggers an alert on the ground control station or a preprogrammed action when a UAS enters or exits a preset virtual boundary. It helps ensure separation from conventional and other UAS traffic. Experiences from the LVC have shown that many UAS operators struggle with the construction of complex geo-fences.
- **Detect-and-avoid** — These features prevent airborne collisions with other aircraft or UASs in cases were separation assurance, "the capability to maintain safe separation from other aircraft"[120] fails. Although relying on communication with RPSs and Flight Information Systems (or UTMs) traditionally, there is an increasing push for UAS platforms to support direct communication with other LTE- or 5G-equipped aircraft in the surrounding environment[121].

To this end, UTM functions as a complementary yet separate tool to ATM for conventional aviation. The ICAO considers UTM a "specific aspect of air traffic management which manages UAS operations safely, economically, and efficiently through the provision of facilities and a seamless set of services in collaboration with all parties and involving airborne and ground-based functions"[122]. A UTM system can be of a persistent or a more portable nature (see Box 2.5 for examples):

- **Persistent —** Functions similar to traditional ATC with a defined geographic coverage, making it appropriate for urban areas with high rates of air traffic and necessary human resources and infrastructure
- **Portable —** Can be set up anywhere to support emergency operations, or for small-scale operations such as precision agriculture or infrastructure monitoring use cases

In general, the portable option should be considered a last-resort tool rather than for supporting sustainable operations. Significant infrastructure and software to power detect-and-avoid systems, enable analytics, and support navigation in low-to-no-connectivity areas are required to enable and safely and securely manage the widespread use

Box 2.5 — UTM service provision in Europe and during the African Drone Forum

Whereas the European U-Space approach123 relies on the use of a persistent UTM, both the Lake Victoria Challenge (LVC) and Lake Kivu Challenge (LKC) flying competitions employed a portable UTM.

- The European U-Space approach — To enable a common approach to manage un-crewed traffic through the same rules and procedures for all UAS operators across Europe, the European Union Aviation Safety Agency (EASA) and the European Union have developed a regulatory framework that allowed the safe and harmonized use of U-space services. This framework links to UAS regulations across the EU member states. It allows member states to remain responsible for defining their own UAS geographic zones to offer U-space services. Member states adopted the U-Space regulatory framework in April 2021. Mandatory U-Space services include network identification, geofence, traffic information, and UAS flight authorization. Additional services offered at the discretion of member states include tracking services, weather information services, and conformance monitoring services.
- The African Drone Forum — The LVC held near a controlled aerodrome at Mwanza, Tanzania, in October 2018, included safety evaluations of both Visual Line of Sight (VLOS) and Beyond Visual Line of Sight (BVLOS) UAS flights. In 2020, the LKC flying competitions took place near Gisenyi, Rwanda. In both cases, a basic UTM was to support risk mitigation during BVLOS flights. Real-time UAS locations and movement fed the traffic management system. It was not advanced enough to include varying airspace, weather, and advanced geo-fencing at the same time as segregating UAS and conventional airspace users, all of which had to be set manually by the Operations Manager. At the LKC 2 years later, the UTM tracked all flights via mobile networks, relying on either an inbuilt transceiver or attached hardware such as the "Unifly BLIP" and adequate coverage.

of low-altitude UAS operations, regardless of the type. Although the term UTM is used generically, there are many components (for example, software, relay antennas) to a UTM system that no single company can fulfill at present. Some implementation options available to countries include 1) operating their own UTM, for example, through their ANSP; 2) contracting a separate UTM service provider, or 3) procuring UTM capabilities as part of a closed model such as those provided by Zipline or Swoop Aero. UTMs can be provided as a service to UAS operating in segregated airspace or a combined package if used with ATM service provision in ICAO airspace (see 2.4). However, the interface between the UTM and ATM requires tailoring to local contexts and systems.

Figure 2.2: GSMA[124] overview of UTM capabilities related to phases of a UAS operation

	Phase	Capabilities	
1	INITIAL PREPARATION	Electronic Registration	Electronic Identification
2	FLIGHT PREPARATION	Flight Planning Flight Approval Capacity Management	Geofencing Meteorological Information
3	FLIGHT EXECUTION	Tracking Airspace Dynamic Information	Conflict Detection Interface with other Traffic Control (ATC/ATM)
4	POST FLIGHT	Recording	Playback/Logs

Discussion

Pertinent questions

- Will the UTM system integrate with the existing ATM?
- What is the appropriate sensor technology to use?
- Who will cover the costs for relay antennas and other sensor infrastructure necessary to make UTM systems work?

UTM software platforms work on the principle of reliable network coverage, cloud access, and integration with conventional ATM. Setting up a UTM system requires a lot of effort because it involves integration with the existing ATM system, as awareness and traffic management capability for drones and commercial aviation in harmony are crucial to ensure safety within the airspace. Thus, UTM may not work in scenarios without an existing or only a rudimentary ATM. This challenge also relates to earlier discussions on capacity (see 2.1), as local ATC will need both capacity and capability to engage with a chosen UTM system. Internal processes and operations can be a block to integrating ATM and UTM. Having internal champions of trust alongside basic rulesets and protocols to protect operations safety can help alleviate those blocks.

The ability to track drones as they move through the airspace is at the core of any UTM system. Such capabilities can also support law enforcement and policing as well as the communication of ad hoc and static no-fly zones. Currently, several different technology options for tracking exist:

- Network-based UAS specific transponders — This option can include GSM trackers, for example, and requires mobile network infrastructure to function. Current 3G and 4G networks in populated areas are often sufficiently developed to deliver connectivity, real-time data, security, and identity management to support UTM.
- Broadcast-based — ADS-B transmits ICAO IDs and GPS positions over the 1090MHz frequency commonly used in commercial aviation. Besides being very expensive, their use may lead to potential crowding of the frequency depending on the airspace's busyness[125].

- Broadcast-based UAS-specific transponders — This option can include WiFi or Bluetooth, may integrate with a UTM system for remote identification[126], and are widely used in the U.S., Europe, and Japan. They are limited in range and may pose problems sharing data and feeding it into a UTM, making them more tailored for emergencies than routine traffic management.

Depending on the chosen sensor technology, investment in additional network infrastructures such as relay antennas, additional cell towers, or solar-powered HAPSs may be necessary to provide sufficient coverage for a UTM system to work reliably. Regardless of the chosen technology, however, the need for a safe, secure, and efficient globally interoperable identification system persists. Yet non-cooperative drones, those operating without active tracking technology, represent a significant challenge and may warrant the installation of Counter UAS or anti-drone systems. Such systems may include electronic signatures, geo-fencing, and frequency interference, among other features.

For more information, see also

African Drone Forum (2021b). *Traffic Management of the Future, Today: A Primer on UTM* — A high-level use case-based overview of UTM systems, why they are relevant, and what they entail.

ASTM (2019). *Standard Specification for Remote ID and Tracking (F3411-19)*, West Conshohocken, PA: ASTM International — Standard specification for use of broadcast-based UAS specific transponders for remote identification

Creamer, S. P. (2018). *Aircraft Registration Network (ARN) for Drones*. Presentation delivered at Drone Enable/2 — Update on ICAOs efforts in the registration and identification of UAS

FAA (2020, Mar 2). *Unmanned Aircraft System (UAS) Traffic Management (UTM). Concept of Operations 2.0*. Washington: FAA — Federal Aviation Administration (FAA) reflection of their work on UTM implementation in their National Airspace.

GSMA (2018). *Using Mobile Networks to Coordinate Unmanned Aircraft Traffic*. London: GSMA— Guidance note highlighting the role that mobile networks can play in providing Command and control (C2) Link, support UTM operations, and other aspects of connectivity essential for safe and sustainable high-frequency drone operations with a specific focus on 5G.

ICAO (2021, Feb 9). *Unmanned Aircraft Systems Traffic Management (UTM) – A Common Framework with Core Principles for Global Harmonization (Edition 3)*. Montreal: ICAO — Provides States considering implementing a UTM system with a reference framework and core capabilities of a "typical" UTM system.

Scorer, D. (2019). *Aircraft Registry Network (ARN) Concept.* Presentation delivered at Drone Enable/3 — Overview of existing ICAO framework, the concept of ARN, why states need it, and how ICAO is addressing this need

SESAR (2020). *U-space. Supporting Safe and Secure Drone Operations in Europe. Consolidated report on SESAR U-space research and innovation results*. Luxembourg: Publications Office of the European Union — Summary and background on U-Space, the joint European UTM implementation.

2.8 PRIVACY, DATA MANAGEMENT, QUALITY, AND TRANSPARENCY

Themes:
Data and connectivity, safety and risk
Involvement: Security services, other non-aviation government entities, and CAA or another designated authority involved in developing regulation and compliance. UAS service providers and end-users such as a postal service or Ministries in charge of Agriculture, Infrastructure, Commerce, Land, or HealthLocal Government Authoritiesas data generators and consumers.

Background

As most drones are equipped with sensors or cameras for data collection either as part of the mission objective or as part of the flight management and safety

Box 2.6 — Examples initiatives to ensure the responsible and ethical use of UAS and reduce privacy concerns

- **Ethical approval** — The responsible and ethical use of drones reduces the risk profile of operations and contributes to increasing public acceptance of UAS. In Malawi, drone operations involving or impacting human subjects require ethical approval from the "Malawi National Health Sciences Research Committee (NHSRC) or the National Committee on Research in Social Sciences and Humanities (NCRSSH)" before the commencement of operations[129].
- **Image resolution** — UAS can collect centimeter-level resolution imagery, potentially leading to severe privacy invasions. Although there is no standard definition of what image resolution constitutes an invasion of privacy, it has given rise to interesting debates. In Zanzibar, during the 2017 land mapping initiative using drones, processed images were available at two resolutions — 2.5cm and 7 cm. Owing to many latrines in Zanzibar lacking roofs, images were deemed too high in resolution if they could show an occupied latrine. Although both 2.5cm and 7cm resolution imagery were collected, the prior was reserved for government use, with only the latter released for public use. Although this is not an industry standard, the recommendation is that local stakeholders be aware of and discuss the privacy concerns of acquiring and publishing imagery or allowing private companies to host images with private significance.
- **Public Availability and Access** — OpenAerialMap[130] is a set of tools for searching, sharing, and using openly licensed satellite and drone imagery built on top of the Open Imagery Network, an open service providing search and access to this imagery. It presents a potential low-cost solution for many drone imagery data sharing needs, where data are openly licensed and encouraged for broad reuse
- **Privacy-by-design** — India's Civil Aviation requirements only allow the use of drones, whose manufacturers implemented privacy-by-design standards in their drones to reduce risks of future privacy harms by UAS operators[131]. Although the regulations do not provide any specific guidance, the Future of Privacy Forum has considered different approaches of embedding privacy-by-design across detect-and-avoid capabilities, Navigation Controls, and the automatic analysis of video feeds[132]. Such technologies can also include automatic encryption of imagery and other potentially sensitive data collected during flight[133].

systems, they can potentially represent a significant privacy hazard.

> *"Drone operations can result in collection, use, or sharing of personal information, including information about individuals who are not involved in the flights. Some consumers have concerns about drone data collection, and policymakers agree that responsible data practices are crucial to building trust in drone services"*[127].

Hence, operators need to consider transparency, consent, and data management, including retention, storage, access, and the impact of the operation on individual privacy and, national security, and whether they comply with national data protection laws[128]. Having a data lifecycle plan, a detailed chain of custody from raw images, and flight log data to process data sets for distribution to users and backup repositories is considered best practice. Such plans should include dates for data acquisition, processing, deletion, and records of access (see 3.1). Operations also need to comply with local data protection regulations, which exist in nearly all countries to some degree. Although not all countries' laws reference UAS technology specifically, attitudes are shifting with increasing recognition of UAS in future iterations of regulations. Ideally, the UAS platform itself should also have technical data protection capabilities, such as encryption of collected data, to secure it from unauthorized access by third parties.

Discussion

Pertinent questions

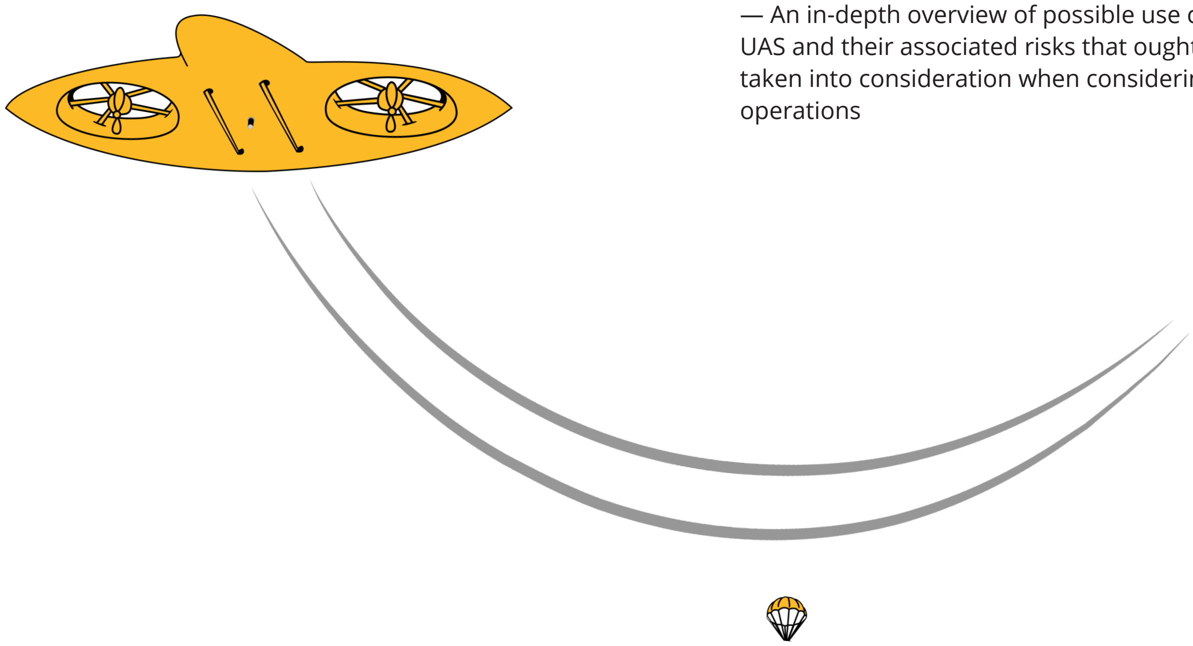
- Who is responsible for proving that operations comply with local data protection and privacy laws?
- How do operators deal with sensitive sites during large-scale mapping operations?

Countries may want to require operators to demonstrate their ability to comply with local privacy or regional laws as a condition for obtaining operational approval (see 3.3)**.** Such requirements are increasingly common and coincide with the growing recognition of the value of individual privacy and data protection and efforts to "harmonise the understanding and management of data protection [...] and align it with the evolution of UA regulations"[134]. Regardless of the legal situation, conducting a Data Protection Impact Assessment can help identify appropriate measures to guarantee sensible data and privacy protection levels[135].

In some cases, data sets generated through the use of UAS hold high public interest and are valuable for uses beyond their original intent. In cases where data may be considered a public good by local stakeholders, it is vital to develop a data publishing, hosting and maintenance, and access plan for the final outputs. This process should begin with selecting a data license that determines how anyone can use the data. Typically, public data sets will choose an attribution license[136], which allows for all legal uses as long as they attribute the data source (and thus cannot claim the data as their own), with the onus of enforcing the licensing falling on the copyright holder. Alternative types include non-commercial use, whereby data sets are available for research, education, and other activities rather than commercial purposes. Once a licensing regime is selected based on envisaged reuse purposes, data should be curated and published in a user-friendly and privacy-compliant manner — including complete meta-data labels, details on acquisition dates and processing methods, presentation in machine-readable file formats, and hosting on indexed, searchable databases. The resources to maintain large imagery data sets for general public use are non-trivial, as data sets can quickly reach several terabytes in size.

At the same time, operators involved in data generation need to consider how to handle sensitive areas as part of the operations and seek guidance from

national authorities where necessary. It is often impractical to avoid flying over such areas, whereas the deliberate omission from either the flight plan or the output data can draw unwanted attention to such sites. Ultimately, security agencies will determine how to handle those cases, and UAS operators must consider precedents and possible solutions. A common approach to minimize disruption and avoid drawing attention to sensitive areas is to publish imagery of sensitive areas in a degraded form (that is, lower resolution) — this could be in line with Google earth imagery (typically 50cm) or using older images. However, this approach affects data quality, and depending on the purpose of the survey, different methods may warrant consideration.



For more information, see also

Bothner, M., et al. (2021). Humanitarian UAV Code of Conduct & Guidelines. — UAS code of conduct guidelines on data protection

GFDRR (2018, Dec 21). ***Machine Learning for Disaster Risk Management*****. Washington: World Bank** — Guidance note on how machine learning can support disaster risk management, including key definitions, case studies, and practical considerations for implementation.

ICRC (2020). ***Handbook on Data Protection in Humanitarian Action (2nd Edition).*** **Geneva: ICRC** — Explores data protection challenges related to data analytics and provides guidance on addressing those.

Molinario, G., Deparday, V. (2019, Mar 6). Demystifying machine learning for disaster risk management. ***World Bank Blogs*** — Summary of Global Facility for Disaster Reduction and Recovery (GFDRR) experiences of using machine learning in mapping applications

Oren, C., Verity, A. (2020). ***Artificial Intelligence (AI) Applied to Unmanned Aerial Vehicles (UAVs) And its Impact on Humanitarian Action*****. Digital Humanitarian Network** — Update on earlier work by OCHA on using UAS for humanitarian response, focusing on how AI has enabled more effective uses of UAS.

World Bank Group (2016). ***UAV State of Play for Development: Innovations in Program and Humanitarian Contexts*****. Washington: World Bank** — Guidance on the use of UAS for data collections (although not covering data policy)

World Bank Group (2017). ***Guidance Note: Managing the risks of unmanned aircraft operations in development projects*****. Washington: World Bank** — An in-depth overview of possible use cases of UAS and their associated risks that ought to be taken into consideration when considering UA operations

2.9 LOGISTICS AND CUSTOMS

Themes: Equipment
Involvement: Customs authorities with support from freight companies, clearing agents, and dangerous goods shipping agents when dealing with lithium battery transport, import, and export, UAS service providers or manufacturers for importation and exportation of equipment
Timeline: Up to three months for the transport of lithium batteries, for example

Background

Most drone operations will rely on the importation and exportation of some or all of the UAS equipment required. Besides the initial import and final export, operators may require additional equipment and spare parts at various stages throughout the operational life cycle. Clear customs rules and release procedures can help reduce holdups of equipment in bonded warehouses, accelerate release timelines, and prevent other undue delays. Procedures should be clear, objective, and openly communicated to ensure transparency and increase trust by international stakeholders. In Malawi, UNICEF, VillageReach, and the Malawi Revenue authority can recommend clearing agents to assist with temporary importation and ease the processes for foreign UAS operators.

The equipment that drone service providers may be looking to bring with them broadly falls under three categories: Drones, batteries or other fuel technology such as hydrogen cells, and ancillary equipment.

- **Drones** — Involves the drone platform itself. Most countries expect service providers to register their drones before import into the country. Ghana, for example, requires a clearance letter to be presented to customs, whereas Rwanda requires permanent residents to register drones.
- **Batteries or other fuel technology such as hydrogen cells** — Some providers such as Zipline have opted to transport lithium cells and ancillary circuit boards to assemble lithium batteries in the country to avoid potential issues with dangerous goods regulations.
- **Ancillary equipment** — May include radios for communication, mini weather stations, spare parts, and other equipment to conduct operations "safely, economically and efficiently"[137].

Box 2.7 — Lithium battery transport and temporary importation for the Lake Kivu Challenge (LKC)

Owing to restrictions on lithium battery transports imposed by commercial airlines under international dangerous goods regulations, some of the competitors faced difficulties with the international transport of lithium batteries for their UAS platforms. Partly to address this issue, initial considerations focussed on shipping batteries via sea freight or land. Although most teams were ultimately able to transport batteries through specialist dangerous goods shipping agents, one team resorted to ground transport from one of their other operations in Malawi.
Following the LKC, most teams opted to use the same transport approach for exportation purposes, whereas some teams donated the batteries in-Country. To comply with temporary importation and exportation rules in Rwanda and their respective home countries, German and Spanish teams were required to export the batteries to avoid potential customs charges and other penalties.

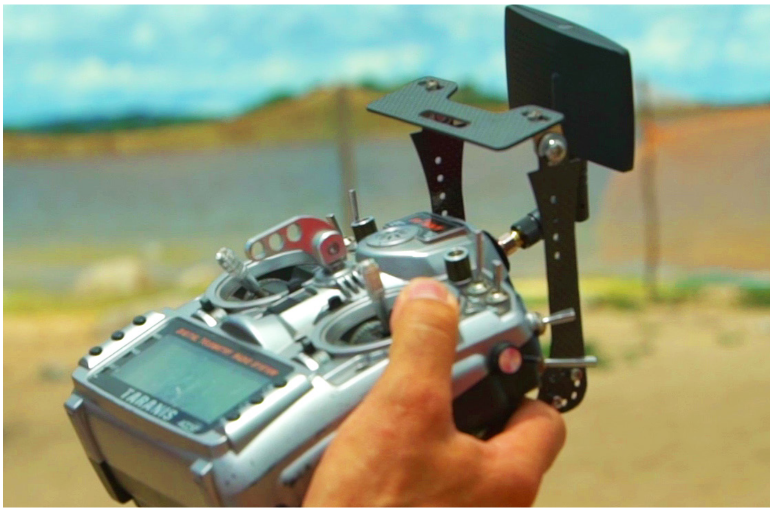
Release procedures provide opportunities to champion green technologies by leveraging different fees for electric or hydrogen and combustion technologies (see 1.5).

International dangerous goods regulations may affect battery logistics for cargo and large mapping drones. Small consumer drones typically use lithium batteries that do not pose any significant international air transport challenges. However, larger electric drones with extended range and endurance require batteries with a far higher capacity, often exceeding the 100-watt-hour rating threshold and classified as dangerous goods[138]. The transport of dangerous goods on passenger aircraft is forbidden unless the State of Origin, State of Destination, and State of the Operator have issued special approvals. They require special packaging and marking and require transport on cargo aircraft only. Additional restrictions and requirements for air transport apply, and even if operators meet all conditions, the decision to onboard the cargo is at the discretion of the pilot and airline. As a result, planning the international transport of lithium batteries becomes an essential element in budgets and implementation timelines. To plan for adequate battery supply for short-term projects, operators can consider maritime or terrestrial shipping options, which are reliable but take longer than transport by air. For long-term implementations, operators can import individual lithium cells (rating < 20-watt-hours) that fall below dangerous goods thresholds to assemble the cells into lithium battery packs in-country.

Discussion

Pertinent questions

- When will the equipment be considered permanently rather than temporarily imported?
- What documentation and provenance are required to import or export UAS platforms, batteries, and ancillary equipment?
- Are there programs or facilities for the safe recycling or disposal of batteries to avoid them being tossed or burned in pits, for example?
- Do operators need to prove everything has left the country or where everything is following the operations?
- "What import and customs duties or other taxes will be levied?"[139]



Some UAS platforms and other specialist equipment needed to set up operations may be considered dual-use goods and subject to export restrictions. Those may include several UAS accessories and components, including electronics, computers, telecommunications and "information security", sensors and lasers, and navigation and avionics[140]. In response, some manufacturers have limited their UAS endurance to under 50 minutes to bypass such regulations. Most cargo drones will be considered dual-use equipment where export restrictions apply, however. In some cases, manufacturers or operators are prohibited from exporting the drone itself, ancillary equipment, or specific components without special declarations or exemptions. Import to the countries of operations is a logistical challenge that changes from country to country and requires working with clearing agents on-site to avoid undue delays on timelines and budgets (through import taxes and tariffs, for example). Such measures present "a significant hurdle to one-off foreign operators such as tourists but can be circumvented for routine and long-term operations by engaging local pilots or operators, or by incorporating a local branch"[141]. Similarly, some countries may impose different import conditions on gasoline-powered equipment[142]. Generally, the preferred way is to work with a trusted national partner who can broker waivers to reduce potential fees and costs.

