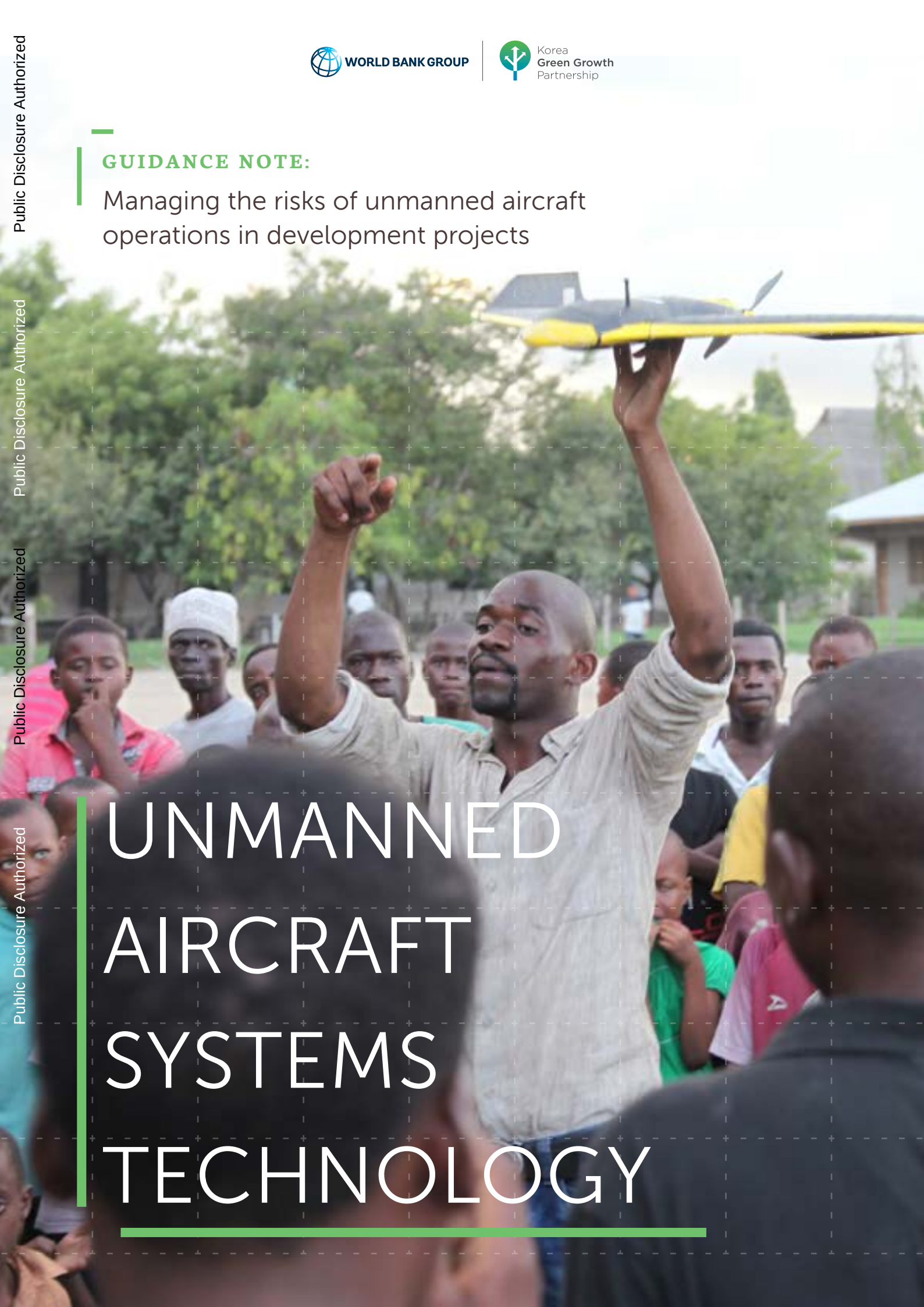
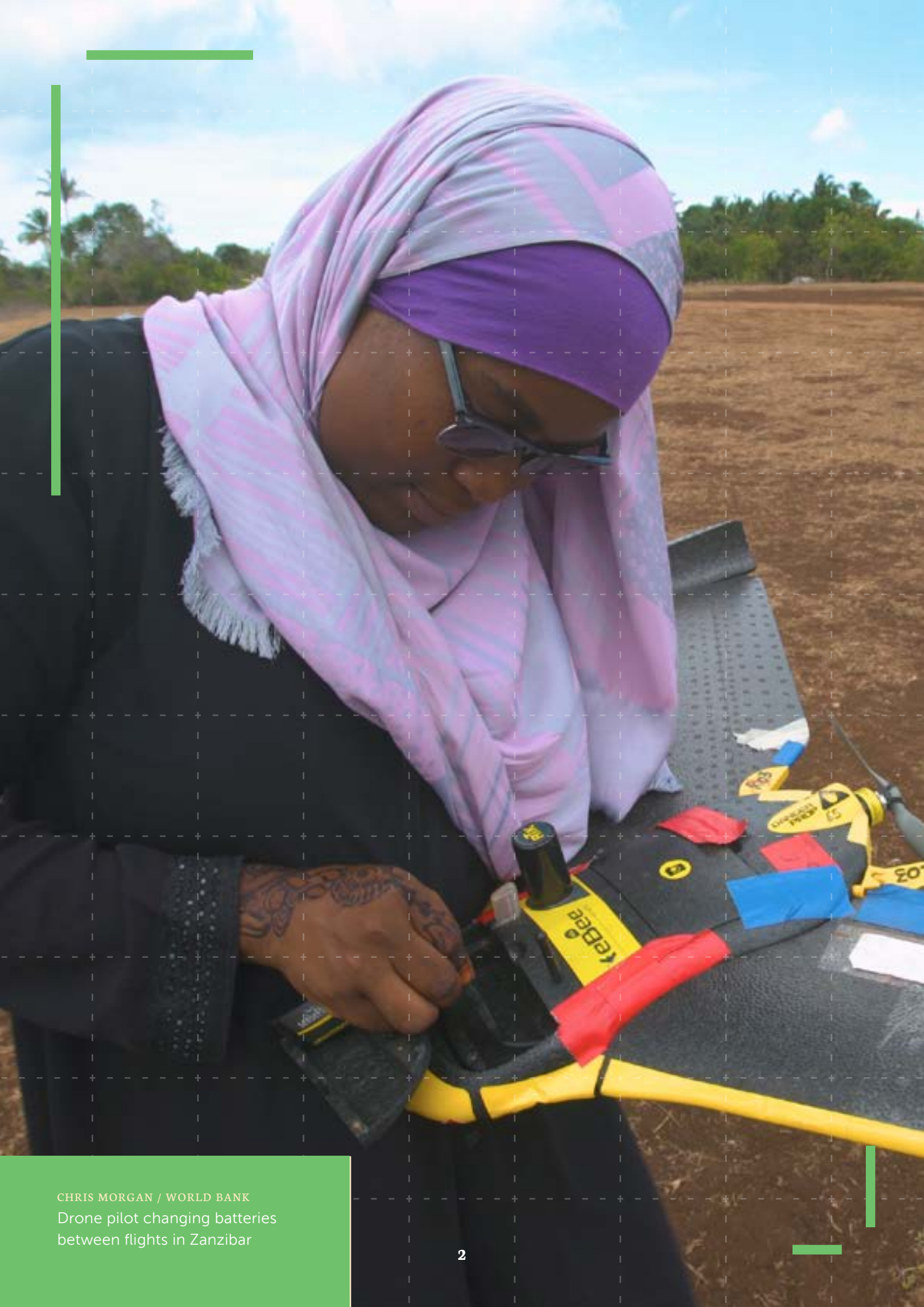
WORLD BANK GROUP | Korea Green Growth Partnership

GUIDANCE NOTE:

Managing the risks of unmanned aircraft operations in development projects



UNMANNED AIRCRAFT SYSTEMS TECHNOLOGY



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Drone pilot changing batteries between flights in Zanzibar

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COVER: MARK ILIFFE
Preparing for launch in a schoolyard.

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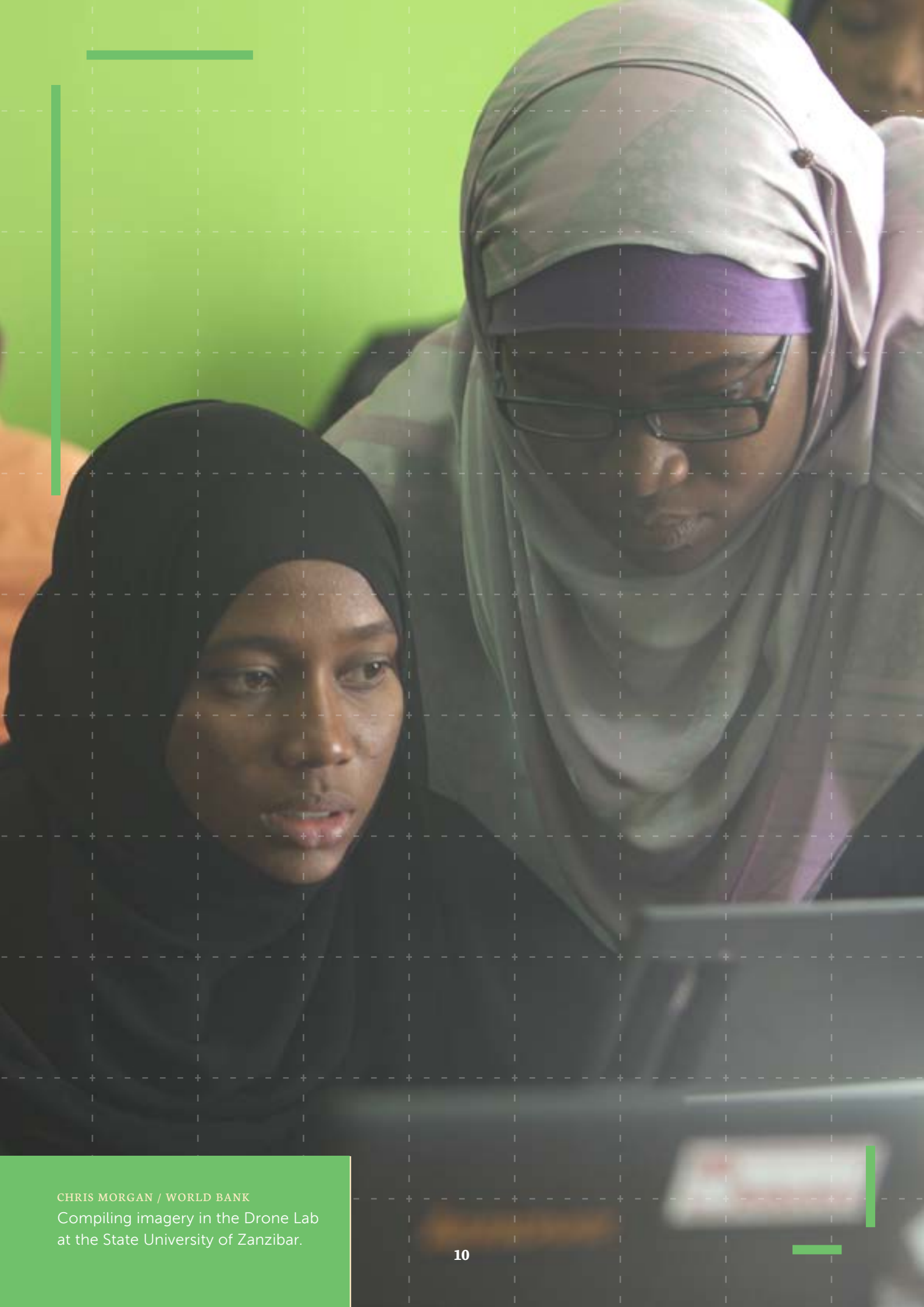
A Sensefly eBee UA in flight.