For more information, see also

Department of Civil Aviation Malawi, MACRA, VillageReach, GIZ, and UNICEF (2019, Dec). ***Malawi Remotely Piloted Aircraft (RPA) Toolkit: A Guideline for Drone Service Providers, Humanitarian and Research Fields.*** — An excellent example handbook providing operators with clarity on how to set up operations and address operating challenges

EC (2009, May 5). ***COUNCIL REGULATION (EC) No 428/2009 on setting up a Community regime for the control of exports, transfer, brokering and transit of dual-use items.*** **Luxembourg: Office for Official Publications of the European Communities —** Appendix I provides an overview of dual-use items subject to export restrictions.

ICAO (2009, Jun 25). ***Transport of Lithium Batteries in Accordance with the ICAO Technical Instructions.*** **Montreal: ICAO** — Guidance note to address commonly asked questions about lithium battery transport

IATA (2019, Dec 12). ***2020 Lithium Battery Guidance Document. Transport of Lithium Metal and Lithium Ion Batteries.*** **Montreal: IATA** — Guidance for complying with provisions applicable to lithium battery transport by air as set out in the IATA Dangerous Goods Regulations

2.10 OVERSIGHT, AUDITS, AND AIRWORTHINESS INSPECTION

Themes: Safety and risk
Involvement: UAS service providers for outsourcing or end-user in case of insourcing with oversight by the CAA or other designated authority for initial audits and periodic inspections
Timeline: The engagement with a CAA or other designated authority in designing the terms of reference (TOR) and auditing protocols should occur as early as possible within the procurement process, which may be months ahead of the ultimate signing of Memorandum of Understanding (MoUs) and service contracts

Background

According to the ICAO, all aircraft, which by definition includes the majority of drones, should be "reliable, controllable, and safe – no matter how small or large, or whether the crew is onboard the aircraft or piloting it remotely"[143]. Yet conventional type certification of UAS platforms is both impractical and cost-prohibitive in many cases (see 2.2). Instead, audits, airworthiness assessments, and due diligence checks ensure that both UAS and pilots can safely and responsibly complete the planned operations.

There are, however, no standard or even harmonized frameworks for regulating "acceptable" standards of airworthiness, operational conduct, and pilot competency for small UAS. Instead, frameworks include tests to certify that systems are safe from interference, robust enough for the operating environment, reliable, as specified in the initial registration and supporting documentation, and most importantly, airworthy. Additionally, operators or pilots should prove they possess knowledge of the operating environment, applicable regulations and laws, and their UAS, including air navigation experience and so forth[144].

The CAA or other designated airworthiness authority is responsible for authorization, audits, and granting of operating licenses. Although a national-level committee (see 1.3) can support the CAA or other designated authority as a quality assurance mechanism, it is considered best practice for operators to have an internal quality assurance system for continuous internal auditing. Whereas the onus is on the operator to ensure the UAS is inspected before each take-off and suitable for safe operation, there are considerations to introduce mandated periodic inspections by approved facilities for increased inspection and maintenance oversight. Thorough maintenance is essential and often an operation's most significant running cost factor, challenging the long-term sustainability of operations. In the absence of certification standards for UAS meant to operate in complex operations (that is, BVLOS, overflying people, and so forth), it is highly recommended to conduct audits of the manufacturer and operators, ideally production site, before any on-site implementations take place. This activity may be delegated to the contracting agency by the CAAs as appropriate while still retaining the full responsibility for safety oversight.

Box 2.8 — Competitor vetting for the Lake Kivu Challenge (LKC)

The competitor selection for the LKC held in 2020, followed a multi-process audit protocol:

1. Phase 1 (Remote) — Due diligence auditing, for example, does the drone physically exist and is it capable of flying;
2. Phase 2 (Remote) — Process auditing and checking of internal documents including operations manual and international pilots licenses and so on;
3. Phase 3 (In-Person) — The operations manager conducted spot checks of hardware and operations on-site alongside incremental flight displays to check whether UAS "technical capabilities and limitations, including communication reliability, and the capacity and reliability of the [... UAS] service operators"[145]. For example, at the LKC in Rwanda, this involved 1) manual inspection of drones; 2) basic hover tests; 3) transitions from vertical to horizontal flight; and 4) transition from Visual Line of Sight (VLOS) to BVLOS.

Discussion

Pertinent questions

- Should maintenance requirements and safety metrics be incorporated within a country's regulations or tender contracts without regulatory frameworks and related legal obligations?

Although every operator should have some form of a maintenance program, many may not have extensive service or retirement schedules based on actual operational experience and information on the lifetime of the UAS (see 1.5). Understanding an operator's approach to maintenance should form part of the initial due diligence checks as part of the service provider or UAS platform selection. In the absence of detailed schedules, robust maintenance protocols and requirements can be devised as part of the operations manual inherent to an operator's safety and risk management (see 3.1) and form part of the requirements for obtaining operational approval (see 3.3). A CAA or other designated authority could then carry out routine audits to determine whether operators fulfill their maintenance and safety obligations.

For more information, see also

USAID GHSC-PSM (2018, Jul 9). *Unmanned Aerial Vehicle Procurement Guide*. Washington: Chemonics International Inc. — Covering recommended specifications and questions for offerors with a specific focus on cargo operations and likely relevant until additional UAS have been certified.

VillageReach (2020, Jun). *How to Select a Drone Service Provider for Transport of Health Products. Lessons Learned*. Seattle: VillageReach — Recommendations for drone service provider selection for the transport of health commodities based on experiences from the Democratic Republic of Congo and Mozambique

2.11 INSURANCE

Themes: Safety and risk, equipment, use cases
Involvement: UAS service provider for outsourcing or end-user in case of insourcing, and insurance provider

Background

Comprehensive and appropriate insurance coverage is essential to protect UAS operations and reduce liability for operators[146]. Each operator should have insurance proportional to the risk of the planned operations. Insurance is necessary to cover damage to equipment, persons, and, in some cases, breakdown of operations in case of a failure of the SMS (see 3.1), which can result in accidents or fly-aways, for example. Many countries do not provide clear guidelines on required insurance, while many local insurance companies do not have the requisite experience to insure drones and their operations, potentially exposing UAS operators to "financial and legal risks from insufficient coverage"[147].

Different types of specialist insurance and payment plans exist. A traditional annual policy usually has monthly installments. In contrast, a pay-as-you-fly model allows operators to cover each flight or a daily rate of flying instead, making them an attractive option for short-term pilot projects with specific insurance needs. The most common specialist insurances include[148]:

- **Third-party or public liability insurance** to cover "damage to third-party property and injury to other people" with a minimum coverage of US$500,000 - 1,000,000 commonly required;
- **Hull insurance** to cover replacement or repair of damage to the UAS platform itself, such as in the event of a crash;
- **Physical damage insurance** for the owner or operator to cover physical damage to the UAS (that is, similar to hull insurance) and additionally ground equipment, or to cover the total loss of the platform or payload (this is

sometimes covered under third-party insurance instead);
- **Employer insurance** to cover UAS operators and associated staff; and
- **Product liability insurance** for the manufacturer or service provider to cover training facilities, consultants, dealers, software designers, for example, in case the insured product caused or contributed to a loss outside of a warranty case.

Some providers' additional coverage option may include professional indemnity (for example, recommendations given to clients), "personal injury (invasion of privacy), non-owned (if you crash someone else's drone), medical expenses, premises liability and war perils such as damage sustained from a malicious act"[149].

Box 2.9 — European Union Regulation 785/2004

The regulation describes the insurance obligations for all aircraft operators. It mandates all commercial UAS operators to purchase third-party liability insurance. As UAS became more widespread, several operators and ancillary businesses raised concerns over high costs and other difficulties in purchasing third-party liability insurance. The European Union found that "the cost to insure a small unmanned surveillance aircraft (SUSA) was almost twice that of insuring a standard family car"[150] in some cases. Several recommendations were made to increase competition among insurers and increase the minimum amount of public liability cover required by commercial UAS operators. Currently, the minimum amount of cover required corresponds to one million Euros per accident.

Discussion

Pertinent questions

- How is insurance coverage managed in remote locations?
- What and how much does the insurance cover?
- What are the contingency procedures in case operations breakdown is caused by mechanical failures, for example?
- Who will cover compensation, for example, in the case of loss of life or health consequences stemming from spoiled blood products or medication caused by a cold-chain failure mid-flight?
- Should there be a requirement for operators to have compensation mechanisms in place for scenarios where drone operations impact locals' livelihoods — for example, when a drone crashes into a field, which bystanders subsequently trample?

There is little data available to insurers for making predictions for the failure rates of commercial UASs. The majority of UASs have not existed long enough for insurers to understand the particular features that could influence the likelihood of an accident or system failure, amplifying the need for testing corridors (see 2.4). Nevertheless, an increasing number of insurers are looking to enter the market and provide customized insurances tailored toward drone operations. Although some commercial insurers allow you to fly only in their country, some offer worldwide coverage pending prior approval. Specialist drone insurance providers, including Moonrock (UK), Flock (UK), Heli Guy (UK), Drone Cover Club (UK), Cover Drone (Europe), Hollard (South Africa), iTOO (South Africa), Santam (South Africa), FEIC (Asia), and others offer flexible policies easy to customize for each kind of flight purpose, type of drone, and period covered.

For more information, see also

UAV Coach (n.d.). *Drone Insurance: a Step-by-Step Guide to Liability and Drone Hull Insurance* — Overview of insurance types, requirements, and example costs.

2.12 PROCUREMENT AND SERVICE CONTRACTS

Themes: Financing
Involvement: End-users such as a postal service or Ministries in charge of Agriculture, Infrastructure, Commerce, Land, or Health, or local government authorities and UAS service providers

Background

A good understanding of the use case identified through the initial needs and opportunity cost assessment is essential in informing the procurement process. Those identify and formulate baseline costs, clear problem statements, and mission objectives for drafting clear Scopes of Work and Terms of Reference. Irrespective of the chosen procurement strategy, clear scopes and terms with specific objectives and requirements make it easier for potential suppliers to design appropriate proposals and budgets. The pre-procurement and procurement documentation should incorporate the scope and ensure the five rights of procurement are addressed:

1. Service of the **right quality**
2. Delivered in the **right quantity**
3. To the **right place**
4. At the **right time**
5. For the **right price**

1. Pre-procurement

This step involves refining and defining specifications, sourcing interest and identifying potential vendors or service providers, and initial prequalifying. Market exploration approaches are common methods to identify and prequalify local, regional, or international vendors or service providers capable of satisfying needs. They include:

- **a. RFI** — RFI is an instrument used to conduct a market survey to obtain information from the market about available services and goods and their capability profiles, which can help refine the final ToR. End-users can use an RFI to identify available or potential solutions capable of fulfilling identified needs within expected costs and service and delivery times. Information received from an RFI is not used to award contracts.
- **b. EOI** — EOI can help clear up uncertainties regarding the number of companies that can fulfill the needs within a specified budget and requirements. They can then be advertised as a part of an RFI to identify interested operators or manufacturers.

Flying competitions similar to the LVC and LKC or other technology demonstrators in a Drone Corridor provide a valuable information source for assessing vendors' operational, safety, and project management practices and performance, especially in low-connectivity, low-resource, and adverse weather settings. They can provide a glimpse of vendor capabilities in ensuring regulatory compliance by gaining approvals and making submissions to the CAA or other regulatory bodies. Alternative options to assess vendors include on-site inspections or visits to their manufacturing bases to understand quality assurance processes and general operational practices and conduct a technical drone solution demo.

2. Procurement

This step involves purchasing equipment for in-house operations (insourcing) or procurement of a service provider to service the identified use case(s) (outsourcing). Government and implementers of drone programs may use a few different management and contracting approaches, with the decision grounded in a thorough feasibility analysis (see particularly 1.2) and made during pre-procurement:

- **Insourcing** — An end user establishes a specific drone service function within their organization and runs drone operations themselves. That involves investment in and purchase of a fleet

of drones, supporting infrastructure, onboarding and training a workforce, adding any other necessary elements to an organization, and making drone operations one of an organization's functions.
- **Outsourcing** — Instead of having the drone operations conducted in-house, outsourcing allows a government or implementing partner to contract an outside vendor/operator to provide drone services for delivery, mapping, humanitarian response, and so forth.

Although a multitude of approaches to procurement exist, the most appropriate for service procurement are:

1. **Request for Quotation (RFQ) or Invitation to Bid (ITB)** — These are most suitable for standard and straightforward equipment or service requirements with precise and detailed Terms of Reference and evaluation criteria.
2. **Request for Tender (RFT) —** Although RFTs generally have detailed terms of reference and descriptions of service requirements, their scope is broader than a RFQ and more specific than a RFP.
3. **RFP** — This is most suitable for cases where the whole nature, specifications, and characteristics of the required services are unknown. RFPs allow the procuring entity to seek out solution-based options and innovations without clearly defined specifications, allowing for greater flexibility.

Less frequently used approaches include single-sourcing and market-led proposals. Among those above, RFQs and ITBs are well suited for mapping services, with RFPs more suited for delivery services.

3. Evaluating and awarding contracts

This step involves determining clear evaluation principles and criteria to ensure the quality and capacity to assess proposals and vendors is in place. There are two critical information sources for the Terms of Reference that define the purpose and structures of the agreement:

1. Operational requirements, including overall service goals, expected outcomes, and desired impacts; and
2. Regulatory frameworks and related legal obligations as prerequisites for operations and flight approval. In the absence of local UAS regulations, operators should consult the CAA to determine a list of regulatory compliance criteria and requirements for manufacturers and service providers.

Some general requirement principles, considerations, and criteria include, but are not limited to:

- **Client references and previous vendor experience** — These should be assessed thoroughly to determine their capabilities in complying with regulations, gaining approvals and permits to conduct BVLOS flights, training staff, and operating in low-connectivity, low-resource settings. Submission requirements should include customer references or testimonials.
- **ConOps** — This can be a good indicator of an operator's thoroughness. A thorough ConOps (see 3.2) lays out clear rules and guidelines underpinning safe and efficient drone operations, including checklists, safety procedures, emergency procedures, and general operational practices.
- **Insurance** — A comprehensive third-party liability with either local or international coverage should be in place. Insurance of equipment is relevant when an end-user opts to purchase their fleet of drones.
- **Licenses and certificates** — Vendors, particularly service providers, should prove they and their employees are sufficiently certified and experienced. Unless local licensing is in place,

the vendor must consult the CAA to determine what international licenses might be accepted. Additionally, a previously conducted risk assessment, completed certificates for the shipment of dangerous goods (hazardous materials), and an Airworthiness Certificate shall also be considered necessary evidence of experience and operational excellence.

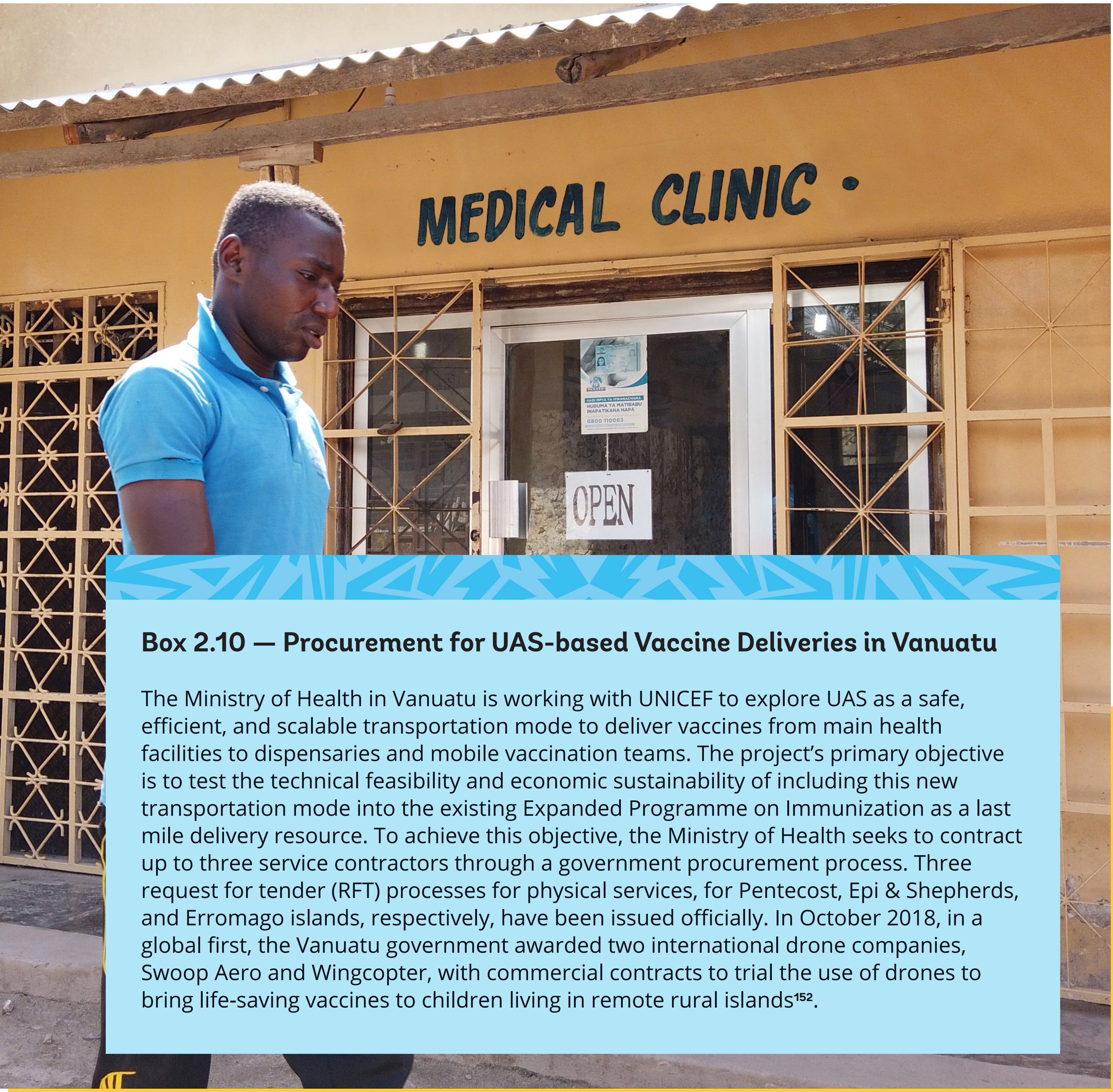
- **Technical drone platform —** Evaluation can be done using an evaluation matrix such as the USAID matrix[151], which helps determine whether a specific drone platform can meet the needs and operational requirements described in the Terms of Reference.
- **Company information** — This should include recent audits, company incorporation documents, as well as a description of the company profile with its relevant subsidiaries or owners to support the regular due diligence assessment of a vendor.
- **Local capacity building** — International vendors or service providers, in particular, should incorporate this as one of their competencies. Contractual requirements might even include:
    - Provisions for a certain degree of in-country sourcing
    - Final assembly or maintenance through local manufacturers
    - A sub-contractual relationship with a local operator
    - Local staff hiring to ensure local sustainability and stimulate the local economy
- **Performance and cost** — Many service providers opt to charge a fixed monthly rate or flat service fee, making cost-for-value monitoring challenging. In those cases, the operational model should require a minimum standard of flight performance, such as the number of flights completed or the percentage of cargo delivery and collection requests fulfilled.
- **Contract duration** — This is primarily a concern in the case of an outsourced or external drone-as-service contract, or where individual service aspects or infrastructure such as UTM systems are procured.

4. Monitoring performance

This step involves measuring and monitoring the performance of operations to evaluate their effectiveness and identify potential areas for improvement. It might be helpful to split the activities into different phases to manage risks and ensure that a supplier or vendor can perform according to the TOR and contractual obligations. However, unless there is a guarantee of a more long-term engagement, some service providers may find it challenging to allocate sufficient resources, which may often be limited, to prioritize activities. In most cases, it will prove a best practice to commit to a provider for the initial phases of a project as long as they deliver as agreed, with some self-funding of part of the activities. Such risk-sharing can increase trust and a sense of ownership among stakeholders as it creates more of a team than a client relationship. All drone operations are subject to varying regulatory approvals and technical demonstrations; therefore, procurement might consider these activities a prequalification process to avoid unnecessary challenges during the contract period.

1. Contracts should include a minimum standard of flight performance, with leeway for factors such as connectivity, weather, and so forth, which might be beyond anyone's control. Requirements for evaluating service providers or vendor performance may consist of the number of flights completed, percentage of mapping area covered, volume of data processed, volume and weight of cargo delivered, or number of re-supply or collection requests fulfilled.

2. Drone service providers also need to be measured and monitored for the efficiency of operations (for example, response time), efficiency and quality of communication, timeliness, quality of reporting (for example, flights, deliveries, cargo, mapping), quality of project management, engagement with stakeholders, training of local and health facility staff, and so forth, with leeway for factors outside the operator's control, such as the unavailability of spare parts due to global supply chain shortages.



Box 2.10 — Procurement for UAS-based Vaccine Deliveries in Vanuatu

The Ministry of Health in Vanuatu is working with UNICEF to explore UAS as a safe, efficient, and scalable transportation mode to deliver vaccines from main health facilities to dispensaries and mobile vaccination teams. The project's primary objective is to test the technical feasibility and economic sustainability of including this new transportation mode into the existing Expanded Programme on Immunization as a last mile delivery resource. To achieve this objective, the Ministry of Health seeks to contract up to three service contractors through a government procurement process. Three request for tender (RFT) processes for physical services, for Pentecost, Epi & Shepherds, and Erromago islands, respectively, have been issued officially. In October 2018, in a global first, the Vanuatu government awarded two international drone companies, Swoop Aero and Wingcopter, with commercial contracts to trial the use of drones to bring life-saving vaccines to children living in remote rural islands[152].

Discussion

Pertinent questions

- Will drone services be facilitated by the end-user or by a procured third party?
- Are funders open to procuring multi-modal systems beyond private-sector trucking companies, for example?

Some organizations might use insourcing for some drone program elements and outsourcing for others in a hybrid model.

Table 2.2 outlines the key factors of both approaches.

Table 2.2 — Key resource factors in insourcing and outsourcing of UAS operations

Resource elements	Insourcing	Outsourcing
Up-front investment	Medium to High	Low to Medium[153]
Procurement of equipment	Needed	Not needed
Internal capacity building for drone piloting and operations	Needed	Not needed
Internal capacity to manage regulatory compliance	Needed	Not needed
Internal capacity to maintain and repair drones	Needed	Not needed
Internal capacity to manage liability and insurance aspects	Needed	Not needed
Dedicated personnel to run the operations	Needed	Not needed
Dedicated project management staff	Needed	Needed
Individual insurance	Needed	Not needed
Risk of loss or appropriation of equipment	Likely	Unlikely
Savings/cost-efficiency	Long-term	Short/medium-term

For more information, see also

Dubin, S., Greve, A., Triche, R. (2020). *Drones in International Development. Innovating the Supply Chain to Reach Patients in Remote Areas*. Washington: USAID — Recommendations for the conduct of successful drone operations based on experiences of drone operations along Lake Malawi.

USAID GHSC-PSM (2018, Jul 9). Unmanned Aerial Vehicle Procurement Guide. Washington: Chemonics International Inc. — Covering recommended specifications and questions for offerors with a specific focus on cargo operations

VillageReach (2020, Jun). *How to Select a Drone Service Provider for Transport of Health Products. Lessons Learned*. Seattle: VillageReach — Recommendations for drone service provider selection for the transport of health commodities based on experiences from the Democratic Republic of Congo and Mozambique

World Bank Group (2017). *Guidance Note: Managing the risks of unmanned aircraft operations in development projects*. Washington: World Bank — Guidance for UAS platform selection and in-depth overview of drone service provider obligations and recommendations

Phase 3: Set Up

Once enabling elements are in place, the onus falls on the operator to plan their operations appropriate to the local operating environment. The development of a robust safety risk management strategy and ConOps is fundamental to applying for operational approval and ensuring the overall safety and security of the UAS operations. This phase should continue with previous elements such as stakeholder and community engagement as a cornerstone to successful operations and local buy-in. This engagement might extend to the training and recruiting of local staff and UAS pilots in many cases.

3.1 SAFETY AND RISK MANAGEMENT

Themes: Safety and risk
Involvement: UAS service provider for outsourcing or end-user in case of insourcing and CAA or another designated oversight authority

Background

A SMS fosters a safety culture by providing "a systematic approach to achieving acceptable levels of safety risk"[154]. It applies across all levels of an organization, from strategic management to the operations themselves. Each SMS should consist of four components, covering safety policy (i.e., management and organizational structure), safety risk management (i.e., risk protocols for safe operations), safety assurance (i.e., ongoing evaluation of risk management), and safety promotion (i.e., training and learning from lessons)[155]. In theory, an effective SMS should allow a drone service provider to determine[156]:

1. The most likely cause of a subsequent accident or serious incident
2. How they know what will happen
3. What they will do to mitigate and learn from it
4. Whether their chosen mitigation strategy is working

The ICAO stipulates that all member states must have a state safety program, "an integrated set of regulations and activities aimed at improving safety," including an SMS[157]. ANSPs and aircraft operators beyond a certain organizational size also require an SMS; whether UTM or drone service providers are required to have one in place currently remains at their discretion or that of the host country where they are looking to operate.

Safety risk management is at the core of each SMS and helps eliminate or reduce risks to acceptable levels where practical. It closely interacts with safety assurance, the ongoing evaluation of chosen risk mitigations, and the identification of new hazards. Those hazards are not uniquely limited to the operational level itself as "changes in organisational structures, facilities, the scope of work, personnel, documentation, policies and procedures, etc. can result in the inadvertent introduction of new hazards, which expose the organisation to new, or increased risk"[158]. Each risk management approach should follow a four-step process[159]:

1. Hazard identification — The identification of potential hazards to people and property on the ground and other airspace users during the proposed operations
2. Risk assessment — Risk is the "combination of the frequency (probability) of an occurrence and its associated level of severity"[160] of harm including fatal injury to third parties and damage to critical infrastructure
3. Mitigations — The mitigation of identified hazards and associated risks through avoidance of the hazard, retention of the hazard and acceptance of risk, transfer of risk, or reduction of risk through different measures
4. Determine acceptable risk levels— Rather than prescribing different requirements, states may consider using performance-based criteria to indicate acceptable levels of safety[161]

"Understanding the risks of these future operations as well as the foreseeable introduction of new technologies and operations make adherence to sound safety management principles more important than ever. Therefore, the implementation of safety management principles by RPAS operators will contribute to the ability of assessing the safety risks associated with the RPAS operations and their potential impact on other service providers. The safety management system of an RPAS operator should be commensurate with the scope of the RPAS operator and the scale and complexity of its operations. Proper oversight of the implementation of safety management principles by RPAS operators will contribute to the ability of a State to effectively manage aviation safety"[162].

Box 3.1 — Three ways to approach risk management for UAS operations

- **Specific Operational Risk Assessment (SORA) —** The SORA is an approach developed by the Joint Authorities for Rulemaking on Unmanned Systems (JARUS)[173]. It guides both the competent authority and the applicant on CAA authorization requirements for operations in a UAS in a given operational environment. The SORA methodology consists of ten systematic steps and a primary focus on the "specific" category of UAS operations. The process begins with a Concept of Operations (ConOps, see 3.2) before considering ground risk (Step 2 and 3), air risk Steps 4-6), and final specific assurance and integrity levels (SAIL) and Operation Safety Objectives (OSO) in steps 7-10[174].
- **Declaration of a Standard Scenario (STS)[175] —** JARUS and the European Union Aviation Safety Agency (EASA) conducted risk assessments for different operational scenarios with lower intrinsic risk. Each STS includes a precise list of mitigation steps for operations allowing the responsible CAA or designated authority to be satisfied with an operator's declaration that they will implement the identified mitigation measures during the specified operations.
- **Pre-Defined Risk Assessment (PDRA)[176] —** They are primarily developed by the UK CAA International (CAAi) and function similarly to STS's although providing the CAA with more flexibility in their design.

Appendix B provides an in-depth discussion of the Safety Risk Management approach and SORA chosen for the Lake Victoria Challenge (LVC) held in Mwanza, Tanzania, in 2018 and the Lake Kivu Challenge (LKC) held in Karongi, Rwanda, in 2020 with specific emphasis on the managing of air risk, ground risk, environmental risk, and occupational Health, Safety and Environment (OSHE).

In addition to more conventional air risk, which involves the risk to other airspace users, risk management for UAS operations also requires considerations over ground risk because of UAS's relatively short safety track record.
UAS can pose a threat to people and infrastructure on the ground if they fly over or near crowds or urban areas, close to critical and transport infrastructures such as ports, roads, and aerodromes, or even economic security threats when operating near critical infrastructure. Previous studies have shown that "the amount of energy needed to cause fatal injuries in the case of a direct hit, are extremely low"[163] with the likely outcome of a loss of control of a UAS resulting in it crashing into people causing fatal injuries. Economic fallout and other damage to critical infrastructure are harder to assess, with sensitivities to this harm varying across different countries.
In addition to the sub-part on hazard and risk minimization, the ICAO UAS model regulations[164] also consider ground risk when regulating the dropping of articles from a drone and prohibited UAS operations. Other hazards to consider include[165]:

- **Cybersecurity hazards**—As platforms and ancillary equipment, including droneports, become connected, risks of cyberattacks increase. The hijacking of a UAS by a third party with the intent to purposely crash it or use it for ransomware or other purposes, as has been happening with mission-critical health systems during the COVID-19 pandemic, is a particular concern. Other cyber threats include the jamming of signals over specific areas or the remote deletion or theft of data at droneports or data collected or carried by the UAS. Data encryption and security-by-design approaches built into the drone platform itself can help mitigate possibilities of interference[166]. Both JARUS and its forthcoming Annex J and other groups continue to strive for better protection against cyberthreats and the development of basic sets of standards for evaluating safety risk and consideration within procurement protocols.

- **Environmental hazards**—These are associated with impacts on any living organisms or the environment and may include emissions, spillage of dangerous cargo, noise, and disturbance of breeding grounds. Potential mitigations include airspace restrictions or design requirements to reduce noise or emissions.
- **OSHE**—This considers the physical health and safety of different people attending and conducting operations and flying events. According to ICAO, the "primary difference between aviation safety management and OSHE systems is the intent. In many States employers have a legal duty to take reasonable care of the health and safety of their employees. The intention of OSHE programmes is to meet the legal and ethical obligations by fostering a safe and healthy work environment"[167].
- **Privacy and data protection—**This includes the violation of individual privacy and data protection laws as flights may cause a certain level of local sensitivity. A Data Protection Impact Assessment can help identify appropriate conduct in the absence of national laws or local restrictions (see 2.8). The assessment aims "to identify, evaluate and address the risks to Personal Data [...] and lead to measures that contribute to the avoidance, minimization, transfer or sharing of data protection risks".[168]
- **Reputational damage**—This addresses "an accident or incident caused by mid-air collision with another airspace user; damage to the environment, wildlife, people, or properties in an area; or significant damage during a ground strike by a UA in its employ"[169] and can have consequences for the operator, as well as the larger UA community and industry. In such scenarios, scrutiny will inevitably be placed on the UAS operator, their safety management system, and safety performance.

Discussion

Pertinent questions

- Is there a mechanism for reporting accidents, incidents, and privacy violations?
- What are the risks associated with the carriage of dangerous goods?

The use of heavy or fast platforms raises both air and ground risk significantly, as do operations over populated areas or with complex or busy air traffic. A small UAS operating over a gathering of people might be a higher risk than a large platform operating long distances in an uninhabited region with no other airspace users. The way forward appears to lie in a regulatory framework very different from that of conventional aviation: a risk-based safety approach where the response is in proportion to the operation being conducted, with no people onboard, using atypical flight missions. Dropping items from aircraft, for example, emphasizes the need for a new approach. It is illegal to drop any objects from aircraft in many states, yet this ability could be instrumental in humanitarian missions and could prove to be extremely safe in specific operations, such as utilizing small UAS flying slowly at a low level.

Accurately determining ground risk

remains a particular challenge with different definitions and interpretations of population density, including definitions proposed by the JARUS[170]. Populous areas include those primarily used for residential, commercial, industrial, or recreational purposes, such as sporting fields. Although various definitions exist, the SORA determines ground risk is lower when overflying sparsely populated environments where crashes into terrain are less likely to be lethal to third-party people. Ground risk buffers and control of landing areas around droneports can help achieve OSOs[171]. In case there was doubt about the accuracy and reliability of the UA landing at a remote droneport that would retain risk above acceptable levels, operators could employ other mitigations such as extending buffers to achieve the set OSOs.

Although the SORA methodology provides a comprehensive framework for safety risk management for specific drone operations, it is an exceedingly complex one. An October 2020 UAS survey on European operations and risk methods found that a large segment of the European UAS operator community struggled to fully grasp and comprehend the AMC. Besides, the SORA is only available in a small number of languages leading to language barriers exacerbating challenges of comprehension of the framework (see 2.2). Feedback logged as part of the survey noted that there is potential for online tools to facilitate the safety risk assessment for UAS operators.

Ultimately, the risk of operators not reporting (minor) accidents to preserve a company's reputation and track record remains. Yet accidents and incidents are crucial lessons from the regulatory, manufacturer, and operator side to improve security and safety in the future. Sharing field tests or failure reports help promote transparency and provides learning opportunities with ICAO mandating the investigation of safety incidents[172]. Additionally, visibility of use cases and sharing of impact metrics increase transparency and help realize the market potential to motivate investment and tech development. Realizing potential can help overcome what some manufacturers (and to some extent, drone service providers) see as a lack of appetite for risk and failure because they are early adopters and have to prove their use cases. Having a platform or mechanism and incentives for sharing such knowledge with stakeholders and the general public can help improve transparency in operations and confidence and trust in the technology.

For more information, see also

ICAO (2020) ***U-Aid. Unmanned Aircraft Systems (UAS) for Humanitarian Aid and Emergency Response Guidance*. Montreal: ICAO** — Summary of risks and responsibilities associated with the carriage of Dangerous Goods on UAS.

ICAO (2020, Jun 23) ***ICAO Model UAS Regulations — Unmanned Aircraft Systems (UAS) Carrying Dangerous Goods (Advisory Circular 102-37)*** — Provides guidance to understand the risks and responsibilities for safe carriage of dangerous goods via UAS and includes information for packing and marking of such goods.

ICRC (2020). ***Handbook on Data Protection in Humanitarian Action (2nd Edition).*** **Geneva: ICRC** — Introduction to Data Protection Impact Assessments and their conduct.

JARUS. (2019, Jan). ***JARUS guidelines on Specific Operational Risk Assessment (SORA)*. JAR-DEL-WG6-D.04** — Overview of the JARUS SORA approach for Safety Risk Management of specific drone operations and the underlying ConOps (see 3.4)

Mendez, E. (2019, Aug 13). ***Safety Management Basic Concepts*. Presentation delivered at ICAO NACC Regional Office** — ICAO primer on aviation-specific Safety Risk Management

World Bank Group (2017). ***Guidance Note: Managing the risks of unmanned aircraft operations in development projects*. Washington: World Bank** — An in-depth overview of possible use cases of UAS and their associated risks that ought to be taken into consideration when considering UA operations

3.2 ConOps

Themes: Flight operations
Involvement: UAS service provider for outsourcing or end-user in case of insourcing and CAA or another designated oversight authority

Background

The ConOps aims to identify the technical, operational, and human information related to the intended drone operations. The ConOps serves as a general framework to summarize envisaged operations for all stakeholders involved in the operations. The framework should cover the "**where**" and "**when**" of the envisioned mission, the "**how**" and "**what**" of the drone platform and its specifications to accomplish the mission, and the "**who**" will execute the operation[177]. Answering those questions helps formalize the operational environment framing the UAS operations to ensure a common understanding of the challenges and avenues for either integrating them into conventional airspace or employing segregated airspace. This understanding, in turn, serves as a basis for the crafting of an operations manual and the associated SMS (see 3.1). A ConOps may relate to an individual flight request, a range of flight requests by the same operators, such as for an overarching approval, or may, for a test area or corridor, outline a network of operations. It can also cover emergency or ad hoc missions, beyond planned operations. In the case of a SORA, for example, an applicant's ConOps needs "to collect and provide the relevant technical, operational and system information needed to assess the risk associated with the intended operation of the UAS"[178].

A professional operations manual outlining how a UAS operator will conduct its operations is crucial to setting up safe and efficient drone operations. The manual should provide users with a structured overview addressing everything they need to know to conduct operations described in the proposed ConOps safely — from a summary of characteristics of the drone platform (that is, aircraft operations manual), characteristics of the operating environment, and operational setup to risk management procedures and other policies and processes. It should also cover "the user organization, mission, and objectives from an integrated systems point of view and is used to communicate overall quantitative and qualitative system characteristics to stakeholders"[179]. Although local regulations do not always mandate operations manuals, it would be considered a best practice for operators to have such a document. The JARUS approach stipulates that the operations manual is a subpart of the ConOps. In contrast, OSO and mitigations are identified through the SORA methodology and detailed through the supporting ConOps safety portfolio. The operations manual is a statement of intent in flying operations that should include the following points[180]:

- Organizational structure (including nominated key individuals)
- Statement of compliance with the regulation in relevant areas of operation
- Operational policies
- Personnel policies
- Remote pilot certifications
- Medical requirements
- Currency requirements
- Training policy and structure
- SMS policy
- Risk-management policy
- Quality-management policy
- UAS specifications
- Operational procedures and ERP
- Limitations of the external systems supporting UAS for safe operations
- Environmental conditions required for a safe operation
- Accident and incident reporting process

Box 3.2 — The SORA approach to the Concept of Operations

Whereas the ConOps provides an overview of the proposed UAS operation, the SORA (see 3.1) "provides a logical process to analyse the proposed ConOps and establish an adequate level of confidence that the operation can be conducted with an acceptable level of risk"[182]. The ten-step process of the SORA begins with the ConOps description before progressing through ground risk evaluations to determine whether to proceed with the SORA methodology, require a new application with a modified ConOps, or require other processes such as considering the operation as "certified" instead. The European Union Aviation Safety Agency (EASA) considers the ConOps as the foundation for all other activities as it describes the proposed operations and lends insight into the operator's safety culture. A ConOps should represent an evolving document — "as the SORA process is applied, additional mitigations and limitations may be identified, requiring additional associated technical details, procedures, and other information to be provided/updated in the ConOps"[183].

Discussion

Pertinent questions

- Will there be sufficient capacity to review and understand the submitted ConOps manual and associated SMS?

For more information, see also

ADF (2020). Lake Kivu Challenge: Un-crewed Aircraft Flying: Concept of Operations (ConOps). Version 4.1 — State of the art ConOps for Beyond Visual Line of Sight (BVLOS) flights close to aerodrome approach paths and international borders

EASA (2021, Apr). ***Easy Access Rules for Unmanned Aircraft Systems (Regulations (EU) 2019/947 and (EU) 2019/945)*****, Cologne: EASA —** Article 11 of Annex A provides guidelines for collecting and presenting the system and operational information underpinning and supporting specific UAS operations.

ICAO (2017, Mar). ***Remotely Piloted Aircraft System (RPAS) Concept of Operations (ConOps) for International IFR Operations*****. Montreal: ICAO** — The International Civil Aviation Organization (ICAO) ConOps describing "the operational environment of manned and unmanned aircraft, thereby ensuring a common understanding of the challenges and how those which are remotely piloted can be expected to be accommodated and ultimately integrated into the airspace for international instrument flight rules (IFR) operations"[181].

JARUS (2019, Jan). ***JARUS guidelines on Specific Operational Risk Assessment (SORA) (Issue 2.0) (JAR-DEL-WG6-D.04)*** — Guidelines and annexes describing the SORA methodology

World Bank Group (2017). ***Guidance Note: Managing the risks of unmanned aircraft operations in development projects*****. Washington: World Bank** — Guidance on the contents of a UAS operation-specific SMS and ConOps for operators

3.3 OPERATIONAL APPROVAL

Themes: Flight Operations
Involvement: Civil Aviation Authority (CAA) or another designated authority

Background

Operations should never occur without authorization in the form of permission or a legislated exemption. Operators need to follow the steps outlined by the relevant CAA to obtain approval. Most countries promulgate rules with different processes for public or private entities and commercial or recreational uses, with authorities' involvement and requirements generally intensifying with an operations categorization or risk. Operators also need to ensure compliance with relevant international and domestic legislation and applicable regulatory frameworks including but not limited to customs, liability and insurance, telecommunications standards, the environment, and privacy and data protection. Some countries may also require operators to obtain a security clearance and a specified level of endorsement from the Ministries or agencies responsible for transport, privacy, communications, customs (importation), law enforcement, and possibly aerodromes. Ultimately, the onus will be on CAAs to approve UAS operations based on their regulatory frameworks and categorizations. At minimum, it is a best practice to have an authorization process that accounts for systematic prioritization of meaningful operations with acceptable levels of safety.

Depending on the airspace type and risk involved, a CAA may consider categorizing operations and their likeliness of authorization differently. One example of categorization is the EASA approach based on the JARUS-recommended UAS category A and B operations[184]. It considers drone operations as open (JARUS: Category A), specific (Category B), or certified (Category C), depending on a set of criteria — most notably weight of the drone and the area (i.e., urban or rural) and type of airspace (i.e., controlled or not) used for the planned operations (see Box 3.3). It is essential to determine where operations may be permitted and which areas they should be excluded from regarding airspace, ground structures, and population. The European regulations define this as a UAS geographical zone, which is "a portion of airspace established by the competent authority that facilitates, restricts or excludes UAS operations in order to address risks pertaining to safety, privacy, protection of personal data, security or the environment, arising from UAS operations"[185]. Ideally, UTM systems should be capable of accounting for those geographical zones (see persistent UTM example in 2.7).

Discussion

Pertinent questions

- Which operations do not require a formal application or registration process to accelerate the quick rollout of operations safely?

At the same time as addressing risk and reducing the administrative burden on operators and authorities such as CAAs, certain UAS operations may not require any prior operational authorization. Although it seems justified that such non-approval scenarios exist, the challenge is to find a threshold where a UAS operation passes from one that could cause harm to one that cannot. One difficulty exists in the determination of whether UAS constitutes aircraft, considering:

> *"an aircraft can become arbitrarily small, yet legally all drones irrespective of size are aircraft and therefore governed under the ICAO Chicago Convention and its related Annexes and contained SARPs, as well as regional or national legislation, ordinances, restrictions or other agreed upon guidance. Yet it is impossible and unnecessary for the large number of smaller, lower risk, drones – such as toys - to be considered legally as aircraft"*[186].

Box 3.3 — The JARUS categorization of UAS operations

Working Group 7 of JARUS was officially chartered with developing a categorization scheme describing the level of regulatory involvement for the varying types of UAS operations in April 2015. In 2019, JARUS[190] proposed a risk-based concept for performance-based regulations of UAS operations — a recommended UAS regulatory strategy for all operational environments. The regulatory strategy includes consideration for aircraft design, production, maintenance, operational approval, pilot competency, regulatory enforcement, and safety promotion. Here, operations are considered as “open” (Category A), “specific” (Category B), or “certified” (Category C) depending on the level of risk involved:

- **‘Open’ category operations —** present the lowest amount of risk and do not require any involvement from a CAA. To be classified as an open operation, drones will need to be operated within the operators' Visual Line of Sight (VLOS), below 120m or Very Low-Level altitudes, away from critical infrastructure, and weigh less than 25kg. Drones with a total takeoff weight over 250g generally need to be registered but do not require operational approval for use. Open operations are divided into three types depending on whether they occur over people or populated areas with more stringent requirements imposed as ground risk increases. Although there are no formal registration requirements or minimum pilot age, pilots must know and respect airmanship, air safety rules, airspace restrictions, aviation regulations, human performance limitations, operational procedures, privacy and data protection, and security.
- **‘Specific’ category operations —** represent medium risk operations and go beyond open category operations by allowing for operations in very low-level airspace (up to 500 feet above ground level), above crowds of people, and Beyond Visual Line of Sight (BVLOS). Because of the higher levels of risk and complexity, UAS operators must obtain authorization, which may be for the state of registration and operation, from the CAA or other designated authority — unless granted an exemption. Exemptions or alternative means of compliance may be available when an operator holds a light UAS operator certificate with the appropriate privileges, for example. An operational authorization request submitted to the relevant authorities usually includes a site assessment, the Concept of Operations (ConOps, see 3.4), and an operational risk assessment (see 3.1).
- **‘Certified’ category operations —** represent high-risk operations in controlled airspace shared with conventional aviation. Operations in the certified category require certification of the operator and aircraft and the licensing of remote pilots. The transport of people is always a certified operation, whereas flying over crowds of people with a UAS may be considered specific unless the Specific Operations Risk Assessment (SORA, see 3.1) concludes that it should be certified.

The JARUS categorization (see Box 3.3) is one example of defining a threshold for determining the minimum requirements operators need to fulfill and demonstrate before being granted authorization. Similar wordings and thresholds are often used outside the EU member states, with wording in many countries stemming from the ICAO UAS Model Regulations[187]. In many cases, clear communication of requirements and obligations could alleviate uncertainty among operators, who routinely find that it takes too long between planning and implementation of operations to receive approval: "I really feel that with better communication between the operators and the regulators, we will actually be able to achieve a fast-track process to make sure that our vision turns into reality"[188].

Regardless of operational classification, however, the understanding of airspace and risk by remote pilots looking to operate UAS remains crucial. This involves knowing whether the drone is flying within controlled or uncontrolled airspace because it has a significant impact on categorizing the planned operation(s). Similarly, whereas cargo transport is specific in most cases, "the transport of dangerous goods is in the 'certified' category if the payload is not in a crash-protected container, such that there is a high risk for third parties in the case of an accident"[189].

For more information, see also

EASA (2018). ***Introduction of a regulatory framework for the operation of unmanned aircraft systems in the 'open' and 'specific' categories*** **(Opinion No 01/2018).** — EASA rules for the open and specific UAS operations

14 CFR Parts 11, 21, 43, and 107 — Outlining Federal Aviation Administration (FAA) rules for UAS operations over people and populated areas.

ICAO (2020, Jun 23) ***ICAO Model UAS Regulations — Unmanned Aircraft Systems (UAS) Certification (Advisory Circular 102-1)*** — ICAO guidance for specific UAS operations authorization

ICAO (n.d.-e) ***Special Authorization [Regulators].*** **Viewed May 25, 2021** — Provides a sample decision tree for regulators to support the authorization process for a proposed UAS operation.

3.4 TRAINING AND CAPACITY - OPERATIONS SIDE

Themes: Capacity building
Involvement: UAS service provider or manufacturer and end-user

Background

The ICAO identified operator's education and training as fundamental enablers of safe and efficient UAS operations[191]. Recent proof of concept operations with cargo drones have highlighted the need to strengthen safety management and safety culture within the industry and involved stakeholders[192]. In an ideal case situation, local staff and local entities will be capable of conducting operations management (i.e., planning, monitoring, piloting, communications, safety, and risk management, maintenance, repairs) to reduce reliance on international personnel and ensure sustainability (see 4.2). In the case of international UAS service provider or vendor selection, training and knowledge transfer activities for local capacity building should be key activities to ensure a seamless continuation of operations into the future.

Two key groups of stakeholders and actors will require training: the flight operations team and health staff or other community members assisting the flight operations. The level of training for these two groups differs:

1. **A local flight operations team** may be hired and subsequently trained on various aspects of drone operations. They include piloting a drone; airmanship; battery management; drone assembly, maintenance, and pre-and post-flight checklist management; risk assessment and safety management; communication protocols; route planning, approval, and operations monitoring; reporting; and meteorology. Such staff may either be local license holders or seek to obtain such a license from a competent authority after receiving

training. In any case, getting a remote pilot certification shall be a logical next step after such training.

2. **Local staff, community members, or users receiving the service** need to be trained to handle drone delivery, in particular, to ensure safe operations and continuous communication with the flight operations team to coordinate arrival, loading, and departure. Local health staff will need to receive training in the following areas: order management, communications procedures, clearing and securing of a landing area, handling of cargo (i.e., off-loading, uploading), emergency procedures, basic drone operations, and battery management (i.e., battery charging and replacement, if required). Systematic training and onboarding of health staff will be a catalyst for successful drone integration into the health supply chain, and therefore, constant communication and appreciation are crucial. It is also helpful to issue certificates for such staff, acknowledging their new competency.

In both cases, having clear job descriptions with requirements and expected roles, skills and competency are very important in recruiting the right staff and supporters. Usually, training the local flight operation staff and local health staff shall fall under the service provider or vendor. There are also incredible opportunities for improved gender inclusion in training and recruitment, and championing of female leaders and entrepreneurs.