LIST OF ACRONYMS

ACAS	airborne collision avoidance system
ADS-B	automatic dependent surveillance - broadcast
AGL	above ground level
ALARP	as low as reasonably practicable
ARIES	authority/regulation/insurance/environmental/security
ATC	air traffic control
ATM	air traffic management
ATZ	aerodrome traffic zone
BVLOS	beyond visual line of sight
C2	command & control
CC BY 3.0	Creative Commons Attribution 3.0
CCTV	closed-circuit television
CTR	control zone
EASA	European Aviation Safety Agency
ERSG	European RPAS Steering Group
ESF	Environment and Social Framework
EUROCAE	European Organisation for Civil Aviation Equipment
EVLOS	extended visual line of sight
FAA	Federal Aviation Authority
FPV	first-person view
FW	fixed wing
GPS	global positioning system
ICAO	International Civil Aviation Organization
IFR	instrument flight rules
ISO	International Standards Organization
ITAR	International Traffic in Arms Regulations
JARUS	Joint Authorities for Rulemaking on Unmanned Systems
NAA	National Aviation Authority
NASA	National Aeronautics and Space Administration
OEM	original equipment manufacturer

LIST OF ACRONYMS

PIA	privacy impact assessment
QE	qualified entity
RA	risk assessment
RFID	radio frequency identification
RLP	required link performance
RP	remote pilot
RPAS	remotely piloted aircraft system
RPS	remote pilot station
RTCA	Radio Technical Commission for Aeronautics, Inc.
RW	rotary wing
SAA/DAA	sense and avoid/detect and avoid
SARPs	standards and recommended practices
SMS	safety management system
SORA	specific operation risk assessment
SWaP	size, weight, and power consumption
TCAS	traffic alert and collision avoidance system
TLS	Target Levels of Safety
TOL	take-off and landing
UA	unmanned aircraft
UAS	unmanned aircraft systems
UASSG	UAS study group
UAV	unmanned aerial vehicles
UK CAA	United Kingdom Civil Aviation Authority
US	United States
USD	United States dollar
UTM	UAS traffic management
VLOS	visual line of sight
VTOL	vertical take-off and landing
WBG	World Bank Group



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Compiling imagery in the Drone Lab at the State University of Zanzibar.

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FREDDIE MBUYA / UHURULABS
Drone pilot trainee practicing with a DJI Phantom.

2. INTRODUCTION

From an origin in military and security applications, the use of unmanned aircraft (UA) technology is currently transforming commercial and humanitarian activity. Its evolution started many decades ago, but was limited by the technology of the time; in recent years, advances in this area have facilitated an increasingly rapid expansion of UA technology that has started to move into a variety of sectors. As the societal benefits of UA become clearer, organisations across the commercial and government spectrum seek to exploit the technology to improve their business models and offer a safer, cleaner, and more cost-effective alternative to traditional data-capture methods.

UA activity is limited currently by the slow pace of regulatory change at the global, regional, and national levels. The pace of this change is driven by the need for seamless integration into an existing dynamic air traffic environment such that a proliferation of UA will not compromise levels of aviation safety. Another critical consideration is the safety of people, property, and infrastructure on the ground and how these may be impacted by UA operations that currently do not have the known levels of reliability that conventionally piloted aircraft (i.e., manned aircraft) have. Finally, there is also a need to maintain standards of privacy and the protection of personal data as the industry develops, while considering environmental impact.

All of these factors are important considerations for users, whether they intend to outsource through established services or grow and operate in-house UA capabilities in support of their business. In either case, it is critical to understand what the business and operational risks are and ensure mitigation measures are in place. Understanding the risks will inform commensurate UA platform selection to enable optimal operations. The more expansive and diverse the activity, or the closer the operation's proximity to dense populations, busier airspace, or critical ground infrastructure, the more focus needs to be placed on ensuring that effective governance is applied and safety and operational standards are maintained.

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Zanzibar drone team reviewing flight status.

These considerations are amplified when operating in a large organisation whose strategic reach means multiple concurrent operations in different regulatory environments and industry sectors across the globe.

This guidance note provides an overview of the recent rapid emergence and possible uses of UA; discusses potential risks and appropriate operational and regulatory considerations that need to be taken into account while planning and executing UA operations; and provides recommendations for how to apply UA technologies within World Bank Group (WBG) operations and related client activities. Costing of UA flights is complex and presently considered outside of the scope of this guidance.

There is no universal term that refers to unmanned aircraft (UA). Alternatives are unmanned aerial vehicles (UAV); unmanned aircraft systems (UAS); remotely piloted aircraft system (RPAS); and drone – a term used mainly by the media. This guidance note will use UA unless context requires a different term. If required, the complete system (remote pilot, ground control system, and control/communication links) will be referred to as the UAS. In this case, UA refers to the flying portion.

In addition, Annex C – WBG UAS Operational Checklist Form in this guidance note provides an operational planning framework for UAS operators to apply to each flying task. It provides the planner with a series of operational, authorization, regulation, insurance, environmental, and security questions that should be answered before a flying task is conducted.

provided ways UA can be put to work to further humanitarian goals, a review of UA field use case studies, and an overview of the core components of the UA system.

It is hoped that this guidance note will provide a basis for future discussion of UA in WBG operations. Further work on topics such as data policy, differential analysis of costs, and task team operational manuals,

> The global commercial drone market size was estimated to be USD 552 million in 2014 and is expected to grow at a rate of 16.9% over the forecast period (2014- 2022)[1]

This guidance note acknowledges and complements previous work published in 2016 by the WBG, "UAV State-of-Play for Development," which was intended as a brief overview of how UAS work. It also

among others, would be a welcome and vital addition in enabling the WBG to explore the full potential of this emergent technology for the achievement of its strategic goals.

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Camera being fitted to an eBee UA.

3. WBG USE OF UA TECHNOLOGY

The global market for UA has grown exponentially in the past decade, driven by the needs of civil commercial operations in a variety of industry sectors. Enabling this growth has been the accelerated progress of UA technology, such that capabilities that were unachievable only three to four years ago are now possible.

Future applications are numerous, and although more sophisticated uses are being pioneered, until now, applications have been mainly focused on imagery capture for survey, inspection, and security activities. Applications are commonly segregated under the following operations titles:

"Aerial Delivery," "Aerial Surveillance or Survey," and "Other Uses" and include:

- Delivery (medical supplies, mail, groceries)
- Cargo (including passengers)
- Search and rescue or disaster response
- Meteorology (airborne weather sensors)
- Radiological sensing
- Atmospheric sensing
- Environmental sensing
- Agricultural (data collection and pesticide spraying)
- Internet provision (through a perpetually airborne network of UA)
- Firefighting (urban and forest fires)

Emerging markets include emergency services, agriculture, security, and a wide range of data capture and infrastructure inspection activities in the fields of construction, utilities, energy, insurance, and renewables.

UA offer a new way to perform tasks that previously required the use of conventional aircraft and/or a person working in dull, dirty, or dangerous situations. Humanitarian and conservation applications have also increased and future markets will be driven by the need to manage the earth's scarce resources, from urban development to natural resources and disasters, to energy and people. As industry changes its appetite for the utilisation of UA technology, it has to adapt to new operational challenges and

risks.

The WBG will normally be involved in UA operations in two ways:

1. Recipient-executed activities: The client government or designated agency operates the UA themselves or outsources to an appropriately equipped organisation to deliver the services, using WBG project funds channelled via the government. Although not mandatory, the UAS operator should be selected using a structured selection framework to ensure consistent supplier quality and compliance with recognised best-practice risk-management processes.
    - Outsourced solution - In the case of an outsourced supplier, liability and related insurance requirements will be the responsibility of the nominated organisation. The procurement documents should specifically cover liability/indemnity, insurance requirements, safeguards, and other duties of the contractor.
    - WBG-funded client activity - In cases where Bank funds are purchasing the equipment for the client, the task team will need to make a broader due diligence assessment: capacity of the client to operate and manage UA productions safely, liability and insurance requirements (i.e., does the Bank require the government organization to be insured?), training and certification of operators, etc. Procurement documents should include the necessary training, certification, etc., in addition to hardware/software specifications. Procurement processes should also consider International Traffic in Arms Regulations (ITAR), as they will govern acquisition strategy for these types of operations.

UA come in all shapes, sizes, and weights, although in the commercial sector, the vast majority are small, weighing less than 20 – 25kg. UA have three main configurations· fixed wing (FW), rotary wing (RW), and hybrid.

FW UA – Configured like a traditional FW aircraft, FW UA have a range of landing and take-off profiles usually with a bigger footprint. Their flight profile means that they are more aerodynamically efficient and usually have a longer range and greater flight endurance.

RW UA – RW 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 Vertical Take-Off and Landing (VTOL) capability that makes them more operationally versatile.

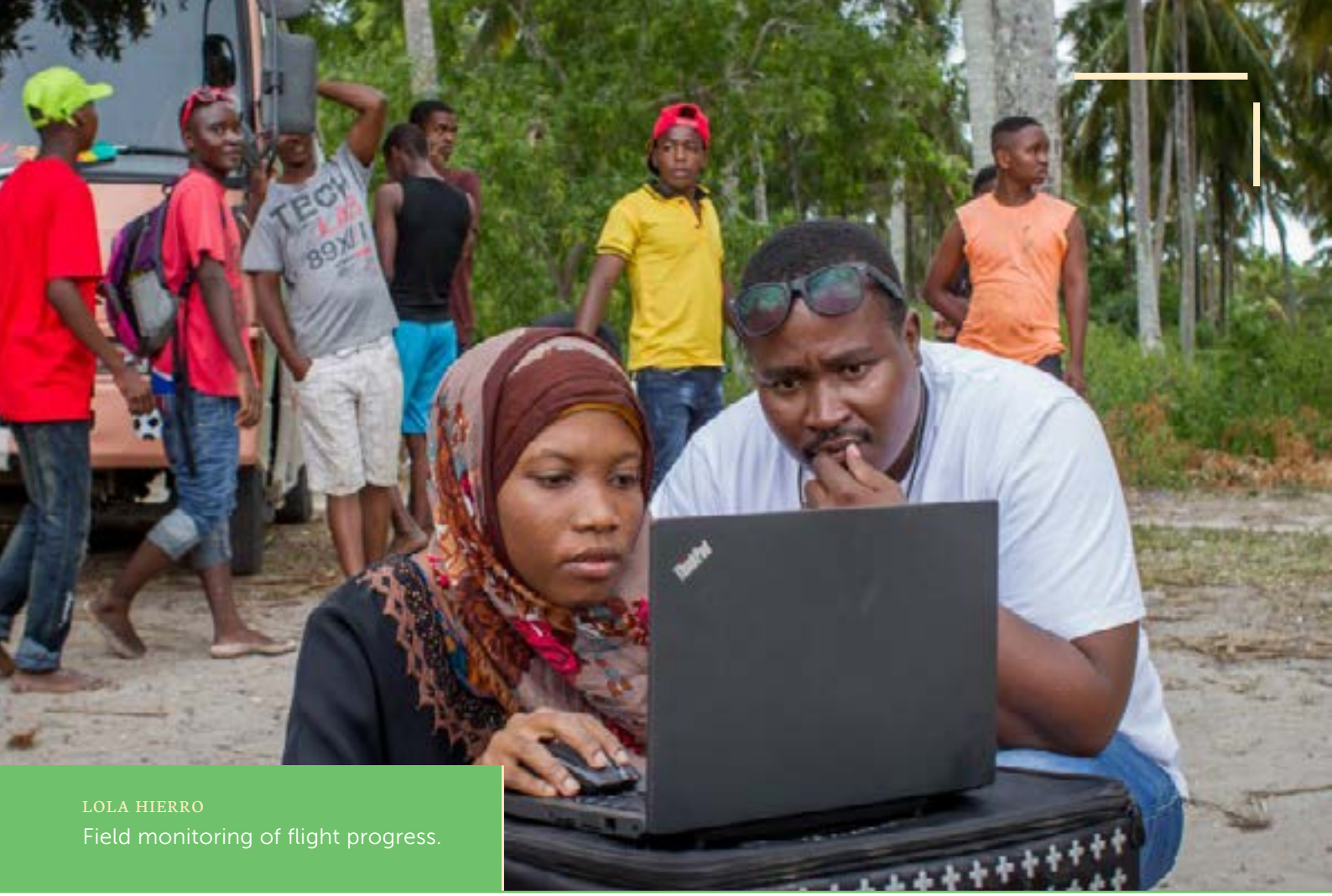
LOLA HIERRO
Overlaying drone imagery for Nungwi, North Zanzibar.