Box 3.4 — Training the next generation of African UAS pilots and operators at the African Drone and Data Academy (ADDA)

Although the Malawi Humanitarian Drone Testing Corridor (see Box 2.4) has managed to attract many academic and private entities to test various drone applications, it did not solve a fundamental issue of gaps in local capacity and skills. Recognizing a need for training, UNICEF and its partners established the African Drone and Data Academy (ADDA) with its first campus located in Lilongwe, Malawi. The academy is operated by Virginia Tech in partnership with the Malawi University of Science and Technology and provides technology education for African students. The Academy offers a range of both on-site and remote courses and modules covering aircraft fundamentals such as the physics of drone flight, communications, mechatronics, and autonomy, but also focuses on operations, regulations, data and geospatial analysis, and entrepreneurship. In the face of growing local and international demand for skilled UAS operators and entrepreneurs, the academy presents a unique growth opportunity for African youth. Graduates of the program become licensed drone pilots under the Malawi Department of Civil Aviation guidelines and certified AUVSI TOP pilots. As of late 2020, 90% of graduates found employment in the UAS sector.

Discussion

Pertinent questions

- What is the minimum number of staff required?
- Is there sufficient local capacity in terms of certified, experienced remote pilots and non-flying staff involved in the operation?
- Who will verify operator training, certification, and experience, and will foreign ones be recognized?

> *"We noticed that there are very few delivery drones out there and even fewer people that are actually trained to fly them. We could not scale cargo deliveries from a regulatory or technology aspect as the underlying tech and knowledge to fly wasn't out there. We ended up in a situation where we had to ship personnel and new technology, which was not particularly sustainable from a business, time, and environmental perspective. When looking at data, we realized that there are many photography drones and drone pilots out there. They already owned drones, were capable, and had the permission to fly them."*
>
> Helena Samsioe, GLOBHE

A lack of capable staff is among the most crucial barriers to creating local business opportunities, scaling up, and sustainability of operations. This comes down to three key challenges:

1. **Finding talent with the right experience —** Most local drone pilots were found not to have an aviation background. Many local pilots, for example, are engineers and require extensive extra training when going beyond multi-copter flights. Yet drone pilots have to share the airspace with conventional aviation. Clear procedures are needed based on a framework that gets updated based on learned experiences. Some drone service providers might build a framework for operations without having an aviation background and appropriate drone risk assessments. An increasing number of initiatives such as ADDA, Dronemasters, Dove Academy, WeRobotics FlyingLabs, and others have started to address this niche over the past few years.
2. **Once trained and certified, connecting that talent with opportunities —** Local capacity is often limited, requiring organizations to bring their staff and equipment, which is not sustainable from a business or environmental perspective. Despite increasing numbers of certified and experienced staff, there is not always a customer demand, however. At a minimum, the staff roster should include an operator and a mechanic as flight personnel. Ideally, all flights should involve the use of spotters to increase operational safety support and reduce risk. Those can be medical or security staff at the operating sites, for example.
3. **The distribution of licensed and certified schools —** Whereas most countries with regulations mandate pilot certification in the form of licenses or other proof of competency, requirements vary widely, particularly when considering increasing complexities or types of operation. The absence of standard curriculums in recognized institutions further exacerbates the challenges of disharmonization (see 2.3)[193]. Although an increasing number of initiatives exist, licensed and certified schools are still few in number depending on the continent, as are regulations needed to certify such schools.

For more information, see also

Dubin, S., Greve, A., Triche, R. (2020). ***Drones in International Development. Innovating the Supply Chain to Reach Patients in Remote Areas*****. Washington: USAID** — Recommendations for the conduct of successful drone operations based on experiences of drone operations along Lake Malawi.

WFP (2019, Jun) ***Unmanned Aircraft Systems (UAS) Training. Report on the Regional Drone Training for Central America*****. Rome: WFP.** — Overview of the Let's FLY, Let's MAP, and Let's COORDINATE training program and lessons learned from its implementation with officials from six Central American countries

Phase 4: Operations And Sustainability

Having determined that operations are feasible, required elements to support safe and efficient scaling of UAS operations are in place, and operators are ready to conduct operations, the final phase of flying and ensuring sustainability begins. Given overall operational approval, operators will likely still need to obtain flight approval for each flight as part of the on-the-day mission preparation. Considering the number of steps, elements, and actions required from initial considerations of use cases to the actual take-off, the flight itself is generally a rather anticlimactic affair once it transitions from VLOS to automated BVLOS. Beyond the flying itself, ongoing engagement, monitoring, and evaluation should form part of any UAS operation to determine whether an operation was successful and strive toward financial and environmental sustainability and overall sustainability of knowledge[194].

4.1 FLIGHT OPERATIONS

Themes: Flight operations
Involvement: UAS service provider for outsourcing or end-user in case of insourcing and CAA or another designated oversight authority, ANSP

Background

Flight operations consist of three phases: mission preparation, flight, and post-flight. Although the primary focus on any UAS operation is on conducting the flight itself, adequate preparation and post-flight evaluation are at least equally, if not more, important, to ensure safe and efficient operations.

Mission preparation

Flight scheduling, routing, and planning should begin with assessing the operating environment, including risks to persons and property near envisaged operations, local weather conditions, and airspace and flight restrictions.

- **Determining ground risk** — Route plans should avoid populated and urban areas to reduce risk to people and infrastructure on the ground. However, accurate base maps to assist with planning paths around (critical) infrastructure are often hard to come by. At the same time, an increasing number of UTM service providers (see 2.7) are considering how to provide dynamic risk profiles to assist with route planning and obtaining approvals.
- **Local weather conditions** — Operators need to make informed judgments as to whether it's safe to operate within the given weather situations given the limits of their UAS platform (see 1.5). Additionally, depending on the type of airspace and local regulations, different visual meteorological conditions such as minimum visibility and distance from clouds may need to be present for a flight operation to obtain clearance from the ANSP or ATC[195].
- **Local airspace and flight restrictions** — Route planning should also consider the proximity of planned operations to conventional aviation activity. Access to NOTAM or TFR will help identify any non-normal activities within the airspace. Flight planning should also account for restricted or prohibited airspace.

Depending on the type of airspace (see 2.4) and operations category (see 3.3), operators may need to obtain an ATC authorization before any flight. Obtaining authorization is especially crucial for operations taking place in or near controlled airspace and aerodromes — both to manage air risk and minimize disruption to conventional aviation. UTM services (see 2.7) are essential to the monitoring of air traffic and approval-based governance. Despite the capabilities of UTM services, however, the ultimate responsibility for evaluating the importance and necessity of proposed flight plans to ensure timely approval and support decongestion remains with the ANSP.

> *"Automated approval-based governance – Providing an easy, low-cost and inclusive way to access airspace is fundamental to promoting an ecosystem of drone use that enables STEM education, low-altitude operations and more long-distance, complex operations. These services are evolving rapidly and being rolled out all over the world, enabling real-time approvals, providing low-overhead management of rule-based airspace, and facilitating deconfliction."*[196]

The final step of mission preparation should include pre-flight briefings and inspections to assess airworthiness, compliance, and safety. Briefings should ensure that all persons involved in the upcoming flight or operations are aware of operating conditions, emergency procedures, contingency procedures, roles and responsibilities, and potential hazards affecting operational safety. Inspections should cover both the UAS platform to ensure it is safe and airworthy and that there is enough available power to operate for the intended operational time and at least five minutes after that. Inspections should further cover the RPS to ensure that C2 links with the UAS are working correctly. A high proportion of incidents and accidents involving UAS are attributable to human error by the Remote Pilot[197]. The use of checklists is a proven foundation for improving aviation safety and standardizing pilot procedures in conventional aviation. Their use helps improve safety and reduce the costs attributable to equipment loss and the risk of damage to third parties.

Flight

Although most flight operations will run under normal procedures as determined during mission preparation, some flight operations may encounter abnormal situations and call for non-normal (contingency) or emergency response procedures. Those scenarios may include a violation of TFR airspace by an unknown or non-cooperative entity (i.e., no transponder, no radio, no flight plan aircraft or other UAS) (see 2.4), the loss of C2 link, and subsequent control of a drone (see 2.6), or sudden strong winds that may exceed tolerances of the specific UAS platform. Operators should anticipate different scenarios and develop contingency procedures and an ERP (see 3.1) in advance for inclusion in their operations manual (see 3.2). Having procedures and plans in place can help remote operators mitigate the consequences of a failure at some level to ensure overall safety and reduce risks to others.

An ERP should address situations that escalate beyond normal and contingency conditions to the unrecoverable loss of control of operations. Emergency procedures should be developed as part of the safety and risk management (see 3.1) and ConOps (see 3.2) and be specific to different UAS platforms, operating environments, operations, droneports, and so forth. EASA, for example, provides guidance for the evaluation of ERPs[198]. Each ERP should be suitable to the ConOps; clearly define criteria to identify an emergency; include mitigation measures to reduce risk; be easy to understand and practical to use; clearly delineate remote crew member(s) duties; and outline notification procedures. Emergency procedures commonly involve avoidance strategies such as rapidly descending the UA to a safe altitude, where an encounter with another aircraft is highly remote, or executing an immediate landing in a safe space such as a predetermined emergency flight termination zone (EFTZ)[199]. For most scenarios, it should further include actions to notify first responders in the case of a crash, as well as the ANSP and nearby operators in geo-fence breaches, to reduce air risk.

Post-flight

Evaluations of individual flights can support the continued monitoring and assessment of overall operations and provide learning opportunities for future flights. Reports can include qualitative observations and technical data collected from the UAS information system. Both can assist with understanding and learning from safety-related occurrences and support the evaluation of Key Performance Indicators (KPIs) related to the overall UAS operation (see 4.2). Overall flight quality metrics can include flight duration and distance, battery consumption, “altitudes, routes/waypoint tracks, flight operational time (including preparation, take-off, landing and post-flight tasks) average and maximum airspeeds and groundspeeds, environmental conditions”[200]. Similarly, the report can capture any safety-related occurrences, such as breaches of NO-FLY-ZONES, organizational or administrative issues that may impact future flying safety and security, and other aspects that prompted a deviation from normal flight procedures.

Box 4.1 — From contingency procedures to emergency response plan (ERP) — C2 Link loss

As long as a UA continues along the pre-planned route and flight plan, within the agreed-upon geofence parameters, and is trackable via UTM, operations may generally be considered normal (no further action) or, at worst, invoke contingency procedures (such as briefly holding position in hover mode). Additional complicating factors, such as straying off routes toward the edge and beyond the geo-fence, a breakdown in tracking via UTM, loss of power to the UTM systems, or failure to regain C2 link, may require operators to invoke emergency response procedures. In the case of such a loss of control event, operators should invoke their predetermined ERP. For example, in the case of the Lake Kivu Challenge (LKC) in Rwanda, this would have involved immediate notification of the Rwanda Approach Control Centre, L'Autorité de l'Aviation Civile du Congo (RDC), and Goma ATC (see Appendix B). Owing to the absence of parachutes and other "*arrestor systems*"[201] for safe landings UAS at the LKC were pre-programmed to first continue flying along the pre-planned flight path to try and reestablish the C2 link (contingency) before seeking out a predetermined EFTZ in case of failure of reconnection events (emergency). EFTZ's were located away from populations and clear of other UAS to reduce ground and air risk at the same time as offering the option to recover UAS both for salvaging for future operations and reduce environmental concerns over abandoned equipment.

For more information, see also

ADF (2020). Lake Kivu Challenge: Un-crewed Aircraft Flying: Concept of Operations (ConOps). Version 4.1 — State of the art ConOps for Beyond Visual Line of Sight (BVLOS) flights close to aerodrome approach paths and international borders

Bothner, M., *et al.* (2021). Humanitarian UAV Code of Conduct & Guidelines. — UAS code of conduct guidelines on data protection

4.2 SUSTAINABILITY OF OPERATIONS AND THE ECOSYSTEM

Themes: Capacity building, community engagement, use cases, and regulations
Involvement: Everyone

Background

Continued monitoring and evaluation of ongoing operations, considerations of financing beyond initial donor-funding, continuity of knowledge, and minimizing environmental impact are crucial to ensuring the sustainability of both operations and the broader ecosystem.

Monitoring and evaluation of operation performance

Monitoring provides insight into how well the operation meets its goals and performance targets, informs suggestions for timely changes to live service provision, and assists with impact assessment and evaluation against alternative technology options. Evaluation supports the "objective assessment of success or failure" and helps shape the direction of future goals, which should form part of the procurement or vendor management. Combined, they determine a project's "effectiveness to deliver **outputs** that translate into **outcomes** and establish their **impact** against measurable **indicators**, against alternative means of **process** delivery cost comparators"[202] and fixed versus variable costs. "Any operation needs to be able to demonstrate that it is not doing the wrong thing very well (efficient but ineffective) not the right thing but badly (effective but inefficient)"[203].

Key performance or impact indicators are fundamental metrics for evaluating the impact of interventions compared with alternative means of service provision. Indicators should be developed early on as part of the use case needs assessment in the initial feasibility assessment phase. Examples of KPIs include turnaround times, payload transported, flight quantity, and failure rate[204]. It is important to note that monitoring and evaluating drone programs, although often under-resourced, shall always be an integral part of a program's design and receive sufficient technical, human, and financial resources. KPIs should align with local and national strategies and policies, such as national health supply chain strategy, national disaster preparedness strategy, or other relevant strategic documents, to ensure they reflect needs and priorities.

Cost evaluation and financial sustainability

Evaluating cost-effectiveness, cost-benefit or cost-utility and planning for financial sustainability requires understanding the costs and performance of the UAS operations and previous systems. The evaluation of costs is separate from conventional monitoring and evaluation of operational performance. It requires a thorough understanding of all costs involved, including capital and pre-launch costs such as infrastructure, training, and ongoing fixed and variable operating costs of operations (see 1.2) at scale over a sustained period, since the costs for pilot operations may not reflect those at scale. In addition, it requires information on the performance of UAS operations obtained through routine monitoring and evaluation and baseline data for previous systems such as land surveying or ground transport, depending on the chosen use case. Unfortunately, there is limited publicly available knowledge on the cost of UAS operations, as stakeholders either do not know or are hesitant to share.

Whereas initial pilot projects are likely to focus on specific use cases, transitioning toward layering of use cases can unlock new business opportunities to ensure the financial sustainability of operations (see 1.1, 1.2)**.** Opportunities for layering and cross-subsidization exist across mapping, cargo, and surveillance with applications of interest to the private, government, and humanitarian sectors. Similarly, the opening of infrastructure, support services, and other elements across the UAS value chain for shared use can help drive cost-effectiveness through increased utilization of infrastructure such as droneports and services such as UTM and UAS platforms themselves (see 1.4)[205]. Opening for shared use can further open additional revenue streams and business opportunities, such as introducing fabrication labs at droneports (see 2.5). Both layering and opening up for shared use can be a vehicle to transition from donor funding to more sustainable financing models. Similarly, the reduction of other upstream or downstream costs through the optimized distribution of medical commodities, for example, can provide cost recovery mechanisms to finance ongoing UAS operations[206]. Opportunities for cost recovery could include on-demand distribution rather than stockpiling of certain commodities, thus reducing the procurement volume, or opportunities for PPPs, such as the delivery, for a monthly fee, of specific commodities, including rabies treatment, HIV/AIDS post-exposure prophylaxis, or antivenoms, to mining companies or international organizations working in remote areas. Ultimately, however, "collaborations with domestic investors are the most likely to provide long-term growth through partnership with government ministries and foreign-direct investment"[207].

Sustainability of knowledge

Exporting of equipment means that foreign organizations did the work, and the legacy risks leave the country. As discussed in Sections 2.1 (Training — Enabling side), 2.12 (Procurement), and 3.4 (Training — Operations side), as elsewhere, "knowledge and skills transfer and capacity development, such as building local skills in addition to community engagement"[208] should both precede and form part of the ongoing operations. Training and knowledge exchange helps ensure local start-ups and stakeholders learn from established manufacturers and operators, thus supporting the growth of the local ecosystem. Leaving equipment, skills, and infrastructure in the country can be good if the ecosystem is in place and there is a real need and use case for the technology. Otherwise, abandoning equipment and batteries should prompt considerations over the environmental impact of operations.

Environmental sustainability

From an environmental perspective, operations involving battery-powered drones should consider how spent or damaged batteries are disposed of or recycled to minimize lasting environmental impact[209]. Whereas bringing lithium batteries into the country can be a significant challenge (see 2.9), recycling or disposal can prove an even bigger one. Lithium batteries commonly used in battery-powered UAS platforms can pose fire and health hazards when damaged or improperly disposed of. Some organizations and universities have started setting up their lithium battery programs as examples for local recycling to address those hazards. However, in many cases, UAS operators will not have considered how to dispose of batteries or have not come up with a clear plan. Operators and manufacturers are often vague or unwilling to divulge information on their disposal plans, while donors will only require that operators and manufacturers need to deal with sustainability themselves, without setting clear sustainability metrics that companies have to fulfill, raising concerns that lithium batteries may end up in a dump somewhere. Selling refurbished drones could also be an exciting pathway to increase sustainability and help lower the cost barrier for some projects.

Discussion

Pertinent questions

- Can the regulatory environment adapt to new technology developments, and is it conducive to long-term operations and funding?

- Will data about the comparative value of drones be shared?
- What are potential pathways and activities to strive toward financial sustainability of operations?

For more information, see also

Knoblauch, et al. (2019). Bi-directional drones to strengthen healthcare provision: experiences and lessons from Madagascar, Malawi and Senegal. *BMJ Global Health,* 4: e001541 — Overview of experiences from implementing cargo drone pilot projects for health service provision across three African countries.

UNICEF Supply Division (2019, Oct). *Unmanned Aircraft Systems: Product Profiles and Guidance. Annexe 2: Value for Money*. Kopenhagen: UNICEF Supply Division —Discussing the ACQUA framework for evaluating operations from a cost-effectiveness point of view.

UPDWG (2019, May 22). *Technical and Logistical Challenges Encountered During Test Flights in Malawi.* Presentation— Details lessons learned from the Malawi drone corridor

VillageReach, ISG-UAS (2019, Nov)*. Toolkit for Generating Evidence around the Use of Unmanned Aircraft Systems (UAS) for Medical Commodity Delivery, Version 2.* Seattle: VillageReach — Evaluation framework to determine the success of UAS operations

WFP Logistics Cluster (n.d.). *Technical Support Guides: Monitoring and Evaluation.* Rome: WFP — Provides an overview of assessment and monitoring cost-effectiveness and impact of interventions over time

Conclusion

This guidebook intends to provide a comprehensive end-to-end overview of elements that underpin safe and sustainable high-frequency UAS operations and the broader enabling ecosystem surrounding them. For operations to be successful, they need to be viable and address a demonstrated need cost-effectively. Broader ecosystem-supporting and operation-specific elements from local capacity to regulations, communication spectrum to infrastructure, and customs to procurement procedures are required. Operators must develop their operations manual and ConOps underpinning safety and risk-management efforts proportional to the planned operations. Community outreach, sensitization, and stakeholder engagement, as well as capacity building, should be ongoing. Crucially, continuous monitoring and evaluation can foster an understanding of the success of operations, provide learning opportunities, and increase financial and environmental sustainability and overall sustainability of knowledge. The broad range of activities and elements helps address and overcome key barriers to the success of UAS operations and ecosystems. Although this guidebook largely builds on African experiences, it is very much region-agnostic and applicable elsewhere.

KEY ENABLING ACTIVITIES

1. Feasibility and buy-in

- **Feasibility assessment** — Although UAS can introduce a plethora of benefits, they do so at potentially significant expense, a particular concern for envisioned use in low-resource settings. A thorough feasibility analysis, including use case needs and opportunity cost assessment, can help determine whether prospective operations align with actual needs and can provide tangible benefits. It may also prevent the setup of unnecessary parallel supply chains that may ultimately compete with existing ones or several other "failure" scenarios[210].
- **Community and stakeholder engagement** — Whereas feasibility assessments may show clear benefits, in theory, they rely on political and social buy-in across all affected stakeholders, local communities, and the general public. Engagement should include dialogue between demand (i.e., non-aviation client sectors such as agriculture, urban, and environment) and supply, such as transport, regulatory, and airspace sides. Early and ongoing engagement is crucial to ensuring buy-in, wider acceptance, alleviation of skepticism and safety concerns of drone technology, and ultimately increasing chances for the long-term sustainability of high-frequency drone operations.
- **Ensure financial sustainability** — A lack of continued funding beyond initial pilots and potential donor dependence can have drastic impacts on the long-term sustainability of projects and can potentially undo much of the existing work and community buy-in. Therefore, implementers should consider how to fund UAS operations beyond the initial pilot and feasibility demonstration phase(s) from the very beginning.
- **Considerations of timelines** — Activities from procurement to transporting batteries and obtaining operational approvals to open up new air routes can take significant amounts of time. A recent survey found that the initial setup of UAS programs can take anywhere from six months to two years, with scale-ups taking "an additional six to nine months"[211], potentially affecting investor interest and confidence.

2. Training and capacity building

- **Operational training** — Many international organizations routinely bring personnel and technology with them, which is not sustainable from a business nor an environmental perspective. A lack of skilled pilots is a particularly pressing concern for cargo operations, requiring more sophisticated technology and skillsets than mapping applications. For mapping applications, capacity gaps are mostly within geospatial analysis rather than on the operations and data collection side. Providing training opportunities and capacity building can increase the employability of youth and skilled professionals, while ensuring enough certified and experienced personnel to meet service demands are available.
- **Regulatory capacity building** — Many aviation regulators may experience UAS as daunting technologies, bringing with them new implications on everything from airspace and ground risk management to security concerns over dropping of cargo and privacy concerns over cameras on board. Understandably, regulators may worry about regulating wholly alien, rapidly evolving technology with widespread ramifications on existing operating procedures, processes,

and arrangements[212]. Fostering an understanding of UAS technology, its implications, and benefits through dedicated capacity building can alleviate concerns and address gaps in knowledge to lay a foundation for designing fit-for-purpose regulations.

3. UAS regulations or rules

- **Overcome language barriers** — Many UAS specific guidance documents, such as the ICAO UAS model regulations, are only available in English. In contrast, the ICAO annexes, for example, are translated into the six United Nations languages. Language barriers further extend to workshops and other materials, often held in English or poorly translated, leading to limited engagement from francophone CAAs across Africa, for example. Translating documents and specific accommodations for other languages in consultative processes such as workshops can increase collaboration and knowledge and learning exchange.
- **Development of fit-for-purpose UAS regulations** — The development of clear and fit-for-purpose regulations relies on a certain level of regulatory capacity and drone knowledge. Compared with conventional aviation, the rapid development of UAS technologies renders traditional views on regulatory elements such as airworthiness certification impractical in many cases. Yet fit-for-purpose UAS regulations need to be compatible with existing aviation regulations and those of other sectors to reflect the latest developments without being overly restrictive.
- **Provide clear rules** — In many cases, UAS operators have found a

  > *"need for regulatory support, or at least clarification, regarding the ability of UAVs [that is, UAS] to operate in the shared civilian air space, including beyond line of sight. In the absence of such clarity, UAV initiatives are bound to remain at the scale of donor-funded pilots, and investment in local technical capacity and necessary infrastructure – including infrastructure in ancillary services such as reliable internet and electricity connectivity efficient internet and electricity services that allow UAV operations to run smoothly – will be discouraged"*[213].

  Uncertainty is an especially pressing challenge for BVLOS in general and cargo operations in particular. Providing clear implementing acts and permitting rules can help alleviate uncertainty and serve as crucial enablers for securing funding and planning timelines for setting up and scaling-up of safe and efficient UAS operations.
- **Harmonization and interoperability** — The alignment of rules, regulations, and processes across countries are crucial enablers to both ease of setting up operations in different countries and ultimately operations across borders. Political motivations from a RSOO or the African Union, in the case of Africa, for example, could accelerate regional dialogues. Although international organizations, such as the Interagency Supply Chain Group or Bill and Melinda Gates Foundation, can aid in building a larger strategy, they are often limited in their ability to lobby for harmonization directly.