> WBG has a responsibility to ensure that all its activities are conducted safely and risks are managed appropriately.

2. WBG-executed operations: The World Bank may require UA services to directly support its activities. These are typically smaller activities focussing on training and knowledge sharing, or on monitoring, supervision, feasibility studies, and risk assessment. To ensure that outsourced services are sufficiently safe and professional, shortlisted companies should undertake an appropriately rigorous due diligence process. The obvious benefit is to ensure that quality - and safety-driven service providers - can be identified and approved.

WBG operations are considered to be commercial and are therefore not under the regulations governing recreational or hobbyist activities.

WBG has a responsibility to ensure that all its activities are conducted safely and risks are managed appropriately. This duty of care extends beyond operational safety and includes the WBG's strong commitment to protection for people and the environment (underscored by



LOLA HIERRO
Field monitoring of flight progress.

the WBG's new Environment and Social Framework (ESF), launched in 2016) as well as to data protection and security.

The use of UA technology offers direct benefits to WBG's wider activities. These benefits are many and varied, and include:

- Higher-quality data available in larger quantities
- Reduced planning cycles
- More efficient work processes
- More flexible, affordable verification tools
- Reduced risks to WBG staff and people and infrastructure in the project area
- Lower costs

The evolution of UAS technology and regulations will have additional beneficial applications outside of the commercial sector, principally in humanitarian applications.

4. REGULATORY EVOLUTION

4.1 CURRENT UA REGULATIONS

For small UA (typically under 20 – 25kgs in weight), there are basic operating principles in place to reduce (but not eliminate) risks to other airspace users and people and property on the ground. Broadly speaking, these principles are:

- Operation within visual line of sight (VLOS) of the operator but not beyond 500m from the launch point
- Flight not above 400ft (120m)
- Flights must yield right of way to other aircraft
- Limits on flights over large groups of people or urban areas
- Limits on proximity to people during flight and critical stages of flight (take-off/landing)
- The UA must be equipped with a return-to-home function in case of loss of radio link
- In most cases, UA may not fly within 5km of an airport

With a few exceptions, these principles have been broadly adopted across many of the countries with emerging market economies as an interim step towards more evolved and integrated UA operations. The regulations are very much geared to providing some procedural separation from people on the ground and conventionally piloted aircraft in relatively low-risk environments. The industry continues to evolve as UA are required (and able) to fly further, higher, and longer and the number of platforms and flights escalates. Only fragmented or restrictive regulatory frameworks impede this otherwise unfettered growth.

The regulating body responsible for international aviation, the Inter- national Civil Aviation Organization (ICAO), is a specialised agency of the UN and has 191 member states. ICAO is tasked with ensuring safe, efficient aviation through the Chicago Convention, including 19 annexes and over 10,000 standards and recommended practices (SARPs). ICAO does not yet stipulate regulations for UA in autonomous or low-level operations, but it does for international cross-border

operations, or if the mission is certified to the level of a conventional aircraft (for example, flying under instrument flight rules (IFR)). Amending SARPs can take five to seven years, while global implementation of new rules can take decades and differences may still exist in several countries. ICAO established the UAS study group (UASSG) in 2007 with the goal of supporting regulation and guidance development. The Remotely Piloted Aircraft Systems Panel superseded the UASSG in 2014, and was scoped to facilitate the safe, secure, and efficient integration of UA into non-segregated airspace and aerodromes while maintaining existing levels of safety for manned aviation. "Segregated" refers to airspace set aside for UA only, with access denied or restricted to conventional aviation.

To fill this regulatory void, several ICAO member states have formulated their own regulations. This has led to a patchwork of different policies and a lack of standardisation when operating in different countries; Europe is an excellent example of this. Since 2015, however, the European Aviation Safety Agency (EASA), under the direction of the European Commission, has expanded its regulatory role beyond its previous mandate of operations heavier than 150kg and will now be responsible for all unmanned regulations in Europe. EASA is successfully adapting the regulatory framework to the rapid adjustments that need to be made to safely and constructively accommodate UA in a harmonised, unhampered manner to create a strong market balanced with the local needs of states.

4.2 TRANSITION TO A RISK-BASED SAFETY APPROACH

EASA has a strong working relationship with the US through the Federal Aviation Authority (FAA). Both participate and are supported by technical groups such as:

- Joint Authorities for Rulemaking on Unmanned Systems (JARUS), delivering mature UA guidance for authorities to use in rulemaking efforts
- Radio Technical Commission for Aeronautics, Inc. (RTCA) developing standards to support authorities' rulemaking programs focussed on Detect and Avoid and Command & Control (C2) performance
- ASTM International, centred on airworthiness systems
- European Organisation for Civil Aviation Equipment (EUROCAE), which works closely with RTCA and deals with the standardization of electronics in aviation

Both Europe and the US have strong steering groups, such as the European RPAS Steering Group (ERSG), Drone Advisory Committee, and Focus Area Pathfinder Program. From these groups, the FAA, EASA, and others have adopted a risk-based safety approach to the integration of UA into the air traffic management (ATM) system. Additional countries and regions are also embracing this method.

The greatest challenges for integration of

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COLA representative preparing eBee for launch

MARK ILIFFE
Preparing an eBee UA in the field.

UA stem from the expectation that they must meet the equivalent levels of safety applied to conventionally piloted aircraft, while integrating in a seamless manner into the present ATM structure and being transparent to air traffic control (ATC), all without penalising other airspace users. Further challenges arise as security, privacy, and environmental issues must also be addressed for UA operations.

Target Levels of Safety (TLS) is a generic term signifying the level of risk that is considered acceptable. It is a concept specific to the aviation industry and one that will – or should – be adopted by the UA sector. The objective of TLS for manned aviation is to protect the human on-board (i.e., crew and/or passengers) by reducing risk through mitigation or prevention to an acceptable level that is as low as reasonably practicable (ALARP). Many aviation risks are mitigated through having a human in the cockpit to, for example, sight and avoid conflicting traffic, fly clear of dangerous terrain or weather, or troubleshoot failure states. This is, of course, different for UA, where trade-offs need to be considered until suitable extraordinary technological advances will replace the pilot on-board. These trade-offs are less difficult for the vast majority of present unmanned missions by small, light vehicles operating at low levels and proximate to the remote pilot (RP), who can visualise the environment around the mission. The risk of injury from the UA to nearby people or damage to sensitive infrastructure, however, needs to be addressed.

This equation is complicated with flights beyond the visual range of the RP or observers, as adequate on-board sensing (i.e., light, functional, low energy consumption) and separation from other airspace users, terrain, weather, wildlife, etc., is not yet possible. In addition, the communication and control links between the RP and the UA are not yet considered reliable outside radio line of sight.

Furthermore, heavier or faster platforms raise the airspace and ground risk significantly, as do operations over areas of high population density or complex/dense air traffic. A small UA 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.

any objects from aircraft in the majority of states, yet this ability could be instrumental in humanitarian missions and could prove to be extremely safe in specific operations utilising small UA flying slowly at low level.

Global and regional regulatory bodies are grappling with the challenges that UA operations present in terms of integration within a dynamic multi-dimensional aviation environment and the risks that UAS technology present to people and property on the ground. A broadly similar approach is being taken at global, regional, and national levels with individual national aviation authorities (NAA) following common lines. Some, like the United Kingdom Civil Aviation Authority (UK CAA), have had interim UA regulations in place for four to five years. The US FAA was late to adopt, but has quickly moved through

Global and regional regulatory bodies are grappling with the challenges that UA operations present in terms of integration within a dynamic multi-dimensional aviation environment.

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 on-board, using atypical flight missions. Dropping items from aircraft emphasises the need for a new approach. It is illegal to drop

to the present Part 107 framework, which offers safety regulations for UA weighing less than 55 pounds (around 25kg) that conduct commercial operations.

Globally, many countries now have a limited interim framework in place, largely in response to the exponential increase of small UA operations, or rely on an operator

having a makeshift, ad hoc arrangement with the NAA or local authorities. Current global UA regulations are summarised at www.droneregulations.info.

Not only must UA regulations be followed where they exist, but other laws must be respected and approvals and clearances must be sought. Examples of these laws and regulations include those for privacy and data, environment (noise, wildlife, emissions), approval from the landowner, defence/military, local council/government, ATC (contacting the air navigation service provider initially and the ATC unit on the day of the flight). These are discussed further in Section 5.3.

4.3 FUTURE REGULATION

There are some slight regional differences in the evolution of future small UA regulation, but most focus on moving away from categorization by weight or mass, and towards risk.

In many countries, UAs that did not exceed 150kg in weight were exempted from meeting regulations imposed on conventional aircraft. For example, until recently in Europe, UA over 150kg were under the remit of the European regulator, EASA, while those below were the jurisdiction of each of the national authorities. The aviation regulatory community now advocates a risk-based approach that links the level of risk to the type of UA operation and the circumstances encountered during the task.

The risks presented by conventional operations rise progressively with an increase in the energy, mass, size, and complexity of the aircraft and the environment that surrounds it. These factors are detailed in a three-category approach. See Figure 1.

The division between the Open and Specific categories is considered easier to describe in terms of operational complexity, and the tool to assess this division is known as a Specific Operation Risk Assessment (SORA) and is further described in Section 7.3.1. A larger UA could feasibly deliver cargo safely under the specific category over the ocean where other aircraft are rare, while flying a small UA over an urban area may present an unacceptably high risk to people on the ground.

It is anticipated that WBG operations will mainly consist of tasks in the Open and Specific categories, with the assumption being that technology and strategic appetite is not yet mature enough to warrant the use of large, sophisticated UA in the Certified category in support of WBG operations. A portion of WBG projects that could benefit from UA data capture support will operate in the Open category, where a small UA may operate in remote areas with low population density and where, consequently, the operational risk is low. Additionally, the degree of difficulty of the task may be low, requiring a simple, uncomplicated flight path. It is also feasible that the WBG could ensure a SORA is followed for operations in regulation dearth environments.

OPEN	SPECIFIC	CERTIFIED
		
• Low risk • Competent authority notified by member states; no pre-prepared approval envisaged • Limitations (25kg; VLOS; maximum altitude; no or limited drone zones) • Rules (no flight over crowds, pilot competence) • Use of technology • Subcategories including harmless	• Increased risk • Approval based on specific operation risk assessment (SORA) • Standard scenarios • Approval by NAA possible, supported by accredited qualified entity (QE) unless approved by operator with privilege • Operations Manual (defined in Section 7.2.6) mandatory to obtain approval • A risk-assessment approach allows taking into account new technologies and operations	• Regulatory regime similar to manned aviation • Certified operations to be defined by implementing rules • Pending criteria definition, EASA accepts application in its present remit • Some systems (e.g., Datalink, Detect and Avoid) may receive independent approval

Figure 1: EASA Proposed Categories[2]

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Local wildlife near a UA.

5. POTENTIAL OPERATIONAL RISKS AND CONSIDERATIONS

5.1 OPERATIONAL RISKS

Operation of emerging technology such as UA brings with it new risks and hazards that must be fully understood and appropriately addressed to enable optimal use. Safety risks are inherently linked to the proximity of people and vital infrastructure, and it is inevitable that some WBG tasking may require UA operations over, or close to, urban areas. The conduct of such operations will be affected by a range of increasing risk factors, which must be sufficiently addressed prior to flight and remain ALARP during the operation. Risk, when relating to UA, is generally divided into two categories: airborne risk, i.e., conflict or collision with another airspace user caused by an aircraft upset or system failure, and ground risk, i.e., people or infrastructure on the ground, related to a UA crashing or causing falling debris. Risk management is a broad area that includes financial, reputational, or occupational risks. Some of these non-operational risks are considered in Section 5.3.

Possible risks include:

- Operational risk to UAS operators subject to operating environment
- Proximity to people not involved in the operation
- Collision with adjacent infrastructure
- Air collision with conventionally piloted aircraft and other UA users
- Environmental factors
- Impact on indigenous wildlife
- Breach of privacy or data protection regulations
- Susceptibility to cyber security hacking and hijacking[3]

5.2 ADVANCES IN TECHNOLOGY AND RISK MITIGATION

The risk to safety increases as more and more UA operate closer to people and infrastructure, nearer to conventional airspace users, and in close proximity to other UA. Europe had an estimated 3 million small UA in operation in 2016, while the FAA estimates numbers will rise from 2.5 to 7 million in the US by 2020[4,5]. Delivery

FREDDIE MBUYA / UHURULABS
Drone pilot doing last pre-flight checks

> The inevitability of wide-scale UAS use should not be underestimated. As with any opportunities brought about by advances in technology, they go hand-in-hand with a set of new and little-understood risks.[6]

platforms also entail missions either beyond the range of the RP or in a fully autonomous manner, as well as during inclement weather and in darkness. The number of reports of incidents involving UA and conventional airspace users is also escalating. Mitigating these safety risks requires several strategic and technical solutions to segregate each of these players, such as ground-based traffic management systems with real-time awareness of the position and intention of all airspace users and any required airspace limits. Additional measures include the ability to identify UA both during flight and through registration of the craft and its pilot. Moreover, tools can prevent a UA from flying out of control or crashing dangerously when control is lost, and the construction of the aircraft can be formulated to reduce injury during an impact.

Significant to the WBG is that supporting technologies may not exist outside of urban areas that have extensive infrastructure and investment to support various programs

(for example, Amazon's Prime Air or Google's Project Wing). In such dearth environments, a hazard-identification and risk-assessment process will assess the risks and possibly propose mitigation strategies reliant on less expensive tools.

Finally, open source software is susceptible to hacking, and the control or automation system for UA can be overridden, creating a possible weapon. Alternatively, the communications links from aircraft can be intercepted, compromising privacy.

5.3 OTHER CONSIDERATIONS

5.3.1 Public perception

Public perception on the use of UA will vary, subject to the country of operation and its exposure to UAS technology. Broadly speaking, in a global context, public knowledge of and interest in UA technology is growing, together with questions on how safe they are to use. In countries with more advanced economies, including the United States, United Kingdom, France, and Australia, public perception is heavily influenced by the media, who will readily feature stories on "drones"—as the media refer to them—when it is considered newsworthy. In many cases, especially where there is a humanitarian or consumer dimension, this coverage is positive, but there is an increasing level of focus on safety and privacy concerns, which generates negative publicity.

It is important to note that there is a strong association between UA and military activity. In active and post-conflict areas where UA have been used for military purposes, public perception may differ substantially. Especially in those high-profile cases where UA have had an active role in warfare, including targeted or mass killings, it is to be expected that the population will not differentiate between UA used for development or humanitarian purposes and those used for military ends. Flying in areas where military UA have been used, or where their use is suspected or feared, is thus a highly complex task and must be undertaken with the highest degree of sensitivity towards the perception of the local populace.

Overall, it is important that, in conducting UA operations in support of its projects, regardless of the location, the WBG can ensure that it determines how receptive the local populace is to UA and seeks to educate on the societal benefits where appropriate.

5.3.2 Social/environmental considerations

UA operations should, where applicable, have a negligible impact on the surrounding environment, populace, and ecosystem in the country in which the task is being flown.

Due to their construction, most UA currently have a typically low CO2 footprint and, therefore, low environmental impact, unless a larger

system using an internal combustion engine is employed. The supporting staff and equipment can have a significant environmental impact, however, depending on the size of the task being flown. This should be factored into any environmental considerations for UA operations.

wildlife response must inform operational planning. Birds of prey and territorial birds, such as crows, have reacted strongly to FW UA, which are comparatively quiet and can resemble a bird of prey in flight. Often, birds are content to shadow the device, but attacks have occurred. Most often, the damage sustained by the UA is non-critical,

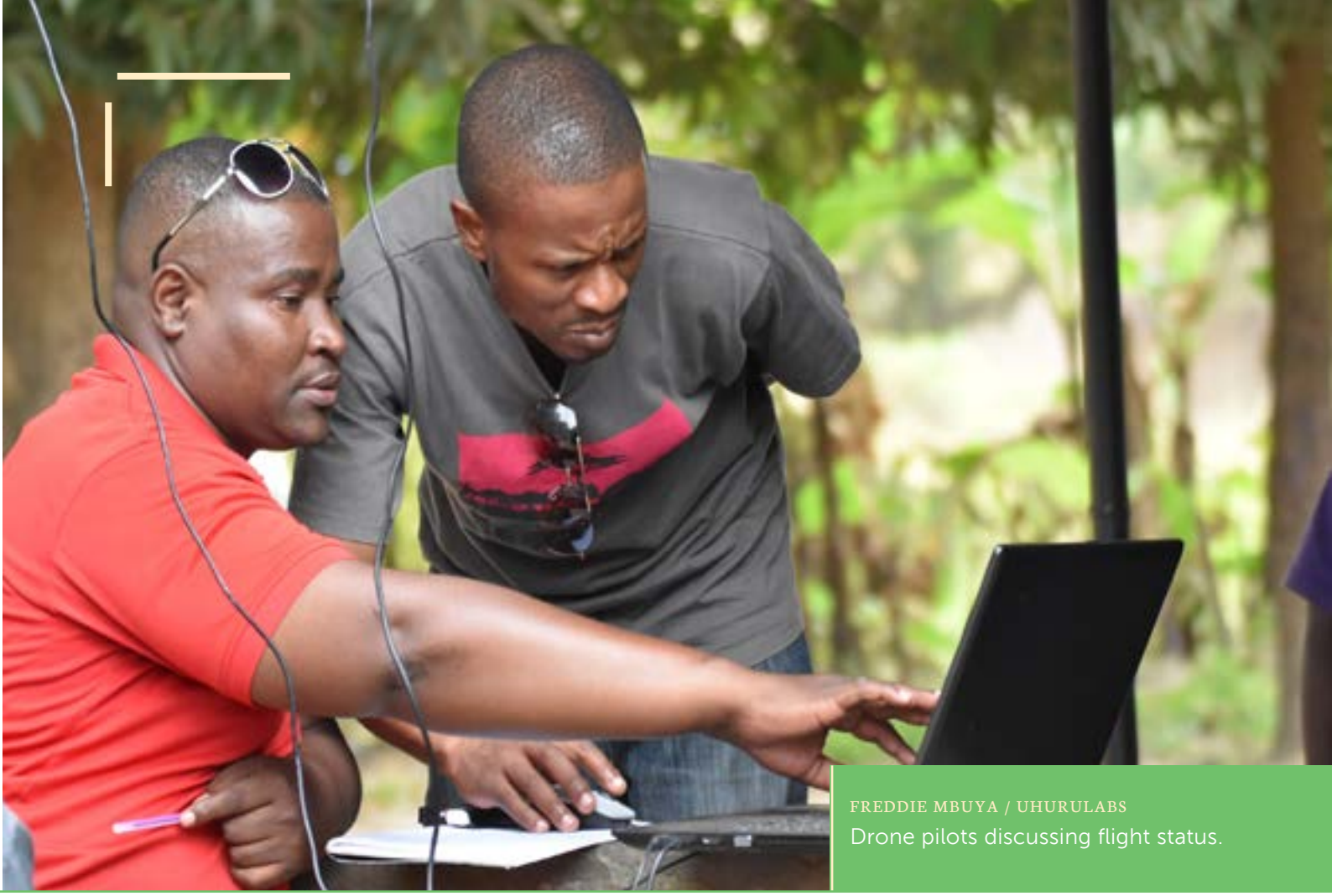
> UAS operators have a responsibility to understand where national and local environmental regulations exist and remain sensitive to the impact their operations may have on the local environment.

UAS operators have a responsibility to understand where national and local environmental regulations exist, remain sensitive to the impact their operations may have on the local environment, and ensure compliance at all times. The privacy, comfort, and safety of local populations should be maintained as much as reasonably possible. Projects that fly over or in proximity to lands populated by indigenous groups, in particular, must ensure that their activities maintain a high standard of cultural sensitivity and cause minimum disruption to the lives of the affected indigenous populations.

This sensitivity to the environment is not limited to the local human populace: UA operations can have a direct impact on local wildlife. The shape, colour, and noisiness of a UA all influence how wildlife perceives the device, and an awareness of

such as damage to wings or body, but large eagles have dived on and downed UA in the past. These scenarios are dangerous not only for the UA and its operators, but for the wildlife itself; in one instance, overzealous staff at a local airport shot a nesting pair of endangered eagles to prevent damage to the UA. Needless to say, incidents such as this run counter to the interest of the World Bank and should be avoided at all costs. The appearance and sound of the UA, its altitude and flying pattern, as well as seasonal events such as bird migrations and mating or nesting seasons of local wildlife must be considered in the choice of vehicle and during operational planning.

UAS operators should understand the environmental impact their operations will have during the planning phase and document the risk and mitigation measures that will be applied. This is



FREDDIE MBUYA / UHURULABS
Drone pilots discussing flight status.

particularly important in the case of emergencies, when the UA may behave in an unpredictable manner. Planning of this nature is important, not only for thoroughness but also because local or national authorities may require this level of documentation to be provided prior to granting authorization for operation, and should be established by the UAS operator prior to flying in each country of operation.

Where no national environmental protection legislation exists, UAS operators nonetheless have a duty of care to ensure that their operation has a negligible effect on the environment, local populace, and ecosystem at all times, and that the measures are documented throughout the operation and available for scrutiny if requested.

5.3.3 Data protection

The use of UA for imagery capture presents numerous challenges in terms of capturing, storing, and publishing data. Data protection regulations exist in almost all countries to a certain degree, and each are designed to protect the privacy of people, such that any imagery should not be stored or used in a way that makes it attributable to a particular individual. This is particularly applicable for people on their private property or going about their normal daily business. One aspect to which particular attention should be paid is that of storage. The imagery should be stored in a way that it is deemed secure and resistant to outside attempts to

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Survey team marks out ground control points.

FREDDIE MBUYA / UHURULABS
Local community members ask questions about a drone.

remove it, while access is limited to only those images that are required as part of the task.

Data protection laws vary from country to country, as do citizens' awareness of the associated risks and regulations in place. Until very recently, there was often no reference to UAS technology in data protection, with the only provision being that of imagery obtained through closed-circuit television (CCTV) systems. This has started to shift as recognition of the emerging technology is better understood, and future data protection laws are set to incorporate these changes. In cases where UAS are referenced in data privacy regulation, there are examples where "the (UAV) covers the whole system, rather than just the device in the air, so you need to ensure that the whole system is compliant"[7]. In some countries (e.g., Germany), a UAS operating authorization may be issued only if the operator can demonstrate that operations will not violate data protection rights. On a regional level, there is also similar activity, such as the drive within the European Union to harmonise the understanding and management of data protection throughout the member states and align it with the evolution of UA regulations[8].

UAS operators should acquaint themselves fully with national data protection laws for the country in which they operate and ensure compliance at all times. It will be the UAS operator's responsibility

to prepare and document what measures have been taken for each task to ensure adherence to local and national data protection regulations. In the case where no regulations exist, it is the UAS operator's responsibility to ensure that an appropriate level of sensible data protection is exercised, as flights may cause a certain level of local sensitivity. This activity should be undertaken at the planning phase and a Privacy Impact Assessment (PIA) conducted if appropriate.

5.3.4 Cyber security

Much like any other connected devices in the Internet of Things ecosystem, UA systems that rely on Internet connections may be susceptible to cyber breach. The motivation for this interference varies from jamming a UA system to prevent it overflying property, exfiltrating or wiping information that the UA may carry, or taking active control of a UA for nefarious or criminal activity. UA can also be used as a platform to conduct malicious activities targeted at other connected devices.

While motivations may differ, the original equipment manufacturers (OEMs) have to incorporate a "security by design" approach to offset the possibility of interference in the systems or operations. The very fact that the systems use radio links and Internet connections to allow remote control between pilot and platform facilitates a way for an external party to directly interfere with that link.

Jamming is one way of preventing a UA from conducting its planned activity and normally results in the UA platform returning to its launch position under an autonomous pre-planned program. A global positioning system (GPS) jammer is cheap to buy and easily available on the Internet, so this may be an affordable way to interfere with a UA performance. For a more advanced hack, sophisticated technology and knowledge of the processes are required, so the risk is consequently lower.