4. Operations and infrastructure

- **Auditing, airworthiness assessments, and maintenance inspections** — Auditing, assessments, and inspections are crucial to the safety of UAS operations, particularly in light of the challenges with providing the airworthiness certification mentioned above. Yet, many CAAs may either be lacking dedicated knowledge or resources to assess rapidly evolving UAS technology. Opportunities exist in setting up national commissions to provide oversight activities funded out of a portion of each UAS operations budget.

- **UTM service provision** — Many CAAs are experiencing challenges with the safe integration of UAS into the national airspace. UTM services can support ANSPs and ATC in their airspace oversight responsibilities and address challenges of managing air risk. It can also help address security concerns emerging from unauthorized drone usage within sovereign airspace.
- **Safety and risk management** — Managing safety and risk are crucial to ensure the safety of operations and others affected by ongoing operations and identify hazards and mitigation steps to reduce or eliminate risks associated with those hazards.
- **The increasing maturity of technical standards and guidance** — As UAS hardware, software, and infrastructure (for example, connectivity, surveillance, and data quality) develop further, they will ultimately achieve the necessary levels of maturity required to underpin safe, higher-risk category operations. Remaining dynamic and open while predicting future know-how is one approach to anticipate developments and ensure regulations and rules are capable of regulating in a fit-for-purpose rather than a restrictive fashion.

ROLES OF KEY ORGANIZATIONS AND INITIATIVES

Several organizations and initiatives can provide varying types and levels of support, with the list being not exhaustive by any means:

- **African Drone and Data Academy (ADDA)** — Based in Lilongwe, Malawi, the ADDA, is established by UNICEF and run by Virginia Tech in collaboration with the Malawi University of Science and Technology (MUST). It represents a local training initiative, recruiting cohorts of future drone pilots from Malawi and beyond. In addition to providing training to prospective UAS operators, it helps share knowledge on drone use cases and applications[214].
- **African Drone Forum (ADF)** — The ADF is a multi-stakeholder engagement platform for drone technologies and services that meets the needs of emerging African market opportunities. The program connects the African drone community, curates knowledge relevant to stakeholders, and defines high-frequency drone service requirements with the potential for significant social and economic benefits. The ADF seeks to demonstrate how a future drone economy will look by showcasing the frontier use cases tailored to African countries' needs and facilitates harmonized rulemaking directions to support African services. The program kicked off in February 2020 as a first-of-its-kind event in Africa, with the potential to evolve into a regular forum on the state of the art and to serve as a showcase for system advances with increasing levels of automation that can make a significant difference for isolated and rural communities.[215]
- **AfricaGoesDigital Inc. (AfGD) —** AfricaGoesDigital Inc. is an industry association representing selected African enterprises that are providing digital services in the sectors of agriculture, forestry, fisheries, natural resource management, infrastructure, and mining, and in the domains of surveying, engineering, inspection, disaster risk management,

humanitarian work, and research. Members leverage the power of digital technologies such as UASs, satellite imagery, or geographical information systems to deliver quality services and high-end products across the continent. Some members of AfGD offer certified UAS training in Africa.

- **AW-Drone** — This is a Horizon 2020 research project to support "the rulemaking process for the definition of rules, technical standards and procedures for civilian drones to enable safe and reliable operations in the European Union"[216]. It provides a comprehensive repository and searchable list of links to technical standards and best practices relating to the SORA methodology (see 3.1). From 2021, the focus shifts to UTM and U-Space (see 2.7) and guidance on autonomous operations.
- **Directorate-General for European Civil Protection and Humanitarian Aid Operations (DG ECHO)** DG ECHO and its humanitarian partner organizations have spearheaded work to integrate UASs safely, securely, and efficiently into its humanitarian initiatives. "The main mission of the Directorate-General for European Civil Protection and Humanitarian Aid Operations is to preserve lives, prevent and alleviate human suffering and safeguard the integrity and dignity of populations affected by natural disasters and man-made crises"[217]. Headquartered in Brussels with a global network of field offices, DG ECHO ensures rapid and effective delivery of EU relief assistance.
- **East African Community Civil Aviation Safety and Security Oversight Agency (EAC-CASSOA)** — EAC-CASSOA is the RSOO for the six East African Community Partner States with a mandate to harmonize aviation regulations, policies, and procedures. Following the first set of RPAS regulations developed in 2017, EAC-CASSOA is drafting performance-based model regulations for the EAC in line with ICAO UAS model regulations for promulgation in 2021.
- **European Organisation for Civil Aviation Equipment (EUROCAE)** — EUROCAE works with industry members and represents the European leader in developing internationally recognized industry standards for aviation. Their WG-105/UAS working group operates across several focus teams "tasked to develop standards and guidance documents that will allow the safe operation of UAS in all types of airspace, at all times and for all types of operations" with WG-115 explicitly focusing on Counter UAS[218].
- **FAA Alliance for System Safety of UAS through Research Excellence (ASSURE) —** ASSURE is a partnership of leading research institutes, private sector and government partners with a mission "to provide high-quality research and support to autonomy stakeholders both within the US and beyond to safely and efficiently integrate autonomous systems into the national and international infrastructure, thereby increasing commerce and overall public safety and benefit"[219].
- **Flight Safety Foundation (FSF) —** FSF "is an independent, nonprofit, international organization engaged in research, education, advocacy and communications to improve aviation safety. The Foundation's mission is to connect, influence and lead global aviation safety"[220]. Its Autonomous and Remotely Piloted Aviation Systems (ARPAS) Advisory Committee is a collaborative industry-government-academic effort to address safety considerations in un-crewed autonomous and semi-autonomous flight operations. It further serves as a forum to inform international safety policy and practices related to UAS.

- **Flying Labs Network** — Flying Labs Network is a network of locally owned and operated knowledge hubs focusing on social-good applications for drones. Flying Labs build and strengthen local drone and data capacity through hands-on training for organizations and individuals and pilot/research projects in collaboration with local stakeholders. They also build and facilitate local ecosystems, convene knowledge-sharing and support local organizations and entrepreneurs with mentorship.[221]
- **Global UTM Association (GUTMA)** — GUTMA "is a non-profit consortium of worldwide Unmanned Aircraft Systems Traffic Management (UTM) stakeholders. Its purpose is to foster the safe, secure and efficient integration of drones in national airspace systems. Its mission is to support and accelerate the transparent implementation of globally interoperable UTM systems. GUTMA members collaborate remotely."[222]
- **Interagency Supply Chain Group's UAS Coordinating Body (ISG-UAS) —** ISG-UAS comprises 11 international organizations and donors that convene stakeholders in the UAS and global health space to align and coordinate UAS investments for payload delivery in low- and middle-income countries. Through this coordination, ISG-UAS aims to understand the potential of UAS in global health, where to focus investments in the near- and long-term, and how to better leverage each other's work to continue this knowledge base and ensure the investments are cost-effective and sustainable. ISG-UAS is a part of the Interagency Supply Chain Group, a global collaboration forum to support country-level improvements in health supply chains[223].
- **International Civil Aviation Organization (ICAO) —** ICAO develops international SARPs and policies to ensure safe, secure, and efficient aviation[224]. The scope of ICAO's work is on conventional (that is, crewed) and RPASs (that is, un-crewed) aircraft abiding by SARPs while operating under IFR in international, ICAO-classified airspace and at controlled aerodromes. Although non-certified UAS in the lower airspace is not part of ICAO's core mandate, they are increasingly recognized. This recognition led to the development of guidance text for UAS model regulations[225] published in 2020 as a milestone of involvement and recognition of UAS within ICAO and stakeholder engagement through both the UAS Advisory Group (UAS-AG) and the annual Drone Enable event.
- **International Organization for Standardization (ISO)** — Committee ISO/TC 20/SC 16 UAS is currently developing global standards with the following scope: "Standardization in the field of unmanned aircraft systems, with the regard to their design and development, manufacturing, delivery, maintenance; classification and characteristics of unmanned aircraft systems; materials, components and equipment used during their manufacturing, as well as in the field of safety in joint usage of airspace"[226] by un-crewed and conventional aviation.
- **Joint Authorities for Rulemaking of Unmanned Systems (JARUS)** — JARUS delivers mature UAS guidance for authorities to use in rulemaking efforts, including the SORA methodology, associated STS (see 3.1), and a UAS operational categorization (see 3.3)[227].
- **Radio Technical Commission for Aeronautics, Inc. (RTCA)** — RTCA working group SC-228 works closely with EUROCAE on developing standards to support

authorities' rulemaking programs focused on detect-and-avoid and C2 performance[228].

- **Single European Sky ATM Research Joint Undertaking (SESAR)** — SESAR is an international Public-Private Partnership (PPP) representing the "technological pillar of Europe's ambitious Single European Sky (SES) initiative. SESAR is the mechanism which coordinates and concentrates all EU research and development (R&D) activities in ATM"[229] including on services and capabilities necessary to facilitate the European U-Space UTM.
- **UNICEF Supply Division** — In collaboration with partners, the UNICEF Supply Division supports governments in strengthening national supply chain systems with a particular focus on the needs of children and emergency response. It provides technical assistance and capacity building to improve drone delivery integration into supply chains and serves as the secretariat for the Interagency Supply Chain Group.
- **Union Economique et monétaire Ouest Africaine (UEMOA)** — The West African Economic and Monetary Union UEMOA is made up of eight member states in French-speaking West Africa. The RSOO supporting the UEMOA member states is Unité Régionale de Supervision de la Sécurité et e la Sûreté de l'Aviation Civile de l'UEMOA (URSAC). In 2018, UEMOA and URSAC drafted model text for use by their Francophone member states when drafting UAS regulations: "*Annexe au reglement d'execution relatif a l'exploitation des aeronefs telepilotes - Première edition*"[230]. The document could be adapted for French speaking CAAs across Africa, although it does not align with the ICAO UAS Model regulations.
- **UAV for Payload Delivery Working Group (UPDWG) —** UPDWG is a global community of 350+ stakeholders interested in developing, advancing, and applying drones for use in public health and supply chain systems. UPDWG provides a platform for members to share information, experiences, and resources on drones for health with a diverse network of professionals and organizations. It also hosts the Medical Drone Delivery Database[231], the world's leading drone database for health implementations.
- **VillageReach —** VillageReach is an international nongovernmental organization that transforms health care delivery to reach everyone so that each person has the health care needed to thrive. In collaboration with governments, the private sector, and NGOs, they aim to demonstrate the potential of drones to improve the availability of health products and increase equity of access. VillageReach has extensive experience developing and managing drone delivery programs from proof-of-concept flights to large-scale drone delivery operations in the Democratic Republic of Congo, Malawi, Mozambique, Dominican Republic, and the Central African Republic.
- **WFP: UAS Coordination Technical Working Group** — The UAS coordination group is a platform for exchanging ideas and best practices among a community of stakeholders involved in the safe and responsible use of UAS, especially in humanitarian and emergency activities. It comprises four technical working groups: connectivity, imagery, ethics, and regulation and operation.
- **World Bank Group (WBG) —** The WBG provides funding and knowledge to developing countries in response to government requests as part of a commitment to reduce poverty, increase shared prosperity, and promote sustainable development shared among its five institutions.
- **World Economic Forum (WEF) —**

The Aerospace and Drones Team is a part of the WEF's Centre for the Fourth Industrial Revolution. It seeks to leverage the global reach of WEF to scale its Performance-Based Regulation framework and enable local economies around the world to begin integrating drones into their supply chains.

- **Women in Drones** — Women in Drones is a membership organization seeking to increase female participation in the economic opportunities of the UAS industry through partnerships with companies committed to promoting inclusivity.

Many of the donor organizations work from the bottom up and can only provide support in response to government-level requests. Having a clear plan on **what is planned, what is needed where and when, and how the needs are meant to be addressed,** which this guidebook can help develop, can significantly increase the chances of collaborations leading to successful, safe, and sustainable high-frequency UAS operations.

FUTURE TRENDS

As technology advances, new breakthroughs with potential for opening new services and broader environmental, societal, and economic benefits are possible. Although by no means exhaustive, the most noteworthy include:

- **4G, 5G, and satellites** — Opportunities exist in the increasing rollout of 4G and 5G technologies, HAPS, and satellite constellations such as the SpaceX Starlink. Providing high bandwidths to remote or rural regions supports drone operations and connects the broader communities surrounding drone ports and operations. Improvements in connectivity are likely to drive broader economic and societal impacts, from enabling new jobs and skills training to unlocking innovation and investment to increasing productivity.
- **Artificial intelligence** — AI represents a fundamental enabler for increasing levels of autonomy, and, in turn, serves as an enabler for higher utilization and thus improved cost-efficiencies of operations[232]. Outside of flight operations, advances in AI will continue to impact data collection and analytics applications significantly.
- **Heavy lift** — The delivery of humanitarian aid, including food and ad-hoc medical infrastructure, commonly rely on large cargo aircraft such as the Hercules C130, which are expensive to operate and require large landing strips. Heavy-lift cargo drones provide an opportunity to serve the middle mile more effectively while reducing risk to staff for operations in fragile or conflict-affected states.
- **Propulsion technology** — Although the energy density of lithium batteries is still too small for most operations, it is improving over time. Breakthroughs of hydrocarbons are still a while off, with hydrogen-powered drones such as South Korea-manufactured Doosan DS30 representing an intermediary solution. Whereas solid-state batteries represent an ideal solution for drones due to their high capacity and small size, they have not yet seen wide market adoption.

Bibliography

ADF (2020, Sep). Newsletter

ADF (2020). Lake Kivu Challenge: Un-crewed Aircraft Flying: Concept of Operations (ConOps)

ADF (2021a). A systematic review of UAS regulations and rules in African Union Member States

ADF (2021b). Traffic Management of the Future, Today: A Primer on UTM

African Union (2018, Jan 25-26). Decision on the Reports of the Specialised Technical Committees (STCs) (EX. CL/Dec. 987 (XXXII). Proceedings of Executive Council Thirty-Second Ordinary Session

Airmap (February 19, 2019). Anatomy of UTM and U-Space: Participants, Services, and Architecture. White Paper

Allen, K. (2016, Mar 15). Using drones to save lives in Malawi. https://www.bbc.co.uk/news/world-africa-35810153

ASTM (2019). Standard Specification for Remote ID and Tracking (F3411-19). West Conshohocken, PA: ASTM International

Bahrainwala, L., et al. (2020). Drones and digital adherence monitoring for community-based tuberculosis control in remote Madagascar: A cost-effectiveness analysis, PLOSOne

Bothner, M., et al. (2021). Humanitarian UAV Code of Conduct & Guidelines. https://uavcode.org/

Brown, A. (2020, Feb 5). Droneports and Infrastructure Services in Africa. Presentation delivered at the African Drone Forum, February 5-7, 2020. Kigali, Rwanda

CASA (2017, Aug 3). Overview of civil aviation safety legislation. https://www.casa.gov.au/standard-page/overview-civil-aviation-safety-legislation

Chakib, M. (2018, Nov). Safety Management System. Presentation delivered at SMS Aerodrome, November 27-29, 2018, Cairo, Egypt. https://www.icao.int/MID/Documents/2018/Aerodrome%20SMS%20Workshop/M1-1-SMS_Aerodrome_Hazard%20Identfication.pdf

Civil Aviation Authority UK (2020, Nov 5). Unmanned Aircraft System Operations in UK Airspace — Guidance (CAP 722) (Eighth Edition). Crawley: Civil Aviation Authority

Civil Aviation Authority UK (2021, Feb 12). Regulations made under powers in the Civil Aviation Act 1982 and the Air Navigation Order 2016 (CAP 393). Crawley: Civil Aviation Authority

Coban, S., Oktay, T. (2018). Unmanned Aerial Vehicles (UAVs) According to Engine Type. Journal of Aviation, 2(2), 177-184

Code of Federal Regulations (2020, Jan 1). Title 14 — Aeronautics and Space.

Cohn, P., Green, A., Langstaff, M., Roller, M. (2017, Dec 5). Commercial drones are here: The future of unmanned aerial systems. https://www.mckinsey.com/industries/travel-logistics-and-infrastructure/our-insights/commercial-drones-are-here-the-future-of-unmanned-aerial-systems

Creamer, S. P. (2018). Aircraft Registration Network (ARN) for Drones. Presentation delivered at Drone Enable/2, September 10-14, 2018, Chengdu, China

Creative Commons (2019). About CC Licenses. Viewed May 12, 2021

Crowne Agents (2017, May 4). Can drones really help us save lives in the world's most fragile contexts? https://www.crownagents.com/blog-post/can-drones-really-help-us-save-lives-in-the-worlds-most-fragile-contexts/

Crowne Agents (2019). Drones na Salone. Saving the lives of women and children: The introduction of a sustainable, cost-effective, on-demand delivery model, utilising drone technology, into medical supply

Bibliography

chain of Sierra Leone. Position paper

Department of Civil Aviation Malawi, MACRA, VillageReach, GIZ, and UNICEF (2019, Dec). Malawi Remotely Piloted Aircraft (RPA) Toolkit: A Guideline for Drone Service Providers, Humanitarian and Research Fields. https://www.updwg.org/wp-content/uploads/2019/12/Malawi-RPA-Toolkit-2019_Dec.-Final.pdf

Directorate-General for Internal Policies of the Union (European Parliament) (2015). Privacy and Data Protection Implications of the Civil Use of Drones., 10.2861/28162

Droneregulations.info (2021). Global Drone Regulations Database. www.droneregulations.info

Dronethusiast (2018). Travelling with LiPo Batteries and your Drone. https://www.dronethusiast.com/traveling-with-lipo-batteries-drone/

Dubin, S., Greve, A., Triche, R. (2020). Drones in International Development. Innovating the Supply Chain to Reach Patients in Remote Areas. Washington: USAID

Economist (2017, Jun 8) Technology Quarterly. Taking Flight: Civilian Drones. https://www.economist.com/technology-quarterly/2017-06-08/civilian-drones

EASA (2015, Oct 12). SPECIAL CONDITION. Equipment, systems, and installations (SC-RPAS.1309-01). Cologne: EASA

EASA (2015, Dec 18) Technical Opinion: Introduction of a regulatory framework for the operation of unmanned aircraft. Cologne: EASA

EASA (2016, Feb 16) EASA Policy and Strategic Plan on the Implementation of Performance Based Regulations. Presentation for WP02 — Performance Based Regulations. http://hub.easa.europa.eu/crt/docs/viewcrdattachment/cid_123501/aid_2662/fmd_85d5d80d0c435bd6ad13c96b49145c7d

EASA (2016, Nov 22). Practices for risk-based oversight (Edition 1), Cologne: EASA

EASA (2018). Introduction of a regulatory framework for the operation of unmanned aircraft systems in the 'open' and 'specific' categories (Opinion No 01/2018), Cologne: EASA

EASA (2019, Oct 9). Acceptable Means of Compliance (AMC) and Guidance Material (GM) to Commission Implementing Regulation (EU) 2019/947 (Issue 1). Annex I to ED Decision 2019/021/R. Cologne: EASA

EASA (2021, Apr). Easy Access Rules for Unmanned Aircraft Systems (Regulations (EU) 2019/947 and (EU) 2019/945). Cologne: EASA

EASA (2021). Drones - regulatory framework background. https://www.easa.europa.eu/domains/civil-drones-rpas/drones-regulatory-framework-background

EASA (2021-b). Drones - regulatory framework timeline. https://www.easa.europa.eu/drones-regulatory-framework-timeline

EASA (n.d.) Acceptable Means of Compliance (AMC) and Alternative Means of Compliance (AltMoc). https://www.easa.europa.eu/document-library/acceptable-means-compliance-amcs-and-alternative-means-compliance-altmocs#group-easa-downloads

EC (2009, May 5). COUNCIL REGULATION (EC) No 428/2009 on setting up a Community regime for the control of exports, transfer, brokering and transit of dual-use items. Luxembourg: Office for Official Publications of the European Communities

EC (2016, June 1). Commission takes steps to modernise EU's standardisation policy (MEMO/16/1963). Luxembourg: Office for Official Publications of the European Communities.

EC (2021, Apr 22). Drones: Commission adopts new rules and conditions for safe, secure and green drone operations. https://ec.europa.eu/transport/modes/air/news/2021-04-22-drones

Bibliography

Eichleay, M., Mercer, S., Murashani, J., Evens, E. (2016). Using Unmanned Aerial Vehicles for Development: Perspectives from Citizens and Government Officials in Tanzania. Fhi360, 10.13140/RG.2.1.3834.8560

Eichleay, M., Evens, E., Stankevitz, K., Parker, C. (2019) Using the Unmanned Aerial Vehicle Delivery Decision Tool to Consider Transporting Medical Supplies via Drone. Global Health Science Practice, 7(4), 500-506

Eurocontrol (2011, Sep 20). Partnering to deliver global interoperability. Brussels: Eurocontrol

European Parliament, Council of the EU (2018, Aug 22). REGULATION (EU) 2018/1139 on common rules in the field of civil aviation and establishing a European Union Aviation Safety Agency, and amending Regulations (EC) No 2111/2005, (EC) No 1008/2008, (EU) No 996/2010, (EU) No 376/2014 and Directives 2014/30/EU and 2014/53/EU of the European Parliament and of the Council, and repealing Regulations (EC) No 552/2004 and (EC) No 216/2008 of the European Parliament and of the Council and Council Regulation (EEC) No 3922/91. Official Journal of the European Union

European Union Committee (2015, Mar 5). Civilian Use of Drones in the EU, Seventh Report. London: The Stationery Office Limited

FAA (2000, Dec 30). FAA System Safety Handbook, Appendix A: Glossary. Washington: FAA

FAA (2016, Feb). Community Involvement Manual. Washington: FAA

FAA (2017, May 9). Aviation Safety (AVS) Safety Management System Requirements (VS 8000.367B). Washington: FAA

FAA (2017, Sep 11). Safety Management System Components. https://www.faa.gov/about/initiatives/sms/explained/components/

FAA (2020, Nov 24). Certification for Advanced Operations Unmanned Aircraft Systems (UAS) Criteria for Special Classes. https://www.faa.gov/uas/advanced_operations/certification/criteria_special_classes/

FAA (2020, Mar 2). Unmanned Aircraft System (UAS) Traffic Management (UTM). Concept of Operations 2.0. Washington: FAA

FAA (n.d.). ALC-42: Airspace, Special Use Airspace and TFRs. https://www.faasafety.gov/gslac/ALC/course_content.aspx?cID=42&sID=505&preview=true

Fabian, C., Fabricant, R. (2014). The Ethics of innovation. Stanford Social Innovation Review. https://ssir.org/articles/entry/the_ethics_of_innovation#

FPF (Future of Privacy Forum) (2016, Aug 2). Drones and Privacy by Design: Embedding Privacy Enhancing Technology in Unmanned Aircraft. Washington: FPF

FSD, DG ECHO (2017). Drones in Humanitarian Action. A Guide to the Use of Airborne Systems in humanitarian crises. Geneva: FSD

GAVI the Vaccine Alliance (2020, Aug). Maintaining, Restoring & Strengthening Immunisation. GAVI Innovation Catalogue. Washington: GAVI

GFDRR (Global Facility for Disaster Reduction and Recovery) (2018, Dec 21). Machine Learning for Disaster Risk Management. Washington: World Bank

GFDRR (2021-a). Drones and the 2017 Sierra Leone Mudslide. ACP-EU Natural Disaster Risk Reduction Program: Online

GFDRR (2021-b). Drone Use in Senegal for Flood Control. ACP-EU Natural Disaster Risk Reduction Program: Online

GFDRR (2021-c). Drones and Response to the 2018 Uganda Landslide. ACP-EU Natural Disaster Risk Reduction Program: Online

Bibliography

Global-Aero (n.d.). Unmanned Aircraft Safety, Risk Management and Insurance. https://www.global-aero.com/unmanned-aircraft-safety-risk-management-and-insurance/

Government of India (2018, Aug 27). Subject: Requirements for Operation of Civil Remotely Piloted Aircraft System (RPAS). CIVIL AVIATION REQUIREMENTS SECTION 3 – AIR TRANSPORT SERIES X PART I

Greve, A., Dubin, S., Triche, R. (2021). Assessing Feasibility and Readiness for Cargo Drones in Health Supply Chains. A Guide to Conducting Scoping Trips in Low- and Middle-Income Countries. Washington: USAID

GSMA (2018). Using Mobile Networks to Coordinate Unmanned Aircraft Traffic. London: GSMA

Haidari, et al. (2016). The economic and operational value of using drones to transport vaccines. Vaccine, 34(34)

IATA (2019, Dec 12). 2020 Lithium Battery Guidance Document. Transport of Lithium Metal and Lithium Ion Batteries. Montreal: IATA

ICAO (1991). Human Factors Digest No. 3. Training of Operational Personnel in Human Factors (Circular 227-AN/136). Montreal: ICAO

ICAO (2005). Global Air Traffic Management Operational Concept (Doc 9854). Montreal: ICAO

ICAO (2006). Convention on International Civil Aviation (Doc 7300/9). Montreal: ICAO

ICAO (2009, Jun 25). Transport of Lithium Batteries in Accordance with the ICAO Technical Instructions. Guidance Note, Montreal: ICAO

ICAO (2011). Unmanned Aircraft Systems (UAS) (Cir 328, AN/190). Montreal: ICAO

ICAO (2015). Manual on Remotely Piloted Aircraft Systems (RPAS) (Doc 10019). Montreal: ICAO

ICAO (2016, Dec 7). The ICAO UAS Toolkit. Helpful tools to assist States in realizing effective UAS operational guidance and safe domestic operations https://www.icao.int/safety/UA/UASToolkit/Pages/default.aspx

ICAO (2017, Mar). Remotely Piloted Aircraft System (RPAS) Concept of Operations (ConOps) for International IFR Operations. Montreal: ICAO

ICAO (2018). Safety Management Manual (Doc 9859), 4th Edition. Montreal: ICAO

ICAO (2019, Nov 8). 1090 MHz spectrum issues and proper management of 24-bit aircraft addresses associated with unmanned aircraft operating exclusively at very low level. (State Letter Ref: SP 44/2 - 19/77)

ICAO (2020) U-Aid. Unmanned Aircraft Systems (UAS) for Humanitarian Aid and Emergency Response Guidance. Montreal: ICAO

ICAO (2020, Jun 23). ICAO Model UAS Regulations. Montreal: ICAO

ICAO (2021, Feb 9). Unmanned Aircraft Systems Traffic Management (UTM) – A Common Framework with Core Principles for Global Harmonization (Edition 3). Montreal: ICAO

ICAO (n.d.-a). RSOOs (Including COSCAPs)/RAIOs. https://www.icao.int/safety/Implementation/Pages/COSCAPs-RSOOs-RAIOs.aspx

ICAO (n.d.-b) Remotely Piloted Aircraft Systems Panel (RPASP). https://www.icao.int/safety/UA/Pages/Remotely-Piloted-Aircraft-Systems-Panel-(RPASP).aspx

ICAO (n.d.-c). Dangerous Goods. https://www.icao.int/safety/airnavigation/ops/cabinsafety/pages/dangerous-goods.aspx

Bibliography

ICAO (n.d.-e) Special Authorization [Regulators]. https://www.icao.int/safety/UA/UASToolkit/DocumentsAndPdfs/Regulators%20-%20Copy.pdf

ICRC (International Committee of the Red Cross) (2020). Handbook on Data Protection in Humanitarian Action (2nd Edition). Geneva: ICRC

IEEE Computer Society (March 19, 1998). IEEE Guide for Information Technology—System Definition—Concept of Operations (ConOps) Document, IEEE Std, pp.1362-1998

ISG-UAS (2018, Dec). UAVs in Global Health: Use Case Prioritization. Presentation delivered at ISG-UAS Group Meeting, December, 2018. https://isghealth.org/wp-content/uploads/2020/04/UAV-use-case-prioritization_Dec2018.pdf

ITU (2012-a). Examples of technical characteristics for unmanned aircraft control and non-payload communications links (Report ITU-R M.2233). Geneva:ITU

ITU (2012-b). Resolution 153: The use of frequency bands allocated to the fixed-satellite service not subject to Appendices 30, 30A and 30B for the control and non-payload communications of unmanned aircraft systems in non-segregated airspaces. In Final Acts WRC-12, World Radiocommunication Conference, pp.229-230. Geneva:ITU

JARUS (2015, Sep). JARUS - FCL Recommendation (JAR_DEL_WG1_D.04)

JARUS (2017, Jun 26). JARUS guidelines on SORA. Annex A: Guidelines on collecting and presenting system and operation information for a specific UAS operation (version 1.0) (JAR-DEL-WG6-D.04)

JARUS (2018, Jul 11). JARUS Glossary. (JAR_DEL_Glossary_D.4)

JARUS (2019, Jan). JARUS guidelines on Specific Operational Risk Assessment (SORA) (Issue 2.0) (JAR-DEL-WG6-D.04)

JARUS (2019, Jun 21). UAS Operational categorization (JAR-DEL-WG7-UASOC-D.04)

JARUS (2019, Jul 11). JARUS Ops A & B. Recommendations for Unmanned Aircraft Systems (UAS). Category A & Category B Operations (JAR_DEL_WG2_D.04)

JARUS (2019, Sep 25). JARUS guidelines on SORA. JARUS-STS-02. Standard Scenario for Aerial Work Operations. (JAR-DEL-WG6-D.04)

JK RPAS Consulting (2019, Sep). Project Report Vanuatu Drone Trial: Phase 1 and 2. Viewed July 20, 2020 https://www.updwg.org/wp-content/uploads/2020/10/UNICEF-Vanuatu-Drone-Report-Final-Executive-Summary.pdf

Jones, Therese (2017). International Commercial Drone Regulation and Drone Delivery Services. Santa Monica: RAND Corporation

JSI (n.d.) What should you Deliver by What Should You Deliver by Autonomous Aerial Systems? Tool for Determining Cost Effective Use Cases for AAVs. https://www.updwg.org/wp-content/uploads/2019/04/UAS-Cost-effective-use-cases-simulation-Tool-v3.xlsx

Knoblauch, et al. (2019). Bi-directional drones to strengthen healthcare provision: experiences and lessons from Madagascar, Malawi and Senegal. BMJ Global Health, 4: e001541

La Cour-Harbo, A. (2017). Mass threshold for 'harmless' drones. International Journal of Micro Air Vehicles, 9(2), pp. 77-92

Levitate Capital (2020). The Future of the Drone Economy. A comprehensive analysis of the economic potential, market opportunities, and strategic considerations in the drone economy. White Paper

Lewis, Noah (2020, May 12). A tech company engineered drones to deliver vital COVID-19 medical supplies to rural Ghana and Rwanda in Minutes. https://www.businessinsider.com/zipline-drone-coronavirus-

Bibliography

supplies-africa-rwanda-ghana-2020-5?r=US&IR=T

Mariani, J., Liu, P. (September 8, 2020). Advancing Drone Technology Innovation in Government. FedTech Magazine. https://fedtechmagazine.com/article/2020/09/advancing-drone-technology-innovation-government

Mauluka, Chancy (2019). When the Drone Flies! Rethinking Communication Models in the Context of Innovations. The Journal of Development Communication, 30(2)

McCord, J., Tien, M., Sarley, D. (2013) Guide to Public Health Supply Chain Costing: A Basic Methodology. Arlington, Va.: USAID | DELIVER PROJECT, Task Order 4

McLeay, Stuart, Neal, David, Tollington, Tony (1999). International Standardisation and Harmonisation: a New Measurement Technique. Journal of International Financial Management and Accounting, 10(1)

Mendez, E. (2019, Aug 13). Safety Management Basic Concepts. Presentation delivered at ICAO NACC Regional Office, August 13, 2019. https://www.icao.int/NACC/Documents/Meetings/2019/SMSANSP/SMSxANSP-P01.pdf

Ministry of Civil Aviation Government of India (2019, Jan). Drone Ecosystem Policy Roadmap. http://www.nishithdesai.com/fileadmin/user_upload/pdfs/NDA%20Hotline/190121_H_R_DRONE-ECOSYSTEM-POLICY-ROADMAP.PDF

Molinario, G., Deparday, V. (2019, Mar 6). Demystifying machine learning for disaster risk management. World Bank Blogs. https://blogs.worldbank.org/opendata/demystifying-machine-learning-disaster-risk-management

Norman Foster Foundation (n.d.). Droneport. https://www.normanfosterfoundation.org/project/droneport/

Ochieng , W., Ye, T., Scheel, C., Lor, A., Saindon, J., Yee, S.L., Meltzer, M., Kapil, V., Karem, K. (2020). Uncrewed aircraft systems versus motorcycles to deliver laboratory samples in west Africa: a comparative economic study. Lancet Global Health, 8, e143-151

OpenAerialMap (n.d.). About. https://openaerialmap.org/about/

Oren, C., Verity, A. (2020). Artificial Intelligence (AI) Applied to Unmanned Aerial Vehicles (UAVs) And its Impact on Humanitarian Action. Online: Digital Humanitarian Network

Penny J., Eaton A., Bishop P.G., Bloomfield R.E. (2001) The Practicalities of Goal-Based Safety Regulation. In: Redmill F., Anderson T. (eds) Aspects of Safety Management. Springer, London. https://doi.org/10.1007/978-1-4471-0713-2_3

Phillips, N., Blauvelt, C., Ziba, M., et al. (2016). Costs associated with the use of unmanned aerial vehicles for transportation of laboratory samples in Malawi. Seattle: VillageReach

Pinto, N. (n.d.). Unravelling the drone blueprint in Africa. Logistics Update Africa. https://www.logupdateafrica.com/unravelling-the-drone-blueprint-in-africa-aviation

Rae, T. (2019, Jul 4). This workshop came along at the right time. Much-anticipated regional drone training offers new options for Central American humanitarian community. World Food Programme Insight. https://medium.com/world-food-programme-insight/this-workshop-came-along-at-the-right-time-14ed453915ef

Rwanda CAA (2018, Jul 19). Aeronautical Information Publication (6th Edition)

Rwanda CAA (2019-a). Part 27: Unmanned Aircraft Systems. Kigali: Rwanda CAA

Rwanda CAA (2019-b). Part 30:Safety Management Regulations. Kigali: Rwanda CAA

SAE International Aerospace Recommended Practice (1996, Dec). Guidelines and Methods for Conducting the Safety Assessment Process on Civil Airborne Systems and Equipment. SAE Standard ARP4761

Bibliography

Scorer, D. (2019). Aircraft Registry Network (ARN) Concept. Presentation delivered at Drone Enable/3, November 12-14, 2019, Montreal, Canada. https://www.icao.int/Meetings/DRONEENABLE3/Presentations/1.02.3%20-%20David%20Scorer.pdf

SESAR (2018). European ATM Master Plan: Roadmap for the safe integration of drones into all classes of airspace

SESAR (2020). U-space. Supporting Safe and Secure Drone Operations in Europe. Consolidated report on SESAR U-space research and innovation results. Luxembourg: Publications Office of the European Union

SkyBrary (2019, Aug 30). Safety Regulation. https://www.skybrary.aero/index.php/Safety_Regulation

Soesilo, D., Rambaldi, G. (2018, Feb). Drones in Agriculture in Africa and other ACP countries. A survey on Perceptions and Applications. (CTA Working Paper 18/02). Wageningen: CTA

Stokenberga, A., Ochoa, C. (2021). Unlocking the lower skies: The Costs and Benefits of Deploying Drones across Use Cases in East Africa. Washington: World Bank

Teravaninthorn, S., Raballand, G. (2009). Transport Prices and Costs in Africa : A Review of the International Corridors. Directions in Development; Infrastructure. Washington: World Bank

Truog, et al. (2020). Insights Before Flights: How Community Perceptions Can Make or Break Medical Drone Deliveries. Drones, 4(3)

UAV Coach (n.d.). Drone Insurance: A Step-by-Step Guide to Liability and Drone Hull Insurance. https://uavcoach.com/drone-insurance-guide/

UEMOA (2019). Annexe Au Reglement D'Execution Relatif A l'Exploitation Des Aeronefs Telepilotes

UK CAAi (2020). Developing an ICAO compliant legal and regulatory framework in Sierra Leone. https://caainternational.com/portfolio/developing-icao-compliant-legal-regulatory-framework-sierra-leone/

UN Aviation Safety Section (2017). United Nations RPAS Experience: Setting the Stage. Presentation given at ICAO 2nd Remotely Piloted Aircraft System (RPAS) Symposium, September 19-21, 2017, Montreal, Canada

UNICEF Supply Division (2019, Oct). Unmanned Aircraft Systems: Product Profiles and Guidance. Kopenhagen: UNICEF Supply Division

UPDWG (2019, May 22). Technical and Logistical Challenges Encountered During Test Flights in Malawi. https://www.updwg.org/wp-content/uploads/2019/05/Technical-and-Logistical-Challenges-Encountered-During-Test-Flights-in-Malawi_UPDWG_2019_05_22.pdf

USAID GHSC-PSM (Global Health Supply Chain Program-Procurement and Supply Management) (2017, Feb), Unmanned Aerial Vehicles Landscape Analysis: Applications in the Development Context. Washington: Chemonics International Inc.

USAID GHSC-PSM (Global Health Supply Chain Program-Procurement and Supply Management) (2018, Jul 9). Unmanned Aerial Vehicle Procurement Guide. Washington: Chemonics International Inc.

Van den Hoven, J., et al. (eds.) (2015). Handbook of Ethics, Values and Technological Design. Springer: Dordrecht

Vaughn, M. (2019). Considerations on the use of 1090 MHz and 24-bit aircraft addresses. Presentation delivered at ICAO Drone Enable/3, November 12-14, 2019, Montreal, Canada. https://www.icao.int/Meetings/DRONEENABLE3/Presentations/1.02.2%20-%20Vaughn%20Maiolla.pdf

VillageReach, ISG-UAS (2019, Nov). Toolkit for Generating Evidence around the Use of Unmanned Aircraft Systems (UAS) for Medical Commodity Delivery, Version 2. Seattle: VillageReach

VillageReach (2020). How to Select a Drone Service Provider for Transport of Health Products. Lessons

Bibliography

Learned. Seattle: VillageReach

WEF (2018, Dec). Advanced Drone Operations toolkit: Accelerating the Drone Revolution. Geneva: WEF

WEF (2021, Mar). Medicine from the Sky. Opportunities and Lessons from Drones in Africa. Insight Report

WFP (2019, Jun) Unmanned Aircraft Systems (UAS) Training. Report on the Regional Drone Training for Central America. Rome: WFP

WFP Logistics Cluster (n.d.). Technical Support Guides: Monitoring and Evaluation. Rome: WFP

World Bank Group (2016). UAV State of Play for Development: Innovations in Program and Humanitarian Contexts. Washington: World Bank

World Bank Group (2017). Guidance Note: Managing the risks of unmanned aircraft operations in development projects. Washington: World Bank

Wright, et al. (2018). What should you deliver by unmanned aerial systems? The role of geography, product, and UAS type in prioritizing deliveries by UAS. White paper, inSupply. https://publications.jsi.com/JSIInternet/Inc/Common/_download_pub.cfm?id=19145&lid=3

Würbel, H. (2017). Framework for the evaluation of cost-effectiveness of drone use for the last-mile delivery of vaccines. MSc Thesis, University of Barcelona

Yadav, P., Lydon, P., Oswald, J., Dicko, M., Zaffran, M. (2014). Integration of vaccine supply chains with other health commodity supply chains: A framework for decision making. Vaccine, 32(50), 6725-6732

Yadav, Prashant (2015). Health Product Supply Chains in Developing Countries: Diagnosis of the Root Causes of Underperformance and an Agenda for Reform, Health Systems & Reform, 1(2), pp. 142-154

Index

Index

Index

Index

Index

Appendix A:

Glossary and definitions

The aim of this Appendix is to *"promote a common understanding of the terms and abbreviations used"*[233] in relation to UAS operations and official ICAO, the JARUS, and the EASA documents. The glossary builds primarily on ICAO definitions and terms followed by EASA, JARUS, and *"other definitions and terms from other organisations and working groups for general informational purposes"*[234]. Among the original definitions, the terms RPAS, UA, and UAS are used interchangeably. For the purposes of this guidebook, they have been standardized to "UAS" where applicable, with changes indicated in the footnotes as "adapted from".

Abnormal situation — One in which it is no longer possible to continue the flight using normal procedures but the safety of the aircraft or persons on board or on the ground is not in danger.[235]

Acceptable means of compliance — Non-binding standards adopted by EASA to illustrate means to establish compliance with the Basic Regulation [level 1] and its Implementing Rules [level 2][236]

Acceptable risk — The level of risk that individuals or groups are willing to accept given the benefits gained. Each organization will have its own acceptable risk level, which is derived from its legal and regulatory compliance responsibilities, its threat profile, and its business/organizational drivers and impacts[237].

Accident — An unplanned event or series of events that results in death, injury, or damage to, or loss of, equipment or property[238].

ADS-B (Automatic Dependent Surveillance – Broadcast) — A means by which aircraft, aerodrome vehicles and other objects can automatically transmit and/or receive data such as identification, position and additional data, as appropriate, in a broadcast mode via a data link[239].

Aerodrome — A defined area on land or water (including any buildings, installations and equipment) intended to be used either wholly or in part for the arrival, departure and surface movement of aircraft[240].

Aeronautical Information Service — A service established within the defined area of coverage responsible for the provision of aeronautical data and aeronautical information necessary for the safety, regularity and efficiency of air navigation[241].

Aeronautical Information Publication (AIP) — A publication issued by or with the authority of a State and containing aeronautical information of a lasting character essential to air navigation[242].

Aircraft — Any machine that can derive support in the atmosphere from the reactions of the air other than the reactions of the air against the earth's surface[243].

Airmanship — The consistent use of good judgement and well-developed knowledge, skills and attitudes to maintain flight safety and accomplish flight objectives[244].

Air Navigation Service Provider (ANSP) — The ANSP is the designated provider of air traffic service in a specific area of operation (airspace). The ANSP assesses whether the proposed flight can be safely conducted in the particular airspace that it covers, and if so, authorises the flight.[245]

Airspace risk class (ARC) — The ARC is an initial assignment of generic collision risk of airspace, before mitigations are applied. ARC is assigned to airspace encounter categories, qualitative classification of the rate at which a UAS would encounter a another aircraft in typical civil airspace found in the U.S. and Europe, based on a qualitative assessment of collision risk of generic types of airspace[246].

Air Traffic Control (service) — A service provided for the purposes of: a) preventing collisions between aircraft and in the manoeuvring area between aircraft and obstructions; and b) expediting and maintaining an orderly flow of air traffic[247].

Air traffic management (ATM) — The dynamic, integrated management of air traffic and airspace (including air traffic services, airspace management and air traffic flow management) – safely, economically and efficiently – through the provision of facilities and seamless services in collaboration with all parties and involving airborne and ground-based functions[248].

Air traffic service — A generic term meaning variously, flight information service, alerting service, air traffic advisory service, air traffic control service (area control service, approach control service or aerodrome control service)[249].

Airworthiness — The condition of an item (aircraft, aircraft system, or part) in which that item operates in a safe manner to accomplish its intended function[250].

Airworthiness certification — Takes into account platform configuration, usage, environment, and the hardware and software of the entire system. It also considers design characteristics, production processes, interoperability, reliability, and in-service maintenance programmes that adequately mitigate safety risks. Technical standards may be used to certify specific components[251].

Applicant — In the context of the SORA, an applicant refers to the individual or organization who desires to operate a UAS in a limited or restricted manner and submits the necessary technical, operational and human information related to the intended use of the UAS for the NAA [that is Civil Aviation Authority (CAA)] to evaluate the risks associated with the operation for the purpose of authorizing the operation in an agreed upon manner according to established conditions and limitations of the operation[252].

Assurance — The planned and systematic actions necessary to provide adequate confidence that a product or process satisfies given requirements[253].

Atypical airspace — Atypical Airspace is defined as; a) Restricted Airspace; b) Airspace where conventional aircraft cannot go (e.g. airspace within 100 feet of buildings or structures); c) Airspace characterization where the encounter rate of conventional aircraft (encounter is defined as proximity of 3000 feet horizontally and ± 350 feet vertically) can be shown to be less than 1E-6 per flight hour during the operation); d) Airspace not covered in Airspace Encounter Categories (AEC) 1 through 12[254].

Audit — An independent examination of the life cycle processes and their products for compliance, accuracy, completeness and traceability[255].

Automated flight — A flight following pre-programmed instructions, loaded in the unmanned aircraft (UA) flight control system, that the UAS executes[256].

Autonomous operation — An operation during which a remotely-piloted aircraft is operating without pilot intervention in the management of the flight[257].

Beyond Visual Line of Sight (BVLOS) — BVLOS is a means of flying the UAS without the direct, unaided visual supervision of the aircraft by the person manipulating the flight controls[258].

Buffer — The area between the "Hard Fence" and the "Soft Fence" in geo-fencing. The buffer must take into account all elements which can have an influence on the size of the buffer as latency, accuracy, wind, altitude, UA-performance etc[259].

Capital costs — Resource that are used over several years[260]

Certification — The legal recognition that a product, service, organization, or person complies with the applicable requirements. Such certification comprises the activity of technically checking the product, service, organization or person, and the formal recognition of compliance with the applicable requirements by issue of a certificate, license, approval, or other documents as required by national laws and procedures[261].

Civil Aviation Authority (National) — The government regulatory agency that governs aircraft, airmen, and operations[262].

Collision avoidance — Averting physical contact between an aircraft and any other object or terrain[263].

Command and control (C2) link — The data link between the remotely piloted aircraft and the remote pilot station for the purposes of managing the flight[264].

Commercial (UAS) operation — An aircraft operation conducted for business purposes (mapping, security surveillance, wildlife survey, aerial application, etc.) other than commercial air transport, for remuneration or hire[265].

Commercial-off-the-shelf — Components designed to be implemented into existing systems without extensive customization and for which design data are not always available to the customer[266].

Community — Broadly defines the term "community" to include local residents, the general public, and other stakeholders[267]

Complexity — An attribute of systems or items which makes their operation difficult to comprehend. Increased system complexity is often caused by such items as sophisticated components and multiple interrelationships[268].

Component — Any self-contained part, combination of parts, subassemblies or units, which perform a distinct function necessary to the operation of the system[269].

Competency — A combination of skills, knowledge and attitude required to perform a task to the prescribed standard[270].

Concept of Operations (ConOps) — A user-oriented document that describes systems characteristics for a proposed system from a user's perspective. A ConOps also describes the user organization, mission, and objectives from an integrated systems point of view and is used to communicate overall quantitative and qualitative system characteristics to stakeholders[271].

Conformance monitoring — A service that provides real-time alerting of non-conformance [Non-fulfillment of an organization’s requirements, policies, and procedures, as well as requirements of safety risk controls developed by the organization[272]] with intended Operation Volume/ trajectory [flight plan] to an Operator or another airspace user.[273]

Consent — The freely-given, specific and informed indication of a Data Subject’s wishes by which the Data Subject signifies agreement to Personal Data relating to him or her being processed[274].

Contingency procedures — Planned course of action designed to help an organization respond effectively to a significant future event or situation that may or may not happen[275].

Controlled airspace — An airspace of defined dimensions within which air traffic control service is provided in accordance with the airspace classification. *Note*: Controlled airspace is a generic term which covers ATS airspace Classes A, B, C, D and E as described in [ICAO] Annex 11, 2.6[276].

Cooperative aircraft — Aircraft that have an electronic means of identification (i.e., a transponder) aboard and operating[277].

Critical infrastructure — Means systems and assets vital to national defence, national security, economic security, public health or safety including both regional and national infrastructure[278].

Dangerous goods — Articles of substances which are capable of posing a risk to health, safety, property or the environment[279].

Data link — A term referring to all interconnections to, from and within the remotely piloted aircraft system. It includes control, flight status, communication, and payload links.[280]

Data Protection Impact Assessment — An assessment that identifies, evaluates and addresses the risks to Personal Data arising from a project, policy, programme or other initiative.[281]

Detect-and-Avoid — The capability to see, sense or detect conflicting traffic or other hazards and take the appropriate action to comply with the acceptable rules of flight[282].

Emergency procedures — Procedures that are executed by the UA pilot in command or by the aircraft to mitigate the effect of failures that cause or lead to an emergency condition[283].

Emergency response plan (ERP) — Plan of actions to be conducted in a certain order or manner, in response to an emergency event[284].

Environment — (a) The aggregate of operational and ambient conditions to include the external procedures, conditions, and objects that affect the development, operation, and maintenance of a system. Operational conditions include traffic density, communication density, workload, etc. Ambient conditions include weather, electromagnetic interference, vibration, acoustics, etc. (b) Everything external to a system which can affect or be affected by the system[285].