To address some of these concerns, UAS operators should acquaint them- selves fully with their UA system, especially its operational and technical specifications. Data encryption should be encouraged where available and operators should seek to understand the risk of potential hacking of their system in the area in which they are flying before conducting the task.

The environment in which the UA is piloted and operated must be malware free, regularly scanned, and incorporate secure protocols. Simply by using virtual private networks, which are widely available, one can secure an Internet connection. In the cases described above, such as malfunctioning of the GPS coordinates, it is important to observe behaviour changes and identify deviations from normal. Multi-factor authentication (e.g., biometric, facial recognition) and access controls can help ensure that only authorized people have access.

DARRAGH COWARD / WORLD BANK
Analysts work with UA imagery.

Ultimately, the UAS operators and owners own the risk of ensuring that the cyber risk is assessed and managed such that the task can be flown as safely as possible.

5.3.5 Reputational risk considerations

A UAS operator should consider the consequences to the WBG and its reputation, as well as to the larger UA community and industry, of 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. In such circumstances, it is inevitable that scrutiny will be placed upon the UAS operator and the processes he/she has conducted to ensure that the task has been flown in compliance with existing regulations and in accordance with best practice safety principles. It is important that the UAS operator considers these broader risks during the planning phase.

LOLA HIERRO
A survey team managing a UA flight.

6. RISK MANAGEMENT

The management of risk is essential in ensuring that WBG UA operations are conducted safely at all times. The approach to risk needs to be based upon a common structure and conducted with rigorous application throughout the whole operations process, not just the flying component. This ensures that the risk-management process encompasses all activity and seeks to reduce the possibility of both cultural and systemic failings causing a catastrophic event. Risk is an inherent part of UA operations and, in reality, can never truly be eliminated, but can be managed in a way to make operations feasible in line with the principle of ALARP.

6.1 HAZARD IDENTIFICATION

The first process of risk management is identifying the hazards that may cause, either directly or indirectly, operational risk. Hazard-identification techniques are too numerous to list in great detail and vary in application, but the output remains the same: to determine what triggers risk in the operational environment. At an operational level, hazard identification is routinely given less focus than other parts of the risk process, and this increases the likelihood that the management effect will be diminished.

The following is a list of considered hazards:

- People – Client or passing pedestrians or observers
- Obstructions – Masts, overhead wires, buildings, train lines, trees, chimneys, power lines
- Water features – Lakes, rivers, canals, streams
- Livestock – Animals or wildlife
- Terrain – Slopes, valleys, farmland, wetlands, flood lands, urban
- Operating surface – Concrete, grass, gravel, sand
- Local areas – Schools, nursery schools, hospitals, homes for the elderly, prisons, military installations, government buildings
- Congested areas – Proximity of buildings and people
- Airspace considerations – Class of airspace, other air users, prohibited,

restricted, and dangerous areas

- Interference - Uplink or downlink interference, control interference
- Cultural – Impact on local populace

Identified hazards should be documented in a "Hazard Identification" log.

6.2 CALCULATING RISK

The calculation of a specific or collective risk is determined by two factors: probability and severity.

- Probability (Likelihood) – Probability determines the likelihood of an event happening in a situation, given the factors that influence the situation.
- Severity (Impact) – If the event occurs, severity determines the consequences and impact it will have on the operational environment.

A basic risk-assessment matrix, typical in UA operations, is shown in Figure 2.

Calculating risk is subjective and the outcomes will, therefore, vary depending on the individual charged with conducting the assessment. By assigning a probability of a risk occurring and the severity of a consequence should this happen, we will arrive at a value that demonstrates whether a risk is acceptable, requires review to mitigate, or is unacceptable. Most matrices are colour-coded in "traffic light" methodology to illustrate risk graphically.

Once the level has been established for a particular risk, an operator can determine if follow-on mitigation is required. If the outcome is Review or Unacceptable (see Figure 2), mitigation is applied and the process is conducted again, with the intention of bringing the risk down to a level acceptable for safe operations. If a risk is shown to be for Review, operators should always apply mitigation if appropriate. If a risk has been mitigated and still sits within the Review category, the operator must make a reasoned judgment about whether that risk can be carried. An example of a documented risk from an operational risk register is shown in Figure 3.

All risk-management activity should be diligently documented in a comprehensive, structured process that can be used as evidence in the event that an accident occurs.

6.3 ADDRESSING RISK

The following overview of technological solutions is for the purpose of providing information about the risk treatment process only and is not a guide to UA selection.

> The bottom line is that a drone is a computer. And computers can be hacked.[9]

PROBABILITY	SEVERITY				
	Catastrophic (5)	**Hazardous (4)**	**Major (3)**	**Minor (2)**	**Negligible (1)**
Frequent (5)	Unacceptable	Unacceptable	Unacceptable	Review	Review
Occasional (4)	Unacceptable	Unacceptable	Review	Review	Acceptable
Remote (3)	Unacceptable	Review	Review	Acceptable	Acceptable
Improbable (2)	Review	Review	Acceptable	Acceptable	Acceptable
Extremely improbable (1)	Review	Acceptable	Acceptable	Acceptable	Acceptable

Figure 2: Risk assessment matrix

6.3.1 Geo-limitation: Either in the form of geographical (geofencing) or performance constraints

Geofencing can prevent unintentional access by UA to sensitive areas such as airports or power stations. It is often GPS linked and will be particularly relevant to low-level operations, generally below 400ft (120m) above ground level (AGL). It may be contingent on a traffic management system, the submission of intent for each operation, a reliable navigation system, and accurate positional knowledge. The software feature that establishes areas within which a UA cannot operate is a recent technology, and currently only available on certain platforms, notably DJI products. Most of the geofencing systems on the market are hard-wired into the UA software and have limited ability to remove or adapt the restriction if required. Most stakeholders and regulators view geofencing as a legitimate safety feature when used in compliance with the manufacturer's instructions and in conjunction with other safety measures. It must be stressed, however, that it should never be used in place of sound decision making and airmanship. Risk assessments should consider that geofencing can be removed

#	Identified hazard	Associated risk	Existing mitigation	Current risk level	Further mitigation measures	Revised risk level	ALARP?
1	Car park	Encroachment of vehicles onto fields	Unknown—likely gates	Review	DANGER signage to be placed in prominent locations of ingress to field	Acceptable	Yes

Figure 3: Risk Register – Risk assessment for a specific risk showing the mitigation process

FREDDIE MBUYA / UHURULABS
A drone after another perfect landing.

or overridden, while the opposite problem is that they may prevent flight even if the mission has been approved, particularly during a humanitarian mission, if the location is within the geofenced area or if the system is erroneous. Additional system functionality, such as "land immediately" commands and return-to-home capabilities, are also being considered, as are alternative positioning means such as cellular technology or radio frequency identification (RFID).

6.3.2 UAS Traffic management (UTM) systems

One step towards addressing the challenge of an increase in UA traffic is the establishment of UAS traffic management (UTM) systems, to manage the expected increased numbers of UA operations, provide support to beyond visual line-of-sight (BVLOS) operations, and create an interface with the current ATM systems[10]. The National Aeronautics and Space Administration (NASA) and FAA appear to be early leaders in UTM research, beginning in 2015, through four systems builds, with decisions on final timelines due in 2019. One aim is to research both portable and persistent UTM systems, to either support operations such as disaster management or provide continuous coverage over urban areas or congested zones. European work will focus predominantly on UA in the Open category; it refers to UTM as U-Space. The scope is to investigate an interacting suite of sensors suitable for small platforms and capable of avoiding other UA, manned

aircraft, and all obstacles and terrain. The mobile phone industry is recognised as a comparison, as it incited an unparalleled spread in small, low-powered electronics across positioning sensors, connectivity and image processors, and communication devices. A robust, interactive UTM/U-Space is envisaged that is Internet based or potentially connected through the Internet of Things, which will resolve conflicts involving both collaborative and known airspace users as well and unknown or non-collaborative platforms[11, 12].

6.3.3 Collision avoidance, autonomous, and BVLOS operations

The majority of UA are small and inconspicuous and therefore problematic for pilots of conventionally piloted aircraft to sight and avoid. Combined with the lack of suitable UA Detect and Avoid systems, it is challenging for UA operations to remain safely clear of each other and other airspace users, and vice versa. This problem is exacerbated during BVLOS or automated missions. Aircraft that are invisible to ATC surveillance systems, such as radar or automatic dependent surveillance – broadcast (ADS-B) surveillance, are often termed uncooperative.

Incorporating the use of miniaturised ADS-B/Mode S transponders is a possible solution, as it increases the UA conspicuousness and its visibility to other airspace users, and such technologies are developing quickly. This should assist small UA in integrating with other UA and manned conventional air traffic in a dynamic environment. The threat of saturation of present ADS-B frequencies, however, must be considered. Currently, no system is fully certified, although several commercial options are available[13]. The ubiquitous hurdles in designing UAS are size, weight, and power consumption (SWaP), along with the possibility of lagging on-board sensor processing, the threat of (cyber) security events, and bandwidth deficiencies. Again, these impediments may be overcome by ground-based options through UTM. ADS-B is reliant on accurate positional information, such as GPS, and precise height or altimetry reporting. Without these, both UTM and the ATM system may have incorrect data leading to false or dangerous Traffic alert and Collision Avoidance System (TCAS) or Airborne Collision Avoidance System (ACAS) advisories and erroneous ATC separation. The solution is probably an array of different surveillance technologies integrated into one system, such as a UTM.

6.3.4 Communication performance, frequency and spectrum issues

In many countries, the infrastructure and satellite availability to support acceptable communication performance for the UAS C2 links may be non-existent or may not be prescribed. UAS have different links between the ground station and the aircraft, and these have certain performance requirements and quality of

FREDDIE MBUYA / UHURULABS
A global navigation satellite system (GNSS) used during ground control point marking.

service levels for the data and information transfer. Once a UA is operated further than line of sight, such as BVLOS, links between the control station and the aircraft need to be relayed, for example, through satellite or mobile networks. C2 links support:

- Uplinking the control of the aircraft, sense and avoid/detect and avoid (SAA/DAA) sensing, geo-limitation data
- Downlinking data to monitor the aircraft's position and status
- Hand-over of control from one RP to another
- ATC voice and data communication tasks
- Monitoring of the data link's health

These may be single or multiple redundant data links and should make

BVLOS operations safer. The health of

this system is termed the Required Link Performance (RLP) and concept papers are available for reference. Historically, there has been a lack of frequency allocation to support C2 and payload data usage. Frequency bands must be allocated for the use of UAS, and this spectrum allocation may differ between countries. This risk needs to be addressed.

6.3.5 Conspicuity , physical markings and registration

In addition to electronic visibility through systems such as ADS-B, consideration needs to be given to making the UA more visible to the public as well as traceable after an incident or in the event of regulation violations. On-board lighting, strobes, or aural alerts can make the UA more discernible so that an airborne conflict

FREDDIE MBUYA / UHURULABS
Future drone pilots.

may be less likely. Of course, the balance is the interference of bright lights on the public. Identification would allow law enforcement agents and UTM and ATM controllers to take timely action during blunders and scrutinise reckless operations as well as manage contraventions of privacy or environmental laws. Many operations will require the UA to be registered and to have this registration physically attached and displayed, along with an electronic identification. The operator or pilot will often also need to be certified or licenced.

6.3.6 Frangibility

Research is expanding our understanding of the complex consequences of a collision between a UA and people or infrastructure on the ground or other airspace users. The following parameters affect the outcome:

- UA's mass, components, and speed, or relative speeds (the effective kinetic energy)
- Location of the impact (head, engine, windshield)
- Behaviour (walking, cycling, aircraft's final approach) of the person/device impacted
- Recipient type (helicopter, large jet aircraft, child)
- Danger from on-board battery, fuel, liquids, or hazardous cargo

Harm can be reduced if the UA is more malleable or frangible, so that it has a latent tendency to break up into fragments rather than deform elastically during an impact[14].

CHRIS MORGAN / WORLD BANK
Explaning a UA component to children.

7. RECOMMENDATIONS FOR WBG OPERATIONS

7.1 INTRODUCTION

This section is intended as a guide to understand the basic level of consideration when choosing a UAS operator on behalf of WBG. The recommendations below are based only upon industry best practices taken from across global operations to date. This should not supersede any department-specific processes already in place, but should inform the selection process for safe and efficient operations using UA in more complex operating environments.

The following general considerations should be factored in for a UAS operator engaged in support of WBG operations.

- Operators shall be familiar with the NAA and local authority regulations that exist in their operational environment. In the event that no national regulations exist in the country of operation, the operator shall comply with the guidelines listed below, where applicable.
- Operators shall be able to liaise effectively with local and national aviation authorities, ensuring that they comply with all authorisation requirements during operation and that the RP holds the appropriate national qualifications.
- As a default, the operator shall conduct a suitable risk assessment of the impact of the operation on the local populace and infrastructure, while taking into account any local cultural sensitivities.
- Operators shall be able to assess and apply appropriate mitigation processes to reduce risk to ALARP. Operators shall be equipped to determine when circumstances dictate that the risk presented at a task site is too great and the task shall not be flown or the mission immediately terminated.
- Operators shall be familiar with the UAS performance and safety features such that they can establish a risk-reduction plan that fits into the overall task picture.
- Unless regulated, operators are not required to have an Operations Manual, but it is recommended.
- VLOS operations shall align with recognised VLOS operational limitations, such as:
    - UA shall be less than 25kg

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Two DJI Phantom UAs share airspace.

  - UA shall not operate at more than 500m radius from the pilot
  - UA shall not operate higher than 400ft (120m) AGL
  - UA shall not operate over, and must remain at least 50m from, any people not involved with the operation
- UA shall remain clear of other airspace users and not interfere with conventionally piloted aircraft.
- UA shall be conspicuous, particularly at night, through the application of appropriate lighting and/or coloured external surfaces.
- UA shall not fly within 5km of an airport, including a seaport, helipad, etc.
- Operators shall fly only one UA at a time and the use of additional ground crew to manage any payload, such as operating video capture equipment, is preferred.
- Operators shall not operate UA from a moving conventional aircraft.
- Operators shall not operate UA from a moving vehicle unless the operation is over a sparsely populated area.
- Operators shall not allow the carriage of hazardous materials.
- UA shall always remain clear of emergency response efforts, such as firefighting, etc.
- UA should be equipped with a "return to home" function in case the data link between UA and transmitter is lost.
- UAS should be equipped with geo-limiting functions.

The UAS operator and the RP are always

responsible for the final decision on the safety of the flight and whether or not to fly.

7.2 CONSIDERATIONS FOR UAS OPERATORS

7.2.1 Regulations

A UAS operator must comply with all applicable national regulatory requirements as specified by appropriate governmental bodies and aviation authorities. In particular, the regulations and permission process of the country of operation should be adhered to unless otherwise stated. Where no applicable national or international regulatory requirements are present, it is recommended that a UAS operator follow and implement best practices adopted by leading aviation authorities.

7.2.2 Operational standards

The International Standards Organisation (ISO), through the work of 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 by unmanned and manned aviation".[15]

This work was approximately 20% complete as of June 2017, so it has some way to go until maturity. Its components, however, should be considered during UA operations.

7.2.3 Quality standards (ISO 9001:2015)

It is recommended that a selected UAS operator has achieved ISO 9001:2015 accreditation. By doing so, an operator can:

- Demonstrate consistent levels of service delivery in order to meet customer expectations, including conformity with statutory and regulatory requirements
- Demonstrate a documented, recognised quality management system, including established processes for continual improvement and an assurance of conformity to customer and applicable statutory and regulatory requirements; this includes regular quality reviews and

A UAS operator must comply with all applicable national regulatory requirements as specified by appropriate governmental bodies and aviation authorities.

a nominated, suitably qualified quality manager

If a UAS operator has not obtained ISO 9001 accreditation, it is recommended that the UAS operator follows equivalent quality management system processes and controls.

7.2.4 Safety management system (SMS)

It is recommended that a UAS operator has an established, comprehensive safety management system (SMS) in place that documents and evidences an organised approach to managing aviation safety and incorporates appropriate organisational structures, policies, and procedures.

An organisational risk-assessment and management process, including a risk register, should be implemented and maintained for all UA operations. The process should be managed by a nominated and suitably qualified safety manager with recognised SMS in aviation qualifications.

7.2.5 Insurance

Insurance is a dimension to UA activity that is emerging as an important component of safe, professional operations. The selection of comprehensive and appropriate insurance provision is critical to ensure that WBG UA operations are sufficiently protected. Great care should be taken that the provisions match the complexity of the task and meet all the risks inherent in it. Recommended coverage is:

- Public liability (covering the use of the UA and its impact on third parties)
- Employer liability (covering the UAS operators and associated task staff)
- Professional indemnity (covering any advice or recommendations given to the client when using the UA data)

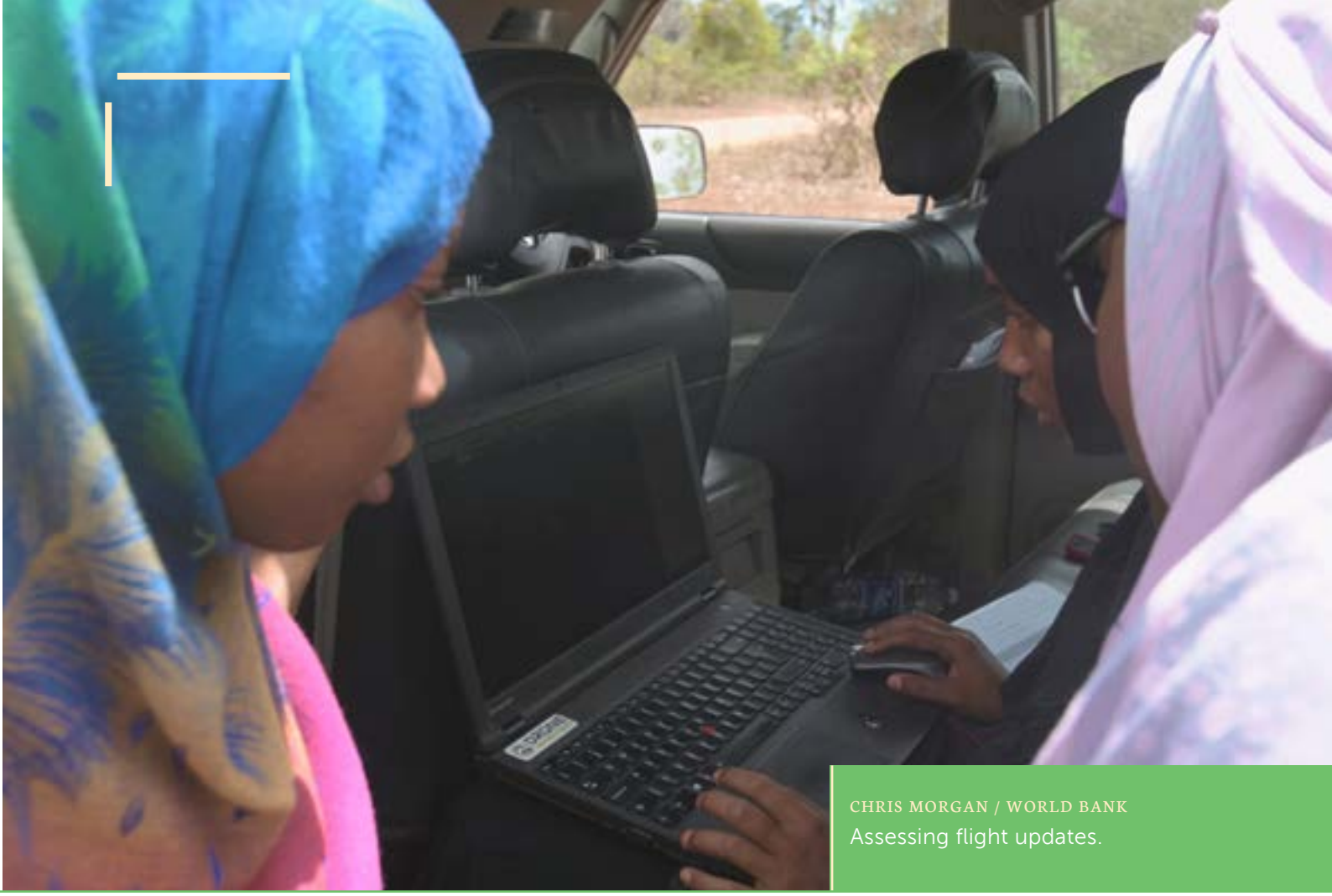
It is recommended that a UAS operator has a suitable level of coverage to ensure that the task(s) are sufficiently insured, in line with the coverage recommended above.

UAS operators may choose to secure coverage for hull damage or loss to limit their risk, but this is at their discretion. Insurance provision should also take into account regional differences and extra considerations if operating in austere environments or where extra risks may be present. For instance, the UAS operator might be operating in support of a disaster relief effort in an area with significant infrastructure damage where there is an additional risk to the flight team beyond that encountered in routine flying tasks.

7.2.6 Operations manual

It is recommended that a UAS operator has a comprehensive Operations Manual outlining how they will operate. The Operations Manual is a statement of intent in flying operations that should include the following points:

- Organisational structure (including nominated key individuals)
- Statement of compliance with regulation in relevant areas of



CHRIS MORGAN / WORLD BANK
Assessing flight updates.

operation

- Operational policies
- Personnel policies
  - RP qualifications
  - Medical requirements
  - Currency requirements
  - Training policy and structure
- SMS policy
- Risk-management policy
- Quality-management policy
- UAS specifications and emergency procedures
- Accident and incident reporting process

7.2.7 Personnel

A UAS operator should be required to provide evidence that his/her RP personnel have the necessary qualifications and competence to perform and maintain the services for which UA operations are intended. This should be in line with the RP's own national requirements and those of the country in which the task will occur. At a minimum, RPs should have a nationally recognised qualification that may then be eligible for transfer to other countries.

UAS operators should have the following personnel records:

- Medical certification/checks
- Formal education and certificate records
- Formal initial and refresher training records

- Formal safety qualifications and certifications
- Resume/curriculum vitae
- Photo identification
- Experience/flight logs

7.2.8 Training

Training is a key aspect of the maintenance of currency and competency of personnel. A UAS operator should be responsible for the qualification and training of their personnel to recognised national, international, or industry regulations, or standards that directly relate to or are required where UA operations are intended. It is also recommended that UAS operators adhere to the additional qualification and training requirements specified nationally, where these exist.

Subject to the complexity of the tasking to be undertaken, UAS operators should ensure that training is appropriate to their expected capabilities. If tasks are to be conducted in difficult environments, then suitably focussed training should be delivered.

7.2.9 UAS platform selection

UAS platforms come in different shapes, sizes, and configurations. The selection of the appropriate platform to conduct the flying activity required is important to ensure that the task is completed on time, within budget, and safely.

It is recommended that UAS operators consider the following as the minimum criteria for selection of a UAS device:

- The UAS OEM should conduct and document a comprehensive system flying test for new products to ensure that reliable and acceptably safe platforms enter the market.
- The UAS device should have self-diagnostic capabilities.
- Depending on configuration, the UAS should have multiple flight modes that mitigate in-flight failure, including the ability to switch to manual backup modes and redundancy for other critical components.
- The UAS should have a "return to home" redundancy function that activates if the data link between the UA and transmitter is lost. This should ensure that the UA diagnoses a lost-link situation and follows a set of pre-determined behaviours in order to return to the GPS registered launch point without intervention from the pilot.
- The UA platform should be able to transmit height information to the pilot via a telemetric data link.
- The UA batteries and housing compartments should be resistant to impact and degradation to limit the risk of catastrophic damage in the event of a crash.
- The UA should have high conspicuity.
- The UA should be generally frangible to reduce the consequences from a mid-air collision or ground impact.

7.2.10 UAS maintenance process

Maintenance of UAS equipment, including

FREDDIE MBUYA / UHURULABS
Community elder asking questions about drone.

all ancillary equipment, is critical for ensuring that a UA system can be operated safely and reliably in all environments. To facilitate this, a comprehensive maintenance structure should be applied consistently throughout the UAS operator's organisation and outlined in the Operations Manual.