Equipment — A complete assembly—operating either independently or within a system/subsystem—that performs a specific function[286].

Error — An occurrence arising as a result of an incorrect action or decision by personnel operating or maintaining a system. [...] (2) A mistake in specification, design, or implementation[287].

Fail-safe — A characteristic of a system whereby any malfunction affecting the system safety will cause the system to revert to a state that is known to be within acceptable risk parameters[288].

Failure — A loss of function or a malfunction of a system or a part thereof[289].

Flight Information Service — A service provided for the purpose of giving advice and information useful for the safe and efficient conduct of flights[290].

Flight plan — Specified information provided to air traffic services units, relative to an intended flight or portion of a flight of an aircraft[291].

Geofence — A virtual three-dimensional perimeter around a geographic point, either fixed or moving, that can be predefined or dynamically generated and that enables software to trigger a response when a device approaches the perimeter. *Note: sometimes referred to as geoawareness or geocaging*[292].

Geo-fencing — An automatic limitation of the airspace a UA can enter[293].

Ground risk buffer — An area over the surface of the earth, which surrounds the operational volume and that is specified in order to minimise the risk to third parties on the surface in the event of the unmanned aircraft leaving the operational volume[294].

Guidelines — Recommended procedures for complying with regulations[295].

Harm — The term harm, for the purpose of this document, relates to undesired events defined as: a. Fatal injuries to third parties on the ground b. Fatal injuries to third parties in the air (Catastrophic MAC with a manned aircraft) c. Damage to critical infrastructure[296].

Hazard — A condition or an object with the potential to cause injuries, damage, loss of material or a reduction of the ability to perform a prescribed function[297].

Hazard identification — Identification of a potentially unsafe condition resulting from failures, malfunctions, external events, errors, or a combination thereof[298].

Holistic — Characterized by comprehension of the parts of something as intimately interconnected and explicable only by reference to the whole[299].

Incident — A near miss accident with minor consequences that could have resulted in greater loss. An unplanned event that could have resulted in an accident, or did result in minor damage, and which indicates the existence of, though may not define a hazard or hazardous condition. Sometimes called a mishap[300].

Inspection — An examination of an item against a specific standard[301].

Integration — (1) The act of causing elements of an item to function together. (2) The act of gathering a number of separate functions within a single implementation[302].

Likelihood — Estimation of the degree of confidence one may have in the occurrence of an event[303].

Lithium Battery — The term "lithium battery" refers to a family of batteries with different chemistries, comprising many types of cathodes and electrolytes[304].

Loss of control — Loss of the ability to manage or direct the continued operation of an UAS[305].

Maintenance — The performance of tasks required to ensure the continuing airworthiness of an aircraft, including any one or combination of overhaul, inspection, replacement, defect rectification and the embodiment of a modification or repair[306].

Maintenance programme — A document which describes the specific scheduled maintenance tasks and their frequency of completion and related procedures, such as a reliability programme, necessary for the safe operation of those aircraft to which it applies[307].

Maximum take-off mass (MTOM) — The maximum Unmanned Aircraft mass, including payload and fuel, as defined by the manufacturer or the builder, at which the Unmanned Aircraft can be operated[308].

Mitigation — A means to reduce the risk of a hazard[309].

Notice to Airmen (NOTAM) — A notice distributed by means of telecommunication containing information concerning the establishment, condition or change in any aeronautical facility, service, procedure or hazard, the timely knowledge of which is essential to personnel concerned with flight operations[310].

Observer — A trained and competent person designated by the operator who, by visual observation of the unmanned aircraft, assists the remote pilot in the safe conduct of the flight[311].

Operating costs — Resource used and replaced, in one year's time (e.g. personnel salaries, medicines, supplies, gasoline, medicines)[312]

Operations manual — A manual containing procedures, instructions and guidance for use by operational personnel in the execution of their duties[313].

Operator — A person, organization or enterprise engaged in or offering to engage in an aircraft operation[314].

Payload — Instrument, mechanism, equipment, part, apparatus, appurtenance, or accessory, including communications equipment, that is installed in or attached to the aircraft and is not used or intended to be used in operating or controlling an aircraft in flight, and is not part of an airframe, engine, or propeller[315].

Personal Data — Any information relating to an identified or identifiable natural person.[316]

Population density — The number of people living per unit of an area (e.g. per square mile); the number of people relative to the space occupied by them[317].

Probability — The measure of the likelihood that an event will occur[318].

Procedure — Standard, detailed steps that prescribe how to perform specific tasks[319].

Process — Set of inter-related resources and activities, which transform inputs into outputs[320].

Pull system — In a requisition (pull) system, the lower-level facility orders commodities as [and when] it needs them, pulling supplies through the chain. *NOTE: In an allocation (push) system [common in many low- and middle-income countries], the higher-level facility decides what commodities to push down the chain and when to move them*[321]

Radio Line of Sight — A direct electronic point-to-point contact between a transmitter and a receiver[322].

Redundancy — Multiple independent means incorporated to accomplish a given function[323].

Reliability — The probability that an item will perform a required function under specified conditions, without failure, for a specified period of time[324].

Remote crew member — A licensed crew member charged with duties essential to the operation of a remotely piloted aircraft during flight time[325].

Remote identification — Services related to the identification of UAS in the national airspace[326].

Remote pilot — A person charged by the operator with duties essential to the operation of a remotely piloted aircraft and who manipulates the flight controls, as appropriate, during flight time[327].

Remotely piloted aircraft system (RPAS) — A remotely piloted aircraft, its associated remote pilot station(s), the required C2 Link and any other components as specified in the type design[328]. *Note: Referred to as UAS in this guidebook*

Remote pilot station (RPS) — The component of the remotely piloted aircraft system containing the equipment used to pilot the remotely piloted aircraft[329].

Restricted area — An airspace of defined dimensions, above the land areas or territorial waters of a State, within which the flight of aircraft is restricted in accordance with certain specified conditions[330].

Risk — The combination of the frequency (probability) of an occurrence and its associated level of severity[331]. *Note: ICAO and the Federal Aviation Administration (FAA) use the term safety risk instead or synonymously*

Risk analysis — The development of qualitative and / or quantitative estimate of risk based on evaluation and mathematical techniques[332].

Risk assessment — The process by which the results of risk analysis are used to make decisions[333].

Risk-based oversight (RBO) — A way of performing oversight, in which: planning is driven by the combination of the risk profile and safety performance; and execution focuses on the management of risk, besides ensuring compliance[334].

Risk control — The Risk associated with the hazardous event under study is adequately controlled, by the reduction of severity and / or likelihood, via the application of engineering and/ or administrative hazard controls. *Note: see also risk mitigation*[335].

Risk mitigation — The process of incorporating defences or preventive controls to lower the severity and/or likelihood of a hazard and the projected consequences[336].

Risk profile — The element of risks that are inherent to the nature and operations of the regulated entity, this includes the: specific nature of the organisation; complexity of the activities; and risks stemming from the activities carried out[337].

Root cause — The contributory events, initiating events, which started the adverse event flow are considered root causes. Should these causes be eliminated the hazardous event [or incident] would not have occurred. It should be noted that accidents are the result of many contributors, both unsafe acts and /or unsafe conditions; *Note: also see Hazard*[338].

Route plan — A set of waypoints for the [… UAS] to follow, as well as general air vehicle commands for auxiliary systems (e.g., lights, IFF, de-icing, etc.) and emergency operation commands. Taxi or flight patterns may be incorporated into the route either as a series of sequenced waypoints or as 'seed' waypoints with range and bearing information, which, will depend on the sophistication of the GCS [that is remote pilot station] and RPAS [that is UAS][339].

Safety — The state in which risks associated with aviation activities, related to, or in direct support of the operation of aircraft, are reduced and controlled to an acceptable level through a continuing process of hazard identification and risk management[340].

Safety assurance — Includes processes within the SMS that function systematically to ensure the performance and effectiveness of safety risk controls and that the organization meets or exceeds its safety objectives through the collection, analysis, and assessment of information[341].

Safety Culture — The shared values, actions, and behaviors that demonstrate a commitment to safety over competing goals and demands[342].

Safety Management System (SMS) — A systematic approach to managing safety, including the necessary organizational structures, accountabilities, policies and procedures[343].

Safety objective — A measurable goal or desirable outcome related to safety[344].

Safety oversight — A function performed by a State to ensure that individuals and organizations performing an aviation activity comply with safety-related national laws and regulations[345].

Safety performance — The demonstration of how effectively a regulated entity can mitigate its risks, substantiated through the proven ability to: comply with the applicable requirements; implement and maintain effective safety management; identify and manage safety risks; and achieve and maintain safe operations. The results of past certification or oversight also need to be taken into account[346].

Safety promotion — A combination of training and communication of safety information to support the implementation and operation of an SMS in an organization[347].

Safety policy — The organization's documented commitment to safety, which defines its safety objectives and the accountabilities and responsibilities of its employees with regard to safety. The Safety Policy links organizational safety objectives to the organization's goals and establishes employees' accountabilities and responsibilities in regard to achieving those goals[348].

Safety risk — The predicted probability and severity of the consequences or outcomes of a hazard[349]. *Note: EASA and JARUS use term risk instead*

Safety risk management — A process within the SMS composed of describing the system; identifying the hazards; and analyzing, assessing, and controlling risk[350]

Segregated airspace — Airspace of specified dimensions allocated for exclusive use to a specific user(s)[351]

Separation — Maintaining a specific minimum distance [buffer] between an aircraft and another aircraft or terrain to avoid collisions, normally by requiring aircraft to fly at set levels or level bands, on set routes or in certain directions, or by controlling an aircraft's speed[352].

Severity — The consequence or impact of a hazard's effect or outcome in terms of degree of loss or harm[353].

Situational awareness — The ability to keep track of the prioritized significant events and conditions in the environments of the subject[354].

Specific Assurance and Integrity Levels (SAIL) — The SAIL parameter consolidates the ground and air risk analyses and drives the required activities. The SAIL represents the level of confidence that the UAS operation will stay under control[355].

Specific category — Category of UAS operation where a proportionate approach to the assessment of the risk will be taken by requiring the UAS operator to present a Specific Operation Risk Assessment of the UAS operation before operational approval will be granted by the appropriate aviation "authority"[356].

Specific operational risk assessment (SORA) — A means by which an aircraft operator is granted approval by certifying authorities to operate an unmanned aircraft system within the limitations set forth by the authorities in the Specific Category[357].

Specification — A collection of requirements which, when taken together, constitute the criteria which define the functions and attributes of a system, or an item[358].

Standard scenario (STS) — A type of UAS operation in the 'specific' category, as defined in Appendix 1 of the Annex, for which a precise list of mitigating measures has been identified in such a way that the competent authority can be satisfied with declarations in which operators declare that they will apply the mitigating measures when executing this type of operation[359].

Standard operating procedure — A set of instructions covering those features of operations which lend themselves to a definite or standardized procedure without loss of effectiveness[360].

Standards and Recommended Practices (SARPs) — SARPs are adopted by the Council under the provisions of the Convention. They are defined as follows: Standard. Any specification for physical characteristics, configuration, matériel, performance, personnel or procedure, the uniform application of which is recognized as necessary for the safety or regularity of international air navigation and to which Contracting States will conform in accordance with the Convention; in the event of impossibility of compliance, notification to the Council is compulsory under Article 38. Recommended Practice. Any specification for physical characteristics, configuration, matériel, performance, personnel or procedure, the uniform application of which is recognized as desirable in the interests of safety, regularity or efficiency of international air navigation, and to which Contracting States will endeavour to conform in accordance with the Convention[361].

State of the operator — The State in which the operator's principal place of business is located or, if there is no such place of business, the operator's permanent residence[362].

Surveillance system — A generic term meaning variously, ADS-B [...] or any comparable groundbased system that enables the identification of aircraft[363].

Testing — The process of operating a system under specified conditions, observing or recording the results, and making an evaluation of some aspect of the system[364].

Threat — Events or errors that occur beyond the influence of the flight crew, increase operational complexity and which must be managed to maintain the margin of safety[365].

Type certificate — A document issued by a contracting State to define the design of an aircraft type and to certify that this design meets the appropriate airworthiness requirements of that State[366]

UAS operators — Any legal or natural person operating or intending to operate one or more UAS[367].

Un-crewed Aircraft Systems Traffic Management (UTM) — A specific aspect of Air Traffic Management (ATM) which manages UAS operations safely, economically and efficiently through the provision of facilities and a seamless set of services in collaboration with all parties and involving airborne and ground-based functions[368].

UAS geographical zone — A portion of airspace established by the competent authority that facilitates, restricts or excludes UAS operations in order to address risks pertaining to safety, privacy, protection of personal data, security or the environment, arising from UAS operations[369].

Uncontrolled airspace — For the purposes of this assessment, Uncontrolled Airspace is defined as Class G airspace[370].

Un-crewed Aircraft System (UAS) — An aircraft and its associated elements which are operated with no pilot on board[371].

Vertical take-off and landing (VTOL) — An aircraft that uses powered lift to ascend or descend vertically or near vertically and does not require forward flight to generate continuous lift by a fixed non-moving lifting surface to remain airborne. Light VTOL aircraft may exhibit forward, rearward and side to side flight or hover in place[372].

Visual Line of Sight (VLOS) — An operation in which the remote pilot or observer maintains direct unaided visual contact with the UAS[373].

Appendix B:

Risk management during the LVC and LKC

International standards require operations such as the LVC and LKC to perform a hazard identification and risk assessment[374]. Yet, the 2018 LVC took place in the absence of suitable international standards for UAS air displays and competitions. To overcome this limitation, the organizers built the LVC safety and risk management approach on a range of guidance, including the UK CAAi, Australian Civil Aviation Safety Authority (CASA), EAC-CASSOA, and Advisory Circular AC-GEN016A, June 2017. In 2018, the LVC facilitated a range of electric, VTOL, VLOS, and BVLOS UAS flights near a controlled aerodrome at Mwanza, Tanzania. Following the success of the LVC, the ADF and LKC took place in Kigali and Gisenyi, Rwanda. In both cases, flights took off from a temporary droneport near a lake. They continued over water to a separate, temporary droneport on an island within Lake Victoria and Lake Kivu.

SAFETY POLICY AND CONOPS

Safety and risk management at the LKC involved a multi-step process of risk assessments, site assessments, and consultations to ensure the highest levels of safety during planned operations. Specifically, the focus was on ensuring:

- The safety of all airspace users operating near the LKC operations;
- The safety and privacy of all individuals residing near the LKC operations;
- The protection of critical infrastructure near the LKC operations;
- Compliance with dimensions, both laterally and vertically, and hours of airspace, including necessary safety buffers surrounding any drone operations, assigned to the LKC operations for the safe segregation of drone flights from other airspace users;
- The protection of the environment nearby to the LKC operations, mainly including the protection of wildlife near the LKC operations;
- The detailing of procedures, lines of responsibility, safety risk management assessments, security processes, an ERP, and a draft program of competition or exhibition events;
- The safe importation and exportation of equipment required by competitors and display groups for the LKC, including drones, a RPS, spare parts and tools, batteries, and radios for communications; and
- Compliance with insurance and liability obligations.

The process sought to foster an environment whereby safety management can be effective, as everyone is responsible for safety.
The organizers expected all personnel to understand the safety policy and requirement to report safety issues. The LKC ConOps supported this mission and followed the JARUS approach in describing what types of operations the operator intends to carry out:

> *"The detailed description […] of how, where, and under which limitations or conditions the operations shall be performed. Relevant charts and any other information helpful to visualize and understand the intended operation […] specific details on the type of operations (e.g. VLOS, BVLOS), the population density to be overflown (e.g. away from people, sparsely populated, crowds) and the airspace requirements […] the level of involvement of the crew and automated or autonomous systems during each phase of the flight"*[375]

AIR AND GROUND RISK

In 2018, the LVC Organizing Committee conducted site risk assessments for the proposed flying location(s) to identify and mitigate against all known or anticipated hazards and threats associated with the operations. Risk assessments included airspace change processes and ground risk to provide a safe environment for the public and uninvolved third-party persons not directly associated with the flight operations. Flying over the lake was favored to avoid populated environments with potential threats to people and infrastructure on the ground. Choosing flight routes also involved identifying emergency landing points as "safe havens" in case of mid-flight issues. Identifying emergency landing points is particularly crucial for flights over water, as alternatives would likely involve ditching a drone into the lake and subsequently losing or severely damaging equipment and potentially causing environmental pollution. Droneports were as close to the shoreline as possible to address ground risk concerns. However, the operation of high-frequency droneports (see 2.5) is likely to require closer proximity to facilities such as medical dispensaries, necessitating an examination of associated increases in risk levels. Such assessments are likely to represent a particular challenge in low-resource settings, where mapping quality may be low and population data may be inaccurate or missing. Meanwhile, the LVC and LKC built on the understanding that understanding and management of ground risk would advance alongside the availability of accurate mapping data, allowing operations to expand away from expanses of water.

The LVC efforts and learning alongside newly developed guidance, including the JARUS SORA, underpinned the subsequent LKC risk-assessment process. Several planning meetings were conducted with essential stakeholders, culminating with a visit to the intended flying and droneport locations, followed by a site assessment workshop in 2019 attended by all those involved. This safety assessment and ConOps workshop assessed any drone flying associated with the LKC during Q1 2020, with the scope of:

- Reviewing previous risk management efforts
- Identifying any new hazards to safety
- Assessment of the likelihood (i.e., will they lead to harm) and consequences (i.e., what will this harm be) of these hazards
- Identifying of risk controls and mitigations (i.e., threat and harm barriers)
- Recording workshop outcomes, including a risk register for input to the LKC ConOps

The LKC Organizing Committee captured action items from the workshop within meeting minutes shared among all attendees. The process followed the Rwanda Civil Aviation Regulations[376] and included follow-up teleconference calls over the subsequent weeks.

The LKC used segregated airspace to manage air risk during both VLOS and BVLOS operations. The Organizing Committee purposefully designed the segregated air routes for the TFR airspace to be as far from conventional flights as possible and over sparse or empty landscapes devoid of infrastructure and people. The operations manager sought approval from ATC before activation or deactivation of any segregated airspace; however, the TFR were left active for the duration of flying activities, reducing the risk of errors in airspace release coordination. Changes in airspace restrictions are usually communicated through published NOTAMs, with ATC and Flight Safety Officers directing the flight information system to affected flights and broadcasting on the necessary frequencies as per local procedures. Clearance from ATC was required, using a case-by-case method for any drone flights outside the segregated airspace. The Organizing Committee delayed flying operations during thunderstorms or hazardous weather.

No operators employed mitigations such as parachute arrestor systems or tethered operations, requiring the use of alternative criteria to assess risk levels. A site assessment of Lake Kivu, Rubavu Town, Bugarura Island, and Karongi indicated few fishing vessels (a potential ground risk), with numbers monitored throughout the event. The evaluation involved community engagement with fishermen and ferry operators to determine fishing patterns and likely impacts. Different OSOs underpinned LKC operations safety and risk management, including robust maintenance schedules, crew training and experience requirements, reliable C2 links, and redundancies with adequate procedures during a lost C2 link. Attendees were aware of their responsibilities, such as the relevant trespass laws regarding operations from private land and the need to obtain the appropriate permission before operating from a particular site. As part of the flying safety process, the Flying Committee produced a Post-Flying Report that identified:

- Any safety-related occurrences;
- Any actions or operations non-compliant with the flying approval, such as breaches of NO-FLY-ZONES;
- Organizational or administrative issues that may have an impact on the safety of further or future flying; and
- A copy of the completed participant sheet and schedule flown.

Those reports are stored safely and securely for at least five years.

ENVIRONMENT

The LKC, where applicable, was to have a negligible impact on the environment, populace, and ecosystem around the venues. Whereas only electric and hybrid aircraft were admitted to the competition, limiting the CO2 footprint, the LKC also considered the environmental impact of supporting staff and equipment. Although the LKC was unable to utilize them in 2020, the use of solar panels and storage batteries was investigated, especially at remote droneports and tracking receiver stations for ADS-B.

The design of the segregated airspace route considered potential impacts on local wildlife caused by characteristics of the un-crewed aircraft that are foreign to the environment, such as their noise, appearance, and flying pattern. The LKC-OC monitored the noise during flying activities to collect data for future work in this area. All operations avoided game reserves[377], with bird concentration information monitored via NOTAMs. A particular concern was Ile Tembabagoyi, the largest of the islands in the LKC flying area, which is a refuge to thousands of African straw bats, an almost-endangered species. The LKC-OC further added an exclusion zone (NO-FLY-ZONE) around Ile Tembabagoyi, and all teams were required to remain clear and not overfly it. The organizers identified no additional nesting or roosting sites during the site assessment boat trip on Lake Kivu in September 2019. The en-route charts within Rwanda's AIP[378] list no areas within Rwanda where wildlife could have impacted flight operations. The LKC team nonetheless briefed the UAS operators on the possible environmental impact of flying over Lake Kivu, with operators advised to remain outside restricted areas to comply with national and local environmental regulations and operate 1,000 feet above or avoid potentially sensitive areas entirely. Although the site assessment identified two rubbish dumps near the main droneport in Gisenyi, the team removed those before the commencement of operations. Those could have attracted many birds to move among them whenever a UA took off or landed. Additional environmental concerns included drone parts recycling, lithium battery recycling, and pollution risks at any potential crash sites.

OSHE

At the LVC and LKC, considerations of electrical safety, slipping and tripping accidents, and exposure to the elements formed part of the safety risk-management process.

- Electrical safety — Exposed wiring,

particularly in the absence of no earth leakage circuit breakers (i.e, safety devices to prevent electric shock), and breaks in the main power supply led to occasional power cuts and surges as diesel generators kicked in. Remote droneports relied on 240V portable generators, potentially without safety switches.
- Fire safety — Fire sacks and sand buckets were made available for potential lithium battery fires, with fire extinguishers located at the refueling point and throughout the droneport. In general, any refueling (hydrogen or gasoline, for example) should be conducted clear of all public and operators, preferably in an isolated location, and monitored for fires during all times of use.
- Acceptable behavior — Smoking within the droneports was strictly prohibited as a potential fire hazard. Similarly, operating under the influence of alcohol or drugs was strictly prohibited.
- Occupational hazards — Risk of injury from slipping over uneven and loose surfaces was considered part of the work area risk assessment. Considerations included the risk of falling or dropped objects, especially as "struck by" injuries are common and can occur almost anywhere. During the LKC, for example, a heavy pole and steel ladder fell and damaged equipment, with no injuries.
- Exposure to the elements — Attendees were briefed on sensible clothing, mosquito repellent, and sunscreens for essential protection alongside the need to keep hydrated and under shade as much as possible. The LKC only used reputable boat transport services, with all passengers required to wear life jackets when on a boat.

Appendix C: International (cross-border) flights and multi-country operations

Enabling seamless and safe operations, either in nearby countries or across international borders, requires standard structure and rules and service level agreements among UAS operators, service providers, and competent authorities. Harmonization is one of the critical enablers of cross-border flights, which are still rare for UAS at this stage. Interoperability builds on harmonization and represents an enabler for multi-country operations. One operator can operate in several countries using the same procedures, crew, and equipment without significant adjustment to techniques. They further represent enablers to beyond-country operations and allow service providers and manufacturers access to markets across several regions.

Interoperability also requires agreed-upon UAS regulations and communication, at least regionally and preferably globally. Specifically, commonality in frequency spectrum usage, risk approaches utilizing UTM, data management assurance standards (for example, cybersecurity or software assurance level), education, Aeronautical Information Service and GIS data usage, and "a system of common horizontal, vertical and temporal reference sources compatible with the accuracy and tolerances needed for UA navigation through the airspace"[379] will need to be aligned.

In conventional aviation, international operations involve an aircraft crossing an international border or operating in high-seas airspace. Remote pilots can operate UAS from any approved RPS, unlike conventional aviation, where the cockpit is an integral part of the aircraft. This segregated nature of platform and control gives rise to additional scenarios for international operations, where the RPS only or both the platform and RPS are outside the territory of the state of the operator, such as:

- The UAS platform is operating in the airspace of only one state (state X) at the same time as it is remotely piloted by a remote pilot located in any other state (state Y);
- Either the UAS platform or the RPS is operated in high seas airspace; or
- The UAS platform and RPS are both being operated in territory of a state other than the state of the operator.

In cases where more than one RPS is used for an operation, they may be collocated or even distributed across the globe. In either scenario, operators must ensure the safe and effective handover of piloting control from one RPS to another and the integrity of C2 Links[380].