The maintenance system should include all phases of operation and initial acquisition, continuing maintenance, and software/hardware updates. The process should list the following:

- UAS product specifications
- Safety data sheet/specifications
- Known/discovered design and operational limitations
- Operational and testing malfunctions and anomalies
- Preventative and reactive maintenance actions
- Preventative maintenance action schedule
- Hardware customisation actions
- All software versions, changes, and patches
- UAS/UA total running flying hours
- Reference to all manufacturing safety and technical bulletins

It is recommended that the OEM of any UAS equipment provides maintenance training and technical bulletins that document any changes or issues of which to be aware and encourages feedback from UAS operators to facilitate continuous improvement.

All maintenance processes and practices, whether developed by the OEM or the UAS operator, should be documented and be kept up to date.

It is mandatory that a UAS operator complies with all technical and safety bulletins issued by an OEM.

> Maintenance is critical for ensuring that a UA system can be operated safely and reliably in all environments.

Any UAS that has undergone changes that may affect UAS operations (i.e., hardware customisation or alteration, software versioning, changes, or patches) should be subject to a functional test flight, risk review, and training to ensure modifications allow operations to be carried out safely and effectively.

7.2.11 Battery management

Batteries are an integral component of the UAS, and have considerable risks attached that need careful management. It is recommended that a UAS operator has an established, documented battery management policy, including the following elements:

- Battery storage procedures
- Battery charging procedures that are considerate of task site requirements
- Battery charging record
- Battery transportation procedure
- Actions in the event of battery emergency
- Support equipment (fire extinguisher, first-aid kit, cordon equipment, signage)

7.2.12 Spectrum

Spectrum is a critical component of UA activity and governs platform control, image downlink, and GPS, and will be a feature in the successful use of future technologies such as Sense and Avoid and UTM. Like regulation, the use of spectrum for UA operations is not globally harmonised and the rules that apply vary from country to country.

The allocation of spectrum is yet to be fully considered. The current maturity of UA technologies means that, under normal circumstances, the UA will mainly retain the link with its transmitter so the impact is minimal. The risk lies in areas where the spectrum is susceptible to interference that may cause disruption to system operation, which may impact task success and safety.

UAS operators shall be aware of spectrum-related regulations in the country in which they are operating and any conditions or actions that they may be required to undertake in order to comply.

Additionally, UAS operators should equip themselves with a spectrum analyser and conduct pre-flight scans for interference on relevant frequencies prior to flight.

CHRIS MORGAN / WORLD BANK
Children watch a UA launch.

FREDDIE MBUYA / UHURULABS
Another successful launch.

7.3 PRE-FLIGHT ACTIONS

Pre-flight activity should focus on task planning, evaluation of risks, and establishing how the task will be flown efficiently and safely to achieve the objective. It involves specific planning activity, allocation of resources, and good levels of communication with the parties involved with or impacted by the task.

7.3.1 Specific operation risk assessment (SORA)

In line with EASA's proposal for a Specific category of operations, it is recommended that prior to any UA operations, the UAS operator should undertake a risk assessment. As described in Chapters 4.2 and 4.3, JARUS has developed the SORA (UAS.SPEC.60 Operational Risk Assessment[16]) and EASA has adopted this process as an acceptable means of complying with the risk-assessment requirements. The purpose of the SORA process is to set basic operational considerations to enable a sufficiently comprehensive risk assessment and reduction process for each task.

A SORA enables the UAS operator to confirm, through documented action, that each risk has been identified and considered and that mitigation has been applied where necessary. Additionally, WBG governance and national authorities may require documentation prior to the commencement of the task or post-flight, if required.

A SORA can be applied to a specific number of flights in a certain area if they relate to the same task, providing that all considerations have been applied. A SORA can also be conducted to address higher complexity or greater risk, as in the following examples:

- UA operations in locations dearth of regulatory guidance
- Flights using a homemade UAS
- Carriage of dangerous goods or dropping of items from a UA
- BVLOS flights
- Larger UA flights over an area devoid of people and infrastructure and free of other airspace users

Considerations for use in the SORA are:

- Operational area and conditions – What is the terrain like? How will you get to the site? Where will you launch/recover? Where will you land in an emergency? What is the prevailing weather for the site?
- Category of airspace and effects on other air traffic and ATM – Are we likely to encounter other air traffic? Are we close to an airfield or airport?
- Design features and performance of the UAS – What is the performance of the UA being used? Is it rotorcraft or FW? What emergency features does it have and how will they be employed?
- Type of operation – What task is being flown? What is the end objective? Does it involve visual line of sight (VLOS), extended visual line of sight (EVLOS), or beyond visual line of sight (BVLOS)?
- Level of competence of the RP – Is the pilot qualified? Competent? Trained on type? Current?
- Organisational factors – Does the UAS operator have the organisational structure and competence to carry out the task safely and efficiently?
- Effects on the environment – What effects will the task have on the local environment and population?
- Consequences of a loss of control – What effects will an uncontrolled UA in a flyaway event have on the ATM system?

7.3.2 SORA task plan

Each SORA should be supported by a task plan that enables the UAS operator to outline how the flight will be conducted in order to achieve the task objectives.

The plan of activities should include at least the following:

- Nature/objectives of the flights
- Intended dates and times for all flights
- Name and contact details for the UAS operator points of contact and management
- Name and contact details for the UAS operations flight team
- System details and serial number of the UA to be used
- Site visit/inspection reporting (where possible)
- Description of the task activity, including:
  - Maps or diagrams of the flight area
  - Planned flight path of UA
  - Planned altitudes of the UA

CHRIS MORGAN / WORLD BANK
Another successful launch.

- Planned take-off, recovery, and return-to-home locations

- Emergency scenarios and procedures for:
  - Loss of control
  - Collision
  - Mechanical or electrical failure
  - Loss of line of sight
  - Sudden changes to environmental conditions (i.e., weather)
- Onsite emergency situations (e.g., access for emergency services)
- Night operations (if applicable)
- Limited visibility operations
- Use of VLOS
- Use of EVLOS
- Use of BVLOS

7.3.3 Flight-specific risk assessment (RA)

It is recommended that UAS operators conduct a flight-specific risk assessment (RA) for each flight to reflect the differences encountered at each take-off and landing (TOL) site, and ensure that specific risks will be identified and mitigated appropriately. The RA should be documented so that UAS operators can refer to it directly on arrival at the TOL site and post-flight, to determine how the RA process was conducted in the event of an accident or incident.

Risk considerations should include:

- Predicted weather during UA operations and how it will affect conditions for the flight team
- Obstacles that present a risk to TOL operations

- Local community awareness: are they aware of the task? If not, how will you communicate and liaise prior to or on the day of flight to address local enquiries and concerns?
- How will the UA flight affect the local environment?
- How will the local environment affect the UA flight, i.e., is there terrain that will affect VLOS operations or gaps in GPS coverage to consider?

7.3.4 Checklist

It is recommended that the following types of checklists be used during operations and reviewed, completed, and verified pre-flight, as well as during the response to other complex operations and high-workload events:

- Annex C
- Location/onsite inspection
- UAS and equipment inspection and test
- Ground control systems inspection and test
- Non-routine operations and emergencies

7.3.5 Pre-flight briefing

The flight team should conduct a pre-flight briefing no more than 30 minutes prior to the beginning of UA operations, to minimise the risk of any subsequent changes to conditions and circumstances that may affect the UAS operation. The intention of the briefing should be to factor in any changes to circumstances or conditions that were not considered in the risk assessment; apply any amendments required to the flight plan and UA operations; reconfirm actions in the event of an emergency; and reconfirm flight team roles and responsibilities.

7.3.6 Flight team size and composition

It is recommended that all UAS operations include a minimum of two personnel:

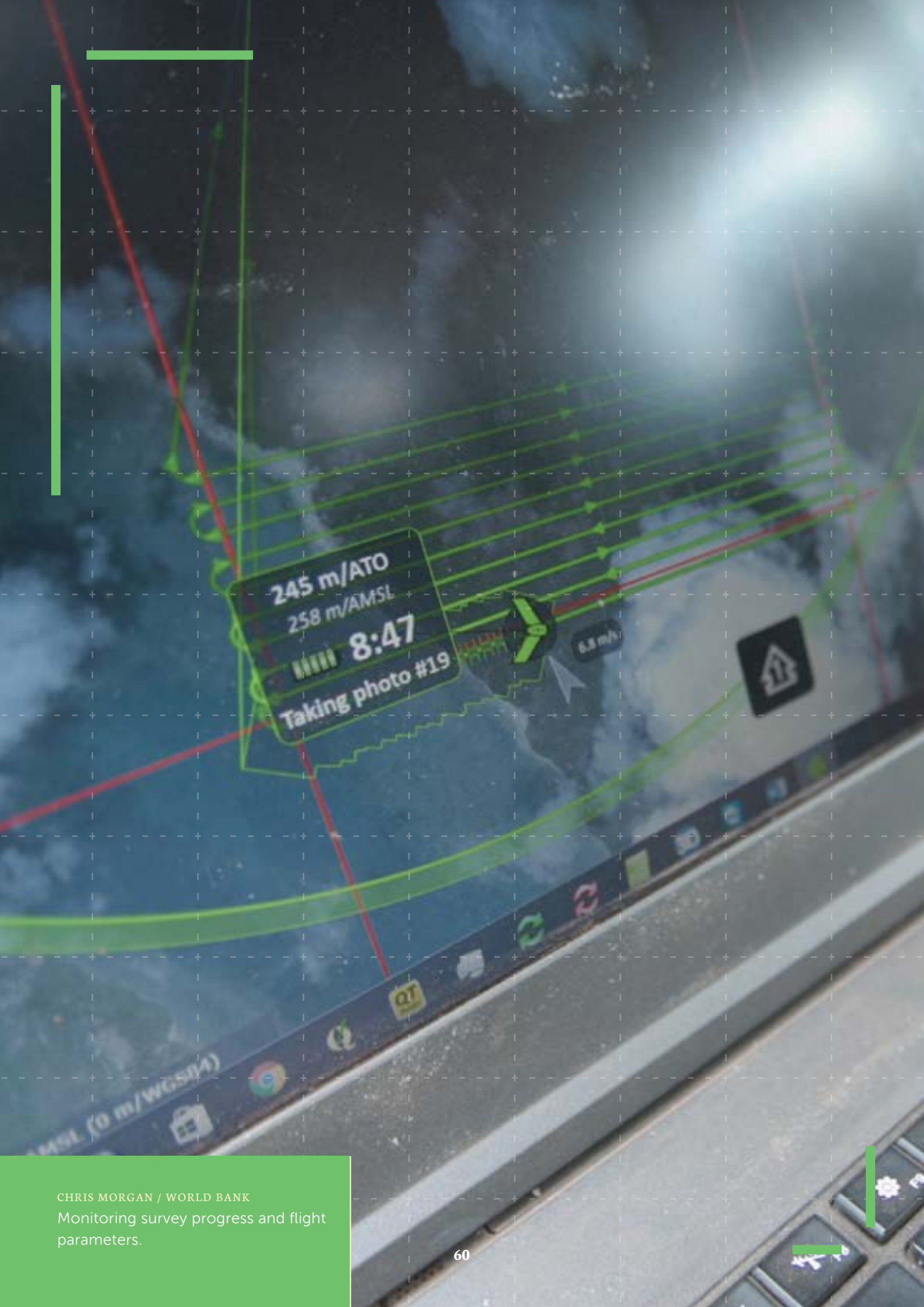
- RP (qualified and current on the UA being flown)
- Camera/payload operator or observer (responsible for control of any attached inspection equipment)

The flight team should be trained appropriately for defined duties and have undertaken sufficient flying that they are current and experienced on the UAS being flown. Any personnel involved with operations or in proximity to the flight team should avoid causing any unnecessary distraction to the pilot (e.g., communication, movement), especially during critical phases of flight. Where appropriate, suitable communication equipment such as radios should be considered.

7.4 IN-FLIGHT ACTIONS

7.4.1 Commencement of flight operations

It is the responsibility of the RP to assess all available information and checklists before deciding to commence with UA operations. The decision to fly should rest



CHRIS MORGAN / WORLD BANK
Monitoring survey progress and flight parameters.

entirely with the RP in charge of the task and should not be influenced by external factors or pressure from clients or relevant authorities.