Cross-border UAS operations may involve ICAO SARPs and the annexes relating to international aviation. Although annexes and SARPs govern conventional aviation and international IFR operations, they do not consider autonomous or low-level cross-border UAS operations. There is no clarity whether it is possible or appropriate for two or more member states to allow exemptions from the ICAO SARPs to allow cross-border flights of UAS in low-level and perhaps even in uncontrolled, Class G airspace — depending on the risk assessment and potentially through atypical situations such as TFR. In theory, SARPs contained within the following annexes may need to be regarded as mandatory. They would apply as the flight crosses a border, even though the UA may be without people or cargo on board:

- Direct impact:
  - Annex 1 – Personal licensing
  - Annex 2 – Rules of the air

- Annex 3 – Meteorological services for international air navigation
- Annex 6 – Operation of aircraft (3 parts)
- Annex 7 – Aircraft nationality and registration marks
- Annex 8 – Airworthiness of aircraft
- Annex 9 – Facilitation
- Annex 11 – Air traffic services
- Annex 12 – Search and rescue
- Annex 13 – Aircraft accident and incident investigation
- Annex 15 – Aeronautical information services
- Annex 17 – Security and safeguarding
- Annex 18 – Transport of dangerous goods
- Annex 19 – Safety management

● Indirect impact:
- Annex 4 – Aeronautical charts
- Annex 5 – Units of measurement used in air
- Annex 10 – Aeronautical telecommunications (5 parts)
- Annex 14 – Aerodromes (4 parts)
- Annex 16 – Environmental protection (2 parts)

The approving member states and ICAO will need to consider how to address complexities and perhaps provide an exemption from many ICAO annexes and SARPs to provide operational approval.

The establishment of a cross-border UTM could help enable such international operations. At the same time as the concept of UTM continues to evolve, it is crucial to ensure global harmonization and interoperability through finding joint agreements on both its framework and principles. To achieve this, ICAO is leading efforts toward the development of a framework for UTM. ICAO recently published its latest version of the UTM framework, which provides the foundations for consistent rules and regulations, promotes best practices and standards, and supports the development of common guidance material consistent with ICAO's principles[381]. Since 2017, ICAO has assembled industry partners at its annual DRONE ENABLE Symposia[382] to provide direction and guidance to harmonize UAS regulatory activities on UTM across the member states. It is a unique opportunity for states, international organizations, industry, academia, and other stakeholders to share their research, best practices, and lessons learned. This common UTM framework will also provide a stepped approach toward integration into the existing ATM system to enable industry, including manufacturers, service providers, and end-users, to grow "safely, economically and efficiently"[383] without disrupting conventional aviation.

The GUTMA and JARUS also provide some guidance toward global harmonization. The Global UTM Architecture proposed by GUTMA represents a framework with interfaces to external systems while representing a potential baseline to define standard interfaces. The methodology requires standardized terminology for phases of operation, procedures, and operational volumes to facilitate effective communication of all aspects of the JARUS SORA. The JARUS SORA Main Body provides key concepts and definitions, with the semantic model being one such notion. Although the SORA aims to support operators and competent authorities and highlight the benefits of a harmonized risk assessment methodology, JARUS also acknowledges the need to accommodate national specificities that cannot be standardized.

From 2020-21, JARUS drafted another of the 10 annexes to the SORA Main Body: Annex H UTM UAS Safety Services Considerations. The annex focuses on the safety functions enabled by third-party services and how services can assure competent authorities that responsibilities are clearly divided among operators and the services they may rely on, at the same time as it addresses core functionality of calculating and mitigating the initial Ground Risk Class or initial Airspace Risk Class, or of fulfilling parts of the OSO. It is important to note that the SORA does not address interactions among multiple UAS, nor does it include wake turbulence as a hazard.


LAKE KIVU
CHALLENGE
Remote Pilot

Endnotes

1 The forthcoming World Bank Report "Towards harmonization of drone regulations" provides an in-depth impact assessment for different sectors.

2 UNICEF Supply Division (2019, Oct), p.9

3 Stokenberga, A., Ochoa, C. (2021)

4 Mauluka, Chancy (2019); Truog, et al. (2020)

5 Cohn, et al. (2017)

6 CASA (2017, Aug 3)

7 The forthcoming World Bank Report "Towards harmonization of drone regulations" provides a framework to support regulatory harmonization efforts.

8 WEF (2018, Dec), p.6

9 ITU (2012-b)

10 FAA (2020, Nov 24)

11 WEF (2021, Mar)

12 WEF (2021, Mar)

13 UNICEF Supply Division (2019, Oct), p.22

14 Whereas the term "unmanned" has been used traditionally, "un-crewed" is increasingly adopted instead.

15 Ministry of Civil Aviation Government of India (2019, Jan); Stokenberga, A., Ochoa, C. (2021)

16 African Union (2018, Jan 25-26)

17 UNICEF Supply Division (2019, Oct), p.3

18 ADF (2021a), p.8

19 WEF (2021, Mar), p.27

20 WEF (2021, Mar)

21 UNICEF Supply Division (2019, Oct), p.9

22 Wright, et al. (2018)

23 Bahrainwala, L., et al. (2020); Haidari, et al. (2016); JK RPAS Consulting (September 2019)

24 Yadav (2015)

25 ISG-UAS (2018, Dec)

26 Stokenberga, A., Ochoa, C. (2021)

27 Levitate Capital (2020)

28 ICAO (2020, Jun 23), Advisory Circular 102-37

29 Yadav (2015); WEF (2021)

30 An updated version of the VillageReach, ISG-UAS (2019, Nov) evidence generation toolkit is currently under development.

31 UNICEF Supply Division (2019, Oct), p.21 provides a summary

32 Stokenberga, A., Ochoa, C. (2021), xvi

33 GAVI the Vaccine Alliance (2020, Aug)

34 ADF (2020, Sep)

35 Phillips, N., et al. (2016); Stokenberga, A., Ochoa, C. (2021)

36 Teravaninthorn, S., Raballand, G. (2009)

37 Stokenberga, A., Ochoa, C. (2021), xiv

38 Stokenberga, A., Ochoa, C. (2021), xiv; Yadav, et al. (2014)

39 Truog, et al. (2020)

40 WEF (2018, Dec), p.9

41 Mauluka, Chancy (2019); Truog, et al. (2020)

42 Greve, A., Dubin, S., Triche, R. (2021), p.7

43 Soesilo, D., Rambaldi, G. (2018, Feb)

44 More about the steering committee can be found here: Department of Civil Aviation Malawi, MACRA, VillageReach, GIZ and UNICEF (2019, Dec)

45 Allen, K. (2016, Mar 15); Crowne Agents (2019)

46 Fabian, C., Fabricant, R. (2014)

47 Van den Hoven, J. et al. (eds.) (2015)

48 Cohn, et al. (2017)

49 WEF (2021, Mar)

50 WEF (2021, Mar)

51 WEF (2021, Mar), p.10

52 WEF (2021)

53 Lewis (2020, May 12)

54 WEF (2021, Mar)

55 World Bank Group (2017)

56 Department of Civil Aviation Malawi, MACRA, VillageReach, GIZ and UNICEF (2019, Dec), p.24

57 ICAO (2021, Feb 9), p.2

58 Rae, T. (2019, Jul 4)

59 ICAO (2021, Feb 9), p.2

60 FSD, DG ECHO (2017)

61 UK CAAi (2020)

62 Ministry of Civil Aviation Government of India (2019, Jan)

63 ICAO (n.d.-a)

64 WEF (2018, Dec)

65 ICAO (2016, Dec 7), 1.1

66 ADF (2021a); Cohn, et al. (2017)

67 EASA (2015, Dec 18); EASA (2016, Feb 16)

68 CASA (2017, Aug 3)

69 EASA (n.d.)

70 Penny, et al. (2001), p.1

71 European Parliament, Council of the EU (2018, Aug 22)

72 EASA (2016, Nov 22), p. 11

73 For example, European Parliament, Council of the EU (2018, Aug 22)

74 ADF (2021a), p.13

75 ADF (2021a), p.13

76 ADF (2021a), p.14

77 SkyBrary (2019, Aug 30)

78 ADF (2021a), p.13

79 SkyBrary (2019, Aug 30)

80 ADF (2021a); SkyBrary (2019, Aug 30)

81 ADF (2021a), pp. 13-14 on Prescriptive vs. performance-based regulatory elements

82 La Cour-Harbo (2017). This does not preclude CAAs from imposing operational limitations, however (see Government of India, 2018, Aug 27, for example)

83 14 CFR § 91.13

84 EASA (2021, Apr), p.10

85 ICAO (2015)

86 ICAO (n.d.-b)

87 ICAO (2020, Jun 23), p. 1 (Parts 101/102)

88 ICAO (2006)

89 ICAO (2021, Feb 9), p.8

90 ICAO (2017, Mar), p.4

91 Ministry of Civil Aviation Government of India (2019, Jan)

92 Ministry of Civil Aviation Government of India (2019, Jan), p.7

93 ICAO (2020), p.7

94 ADF (2021a)

95 ICAO (2005)

96 ICAO (2005), p. 1-1

97 Eurocontrol (2011, Sep 20)

98 McLeay et al. (1999)

99 ADF (2021a), p.15

100 ICAO (2020, Jun 23)

101 EASA (2021-b)

102 SESAR (2018)

103 ICAO Annex 1 - Personnel Licensing

104 ICAO (2020, Jun 23)

105 ICAO (2016, Dec 7)

106 ICAO (2020)

107 ICAO (2015)

108 WEF (2018, Dec), p.6

109 Ministry of Civil Aviation Government of India (2019, Jan)

110 ICAO (2015)

111 FAA (2020, Mar 2)

112 Norman Foster Foundation (n.d.)

113 Crowne Agents (2017, May 4)

114 Brown, A. (2020, Feb 5)

115 ITU (2012-b)

116 ITU (2012-b)

117 FAA (2020, Mar 2)

118 SESAR (2020)

119 Airmap (2019, Feb 19)

120 EASA (2015, Oct 12)

121 GSMA (2018)

122 ICAO (2021, Feb 9)

123 EC (2021, Apr 22); SESAR (2020)

124 GSMA (2018)

125 ICAO (2019, Nov 8)

126 ASTM (2019)

127 FPF (2016, Aug 2), p.3

128 ICRC (2020); WEF (2021, Mar)

129 Department of Civil Aviation Malawi, MACRA, VillageReach, GIZ and UNICEF (2019, Dec), p.8

130 OpenAerialMap (n.d.)

131 Ministry of Civil Aviation Government of India (2019, Jan)

132 FPF (2016, Aug 2)

133 ICRC (2020)

134 World Bank Group (2017), p.35; Directorate-General for Internal Policies of the Union (European Parliament) (2015)

135 ICRC (2020)

136 Creative Commons (2019)

137 ICAO (2021, Feb 9), p.2

138 UN 3480 or UN 3481

139 Greve, A., Dubin, S., Triche, R. (2021), p.9

140 EC (2009, May 5), Annex I

141 ADF (2021a)

142 Greve, A., et al. (2021).

143 FAA (2020, Nov 24)

144 Department of Civil Aviation Malawi, MACRA, VillageReach, GIZ and UNICEF (2019, Dec), p.8

145 Department of Civil Aviation Malawi, MACRA, VillageReach, GIZ and UNICEF (2019, Dec), p.8

146 WEF (2021, Mar)

147 WEF (2021, Mar), p.32

148 UAV coach (n.d.); WEF (2021, Mar)

149 Global-Aero (n.d.)

150 European Union Committee (2015, Mar 5), p.54

151 USAID GHSC-PSM (2018, Jul 9)

152 JK RPAS Consulting (September 2019)

153 Third-party logistics (3PL) model providers in particular might require upfront investments into the infrastructure

154 FAA (2017, Sep 11)

155 Chakib, M. (2018, Nov)

156 Mendez, E. (2019, Aug 13)

157 ICAO (2016, Dec 7)

158 EASA (2021, Apr), p. 215

159 ICAO (2018)

160 EASA (2019, Oct 9); JARUS (2019, Jan)

161 ICAO (2020)

162 ICAO (2017, Mar), p.16

163 JARUS (2019, Jan 30), p.17

164 ICAO (2020, Jun 23)

165 JARUS (2019, Jun 21),

166 World Bank Group (2017)

167 ICAO (2018), 1-5

168 ICRC (2020), p.78

169 World Bank Group (2017), p.37

170 As of January 2021, JARUS will consider areas with fewer than one person as “controlled”, “sparse” with 1-300 people, and “populated” with 300-15,000 people. Discussion on what constitutes a “gathering” are ongoing

171 If the UAS is planned to operate at a height of 400 feet, the ground risk buffer should at least be 400 feet.

172 ICAO (2018)

173 JARUS (2019, Jan)

174 EASA (2019, Oct 9), p.18

175 JARUS (2019, November 11)

176 Civil Aviation Authority UK (2020, Nov 5)

177 WEF (2018, Dec), p.11

178 JARUS (2019, Jan), p.19

179 IEEE Computer Society (March 19, 1998)

180 JARUS (2019, Sep 25)

181 ICAO (2017, Mar), p.1

182 EASA (2019, Oct 9), p.17

183 EASA (2019, Oct 9), p.19

184 JARUS (2019, Jul 11)

185 European Parliament, Council of the EU (2018, Aug 22)

186 ICAO (2015)

187 ICAO (2020, Jun 23)

188 Sanjeev Gadhia as quoted by Pinto, N. (n.d.)

189 EASA (2019, Oct 9), p. 8

190 JARUS (2019, June 21)

191 ICAO (2016, Dec 7)

192 JK RPAS Consulting (2019, Sep), Lake Kivu Challenge (see Annex B)

193 This topic will be discussed more in-depth in a forthcoming World Bank Report, "Towards harmonization of drone regulations"

194 Truog, et al. (2020)

195 ICAO (2015); ICAO (2020, Jun 23), Parts 101 and 102

196 WEF (2018, Dec), p.9

197 ICAO (1991)

198 EASA (2019, Oct 9)

199 See for example, ADF (2020), OSOs: MAC-TB#3

200 Knoblauch, et al. (2019), Table 3

201 JARUS (2019, Jan 30), Annex B

202 UNICEF Supply Division (2019, Oct), p.25

203 UNICEF Supply Division (2019, Oct), p.19

204 Knoblauch, et al. (2019), Table 3

205 Stokenberga, A., Ochoa, C. (2021)

206 WEF (2021, Mar)

207 WEF (2018, Dec) p.18

208 UNICEF Supply Division (2019, Oct), p.22

209 Environmental impacts are covered more in-depth in the forthcoming World Bank Report, "Towards harmonization of drone regulations”

210 210 Greve, A., Dubin, S., Triche, R. (2021).

211 WEF (2021, Mar), p.18

212 Greve, A., Dubin, S., Triche, R. (2021).

213 Stokenberga, A., Ochoa, C. (2021), xix

214 https://www.unicef.org/innovation/AfricanDroneAcademy

215 https://www.Africandroneforum.org/

216 https://www.aw-drones.eu/

217 FSD, DG ECHO (2017)

218 https://www.eurocae.net/about-us/working-groups/

219 https://www.assureuas.org/about/

220 https://flightsafety.org/

221 https://flyinglabs.org/; WEF (2018, Dec), p.19

222 https://gutma.org/

223 For more information, visit isghealth.org and isghealth.org/uas-coordinating-body/.

224 https://www.icao.int/about-icao/Pages/default.aspx

225 ICAO (2020, Jun 23)

226 https://www.iso.org/committee/5336224.html

227 https://www.jarus-rpas.org

228 https://www.rtca.org/sc-228/

229 https://www.sesarju.eu/discover-sesar

230 UEMOA (2019)

231 https://www.updwg.org/md3/

232 Economist (2017, Jun 8)

233 JARUS (2018, Jul 11), p.2

234 JARUS (2018, Jul 11), p.2

235 JARUS (2017, Jun 26)

236 JARUS (2019, Jul 11)

237 FAA (2017, May 9); JARUS (2017, Jun 26)

238 FAA (2000, Dec 30); FAA (2017, May 9); JARUS (2017, Jun 26)

239 ICAO (2015); ICAO (2017, Mar)

240 ICAO (2015); ICAO (2020, Jun 23)

241 ICAO (2021, Feb 9)

242 ICAO (2020, Jun 23), Parts 101 and 102

243 ICAO (2015); ICAO (2020, Jun 23), Parts 101 and 102; ICAO (2021, Feb 9)

244 JARUS (2015, Sep)

245 EASA (2019, Oct 9)

246 JARUS (2017, Jun 26)

247 ICAO (2015); ICAO (2021, Feb 9)

248 ICAO (2021, Feb 9)

249 ICAO (2020, Jun 23), Parts 101 and 102; ICAO (2021, Feb 9)

250 JARUS (2017, Jun 26); SAE (1996, Dec)

251 ICAO (2017, Mar)

252 JARUS (2017, Jun 26)

253 SAE (1996, Dec)

254 Adapted from JARUS (2017, Jun 26)

255 FAA (2000, Dec 30)

256 Adapted from JARUS (2018, Jul 11)

257 ICAO (2011)

258 JARUS (2017, Jun 26)

259 Adapted from geo-fencing in JARUS (2018, Jul 11)

260 McCord, J., Tien, M., Sarley, D. (2013)

261 JARUS (2017, Jun 26); SAE (1996, Dec)

262 JARUS (2017, Jun 26)

263 JARUS (2017, Jun 26)

264 ICAO (2011); ICAO (2015); ICAO (2017, Mar); ICAO (2020, Jun 23), Parts 101 and 102; ICAO (2021, Feb 9); JARUS (2017, Jun 26)

265 ICAO (2011)

266 JARUS (2018, Jul 11)

267 FAA (2016, Feb)

268 JARUS (2017, Jun 26); SAE (1996, Dec)

269 SAE (1996, Dec)

270 JARUS (2015, Sep)

271 JARUS (2017, Jun 26)

272 FAA (2017, May 9)

273 FAA (2020, Mar 2)

274 ICRC (2020)

275 JARUS (2017, Jun 26)

276 JARUS (2017, Jun 26); ICAO (2015)

277 JARUS (2017, Jun 26)

278 JARUS (2017, Jun 26); JARUS (2018, Jul 11)

279 ICAO (n.d.-c)

280 JARUS (2017, Jun 26)

281 ICRC (2020)

282 JARUS (2017, Jun 26); ICAO (2015); ICAO (2017, Mar); ICAO (2020, Jun 23), Parts 101 and 102; ICAO (2021, Feb 9)

283 JARUS (2017, Jun 26)

284 JARUS (2017, Jun 26); JARUS (2018, Jul 11)

285 FAA (2000, Dec 30); JARUS (2017, Jun 26); JARUS (2018, Jul 11)

286 JARUS (2017, Jun 26)

287 SAE (1996, Dec)

288 FAA (2000, Dec 30); SAE (1996, Dec)

289 JARUS (2017, Jun 26)

290 European Parliament, Council of the EU (2018, Aug 22)

291 ICAO (2015)

292 ICAO (2021, Feb 9)

293 JARUS (2017, Jun 26)

294 EASA (2021, Apr)

295 JARUS (2017, Jun 26); SAE (1996, Dec)

296 JARUS (2017, Jun 26); JARUS (2019, Jan)

297 JARUS (2019, Jul 11)

298 JARUS (2017, Jun 26)

299 JARUS (2017, Jun 26)

300 FAA (2000, Dec 30)

301 JARUS (2017, Jun 26); SAE (1996, Dec)

302 SAE (1996, Dec)

303 JARUS (2017, Jun 26)

304 IATA (2019, Dec 12)

305 JARUS (2018, Jul 11)

306 ICAO (2015)

307 ICAO (2015)

308 EASA (2021, Apr)

309 JARUS (2017, Jun 26)

310 ICAO (2020, Jun 23), Parts 101 and 102

311 ICAO (2017, Mar); ICAO (2020, Jun 23), Parts 101 and 102

312 McCord, J., Tien, M., Sarley, D. (2013)

313 ICAO (2015); JARUS (2017, Jun 26)

314 ICAO (2015); ICAO (2017, Mar); ICAO (2021, Feb 9); JARUS (2017, Jun 26)

315 EASA (2021, Apr)

316 ICRC (2020)

317 JARUS (2017, Jun 26); JARUS (2018, Jul 11)

318 JARUS (2017, Jun 26); JARUS (2018, Jul 11)

319 JARUS (2017, Jun 26); JARUS (2018, Jul 11)

320 FAA (2000, Dec 30); JARUS (2017, Jun 26)

321 McCord, J., Tien, M., Sarley, D. (2013)

322 ICAO (2011)

323 SAE (1996, Dec)

324 JARUS (2017, Jun 26); SAE (1996, Dec)

325 JARUS (2017, Jun 26)

326 FAA (2020, Mar 2)

327 ICAO (2015); ICAO (2017, Mar); ICAO (2020, Jun 23), Parts 101 and 102; ICAO (2021, Feb 9); JARUS (2015, Sep)

328 ICAO (2015); ICAO (2017, Mar); ICAO (2020, Jun 23), Parts 101 and 102; ICAO (2021, Feb 9)

329 ICAO (2015); JARUS (2015, Sep)

330 ICAO (2021, Feb 9)

331 EASA (2019, Oct 9); JARUS (2019, Jan)

332 FAA (2000, Dec 30); JARUS (2017, Jun 26)

333 FAA (2000, Dec 30); JARUS (2017, Jun 26)

334 EASA (2016, Nov 22); EASA (2019, Oct 9)

335 FAA (2000, Dec 30)

336 ICAO (2015); ICAO (2020, Jun 23), Parts 101 and 102

337 EASA (2016, Nov 22); EASA (2019, Oct 9)

338 FAA (2000, Dec 30)

339 JARUS (2018, Jul 11)

340 ICAO (2015); ICAO (2018); ICAO (2020, Jun 23), Parts 101 and 102; JARUS (2017, Jun 26)

341 FAA (2017, May 9)

342 FAA (2017, May 9)

343 ICAO (2015); ICAO (2020, Jun 23), Parts 101 and 102

344 FAA (2017, May 9); JARUS (2017, Aug 26)

345 ICAO (2018)

346 EASA (2016, Nov 22); EASA (2019, Oct 9)

347 FAA (2017, May 9)

348 FAA (2017, May 9)

349 ICAO (2015); ICAO (2018)

350 FAA (2017, May 9)

351 ICAO (2011); ICAO (2015); ICAO (2017, Mar); ICAO (2020, Jun 23), Parts 101 and 102; ICAO (2021, Feb 9); JARUS (2017, Aug 26)

352 JARUS (2017, Aug 26); JARUS (2018, Jul 11)

353 FAA (2017, May 9); JARUS (2017, Aug 26)

354 ICAO (2021, Feb 9)

355 JARUS (2019, Jan)

356 Adapted from JARUS (2017, Aug 26)

357 JARUS (2017, Aug 26)

358 SAE (1996, Dec)

359 EASA (2021, Apr)

360 JARUS (2017, Aug 26); JARUS (2018, Jul 11)

361 ICAO (2017, Mar)

362 IATA (2019, Dec 12); ICAO (2015); ICAO (2017, Mar)

363 ICAO (2017, Mar)

364 FAA (2000, Dec 30)

365 JARUS (2015, Sep)

366 ICAO (2015)

367 EASA (2021, Apr)

368 ICAO (2021, Feb 9)

369 EASA (2021, Apr)

370 JARUS (2017, Aug 26); JARUS (2019, Jan), Annex C

371 ICAO (2011); ICAO (2021, Feb 9); JARUS (2017, Aug 26)

372 JARUS (2018, Jul 11)

373 Adapted from ICAO (2015); ICAO (2017, Mar); ICAO (2020, Jun 23), Parts 101 and 102; ICAO (2021, Feb 9)

374 ICAO (2018)

375 JARUS (2017, Jun 26), p.5

376 Rwanda CAA (2019-a, 2019-b)

377 Rwanda CAA (2018, Jul 19), ENR 5.6

378 Rwanda CAA (2018, Jul 19), ENR 6.8, ENR 6.9

379 ICAO (2021, Feb 9), p.10

380 ICAO (2015)

381 ICAO (2021, Feb 9)

382 https://www.icao.int/meetings/UAS2017/Pages/default.aspx

383 ICAO (2021, Feb 9), p.2