7.4.2 Take-off and landing (TOL)

The TOL profiles of UA operated by WBG will vary greatly, subject to the size, weight, and performance characteristics of the platform. TOL zones should be visibly marked and cordoned appropriately to adequately manage the risk of distraction during critical phases of flight. It is expected that operations may attract attention, and the cordon and personnel should be sufficient to ensure that flight operations are undertaken without being affected by external factors, such as the local populace. For those UA that are not vertical take-off, and especially for those UAs requiring longer runways given payload, factors such as the TOL length and width requirements (geometry), aircraft load (bearing capacity), and landing strip roughness (riding quality) are important to ensure that these UA will not be damaged during operations and unable to fulfil their respective missions. Where longer runways are required, social and environmental safeguards need to be considered.

7.4.3 Typical UA TOL profiles

By definition, a RW UA is designed to perform VTOL operations from an area that has a footprint just larger than the lateral dimensions of the platform. This makes it more versatile in confined spaces.

FW UA have different methods of launch and recovery, including:

Take-off

- Hand launch
- Bungee or catapult launch
- Rail launch

Landing

- Parachute recovery
- Conventional landing
- Deep stall landing
- Net recovery

Consequently, each profile has a different footprint in a three-dimensional space and may require specific conditions on the ground to reduce risk and facilitate safe operations, both for the UA and external assets.

7.4.4 Communications

At a minimum, the pilot and camera/payload operator should remain in constant communication throughout the period of the tasking. Verbal face-to-face communications are best unless the flight team is split, in which case a robust radio system is recommended. Cell/mobile phones are not considered reliable for this intended communication, but may act in a backup role as required.

If communication between the pilot and camera/payload operator is lost or significantly distorted for any amount

of time, the pre-determined emergency procedure should be followed.

7.5 VLOS AND EVLOS OPERATIONS

All routine UA operations should normally occur within the stated VLOS parameters for the country within which the task is being flown. The requirements for the task may differ, however, and in some cases, require the UAS operator to use EVLOS or BVLOS principles. Operation in this case is subject to regulatory acceptance and risk assessment, and permission from relevant government and local authorities. This should also be subject to a comprehensive SORA process.

7.6 BVLOS OPERATIONS

Operation of a UA beyond a distance where the RP is able to respond to or avoid other airspace users by visual means is considered to be a BVLOS flight. Due to the technological and regulatory hurdles that BVLOS operations must overcome to become commonplace in a commercial environment, these operations are currently limited, although a number of commercial research projects are underway around the globe. BVLOS operations in a military context have been common for many years but take place in operational circumstances where different regulatory frameworks often apply.

BVLOS operations present an increased level of risk and need to be managed carefully. If WBG UAS operators have a requirement to conduct BVLOS, they shall ensure that they are familiar with the pertinent regulations and comply with all requirements of BVLOS operation in the country of operation. To enable BVLOS flights to take place safely, UAS operators must ensure that they are sufficiently equipped with the enabling technologies and processes to reduce the risk of operation to ALARP.

7.7 FAILURE PROFILES

Operators should consider contingencies to be applied in the event of in-flight failure. Some examples are:

- Failure during launch – Some UAs, especially FW platforms, have a higher performance speed and use complex aerodynamic principles during launch, so consideration should be given to the actions to take in the event that the launch is unsuccessful. In the event of failure during launch, what will the glide profile of the platform allow and, consequently, where will it land?
- Failure during flight – Operators should consider the flight characteristics of the UA during flight to determine potential contingencies in the event that the UA experiences a failure. These might include identifying emergency landing areas and, in the case of a FW UA, the glide profile that might enable a powerless platform to land safely in a designated location.
- Failure during landing – If the UA recovers using a parachute system, then consideration should be given to a contingency in the event of a system failure.

FREDDIE MBUYA / UHURULABS
Drone pilot engaging with the community.

7.8 POST-FLIGHT ACTIONS

7.8.1 Flight logbooks

A record of every UA operation, including those for training purposes, should be maintained by the pilot in a logbook (hard copy or electronic) for presentation to regulatory authorities when requested.

7.8.2 Accident and incident reporting

All accidents and incidents should be documented and reported to the client representative and appropriate authorities subject to national requirements.

All accidents and near-miss incidents should be captured and stored by the UAS operator in a flight issue log.

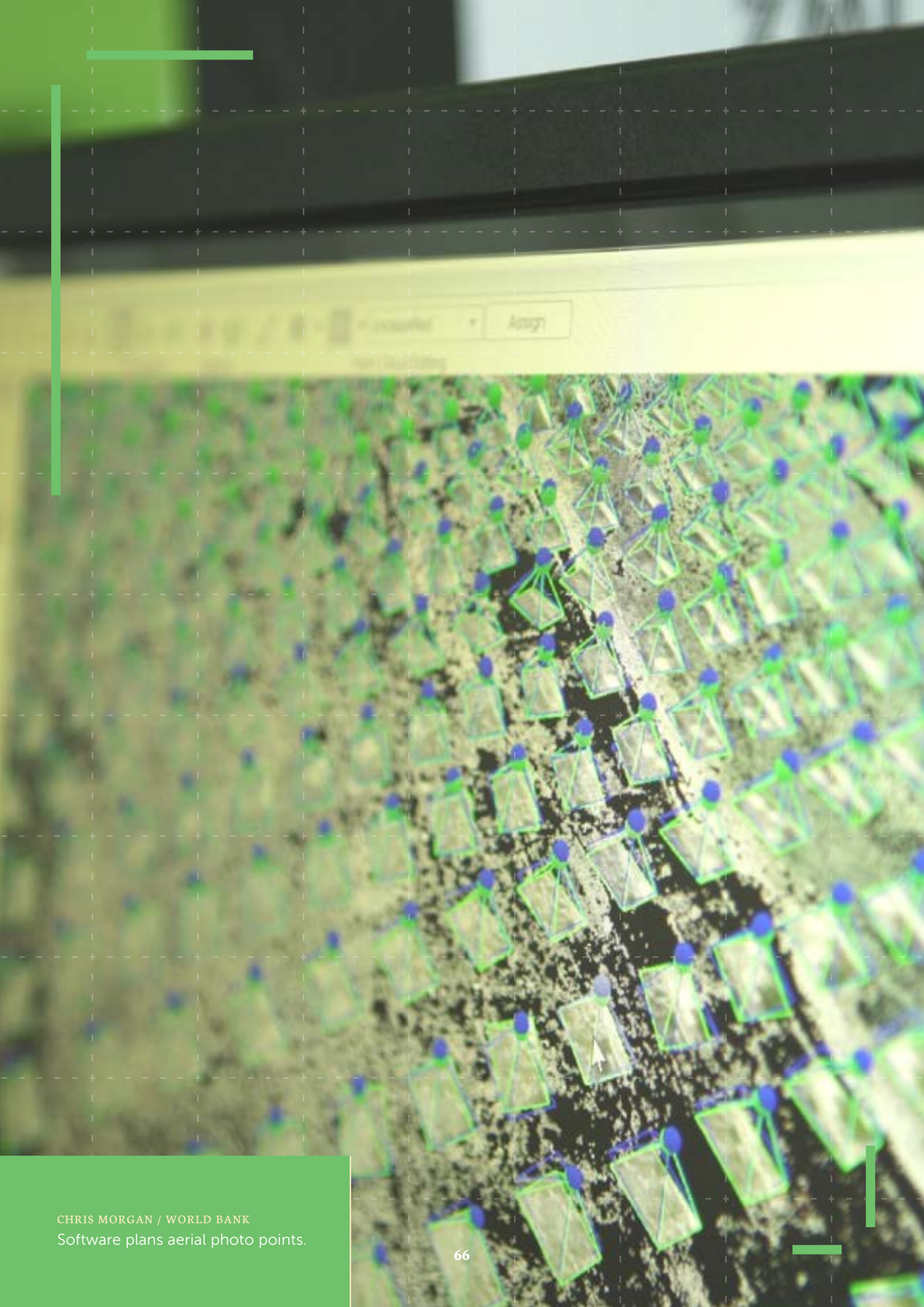
COMMISSION FOR LANDS, ZANZIBAR
Houses under construction in Zanzibar.

8. CONCLUSION

As WBG widens its use of UA in support of its global projects, it should look to adopt a series of principles that promote a responsible approach for use of this technology. UAS operators acting on behalf of WBG must adopt best practices to ensure an appropriate level of safety and professionalism while flying. This will require a focus on reaching and maintaining defined levels of safety, where they exist, while also managing the impact on the environment and addressing concerns on data storage and public privacy.

UA technology is advancing quickly, faster than most regulatory frameworks can evolve. WBG UA operations are increasingly numerous and diverse and conducted in a range of regulatory environments at different levels of maturity. The challenges generated can be mitigated through a thorough knowledge of, and compliance with, the regulations in the country in which the task is being flown. In cases where regulations may not be well defined, a responsible, safe approach to operations should be applied, supported by a robust and well-applied risk-management framework.

The recommendations in this guidance note are designed to introduce a framework that can be applied in all WBG UA operations, wherever they may be conducted. The consistent and responsible implementation of these recommendations will help to instil a safety culture within WBG and propel it forward as a widespread adopter of UA in support of its projects. It is hoped that this document will pave the way for a closer exploration of UA uses for WBG operations, and of the associated factors and considerations. Further work on data policy, differential analysis of costs, and task team operational manuals would be helpful in guiding WBG teams towards project designs that draw the maximum benefit from this promising technology. These cumulative efforts will enable WBG to fully exploit the benefits that this technology will bring and help support its strategic goals.



CHRIS MORGAN / WORLD BANK
Software plans aerial photo points.

ANNEX A. GLOSSARY AND DEFINITIONS[17,18,19,20]

Automatic flight	A flight following pre-programmed instructions, loaded in the UAS flight control system, which the UA executes
Beyond visual line of site (BVLOS)	Operation of a UA beyond a distance where the RP is able to respond to or avoid other airspace users by visual means
Commercial UAS operation	Operation flown for work, business purposes, or compensation or hire
Drone	The term used by the general public or media to refer to an UA
First-person view mode (FPV)	A mode of operation of a UAS where the RP monitors the UA position through a camera installed on the aircraft
Frangibility	The ability of an object to retain its structural integrity and stiffness up to a specified maximum load, but when subject to a load greater than specified or struck by an aircraft, will break, distort, or yield in a manner designed to present minimum hazard to an aircraft
Geofence	A geographical fence or two-dimensional virtual boundary defined by geographical coordinates
Geofencing	Function to make a UA comply automatically with one or more geo-limitations based on geofences; the function can be implemented only in the UA or distributed between the UA and an external system (e.g., UTM system)
Geo-limitation	A geographical limitation; any limitation applied to a UAS to constrain the UA access to or exit from a defined zone or airspace volume; a geo-limitation can be constructed with elements of geofence or performance limitation
Hazard	A condition or item with the potential to harm, including causing death, injury, or damage
Hobbyist operation	Operation flown for hobby or recreational purposes only (see: commercial UAS operation)
Remote pilot (RP)	A person who manipulates the flight controls of a UAS, as appropriate, during a flight and is responsible for safely conducting the flight; the UAS operator during autonomous flight
Remote pilot station (RPS)	Component of the UAS containing the equipment used to control the UA

FREDDIE MBUYA / UHURULABS
Three radios for three UAs in flight.

Risk	The projected likelihood and severity of consequences and outcomes from an existing hazard
UA observer	A person who, by visual observation of the UA, assists the RP in safely conducting the flight
UAS operator	Any person who operates or intends to operate a UAS
Unmanned aircraft (UA)	Any aircraft operated or designed to be operated without a pilot on-board
Unmanned aircraft system (UAS)	The UA and any equipment, apparatus, appurtenance, software, or accessory that is necessary for the safe operation of the UA
Visual line of sight (VLOS)	A type of operation in which the RP maintains continuous unobstructed and unaided visual contact with the UA, allowing the RP to monitor the flight path of the UA and any equipment, apparatus, appurtenance, software, or accessory that is necessary for the safe operation of the UA in relation to other aircraft, persons, and obstacles, for the purpose of maintaining separation from them and avoiding collisions

ANNEX B. CITATIONS AND REFERENCES TO KEY RESOURCES

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FREDDIE MBUYA / UHURULABS
In-field battery swap.

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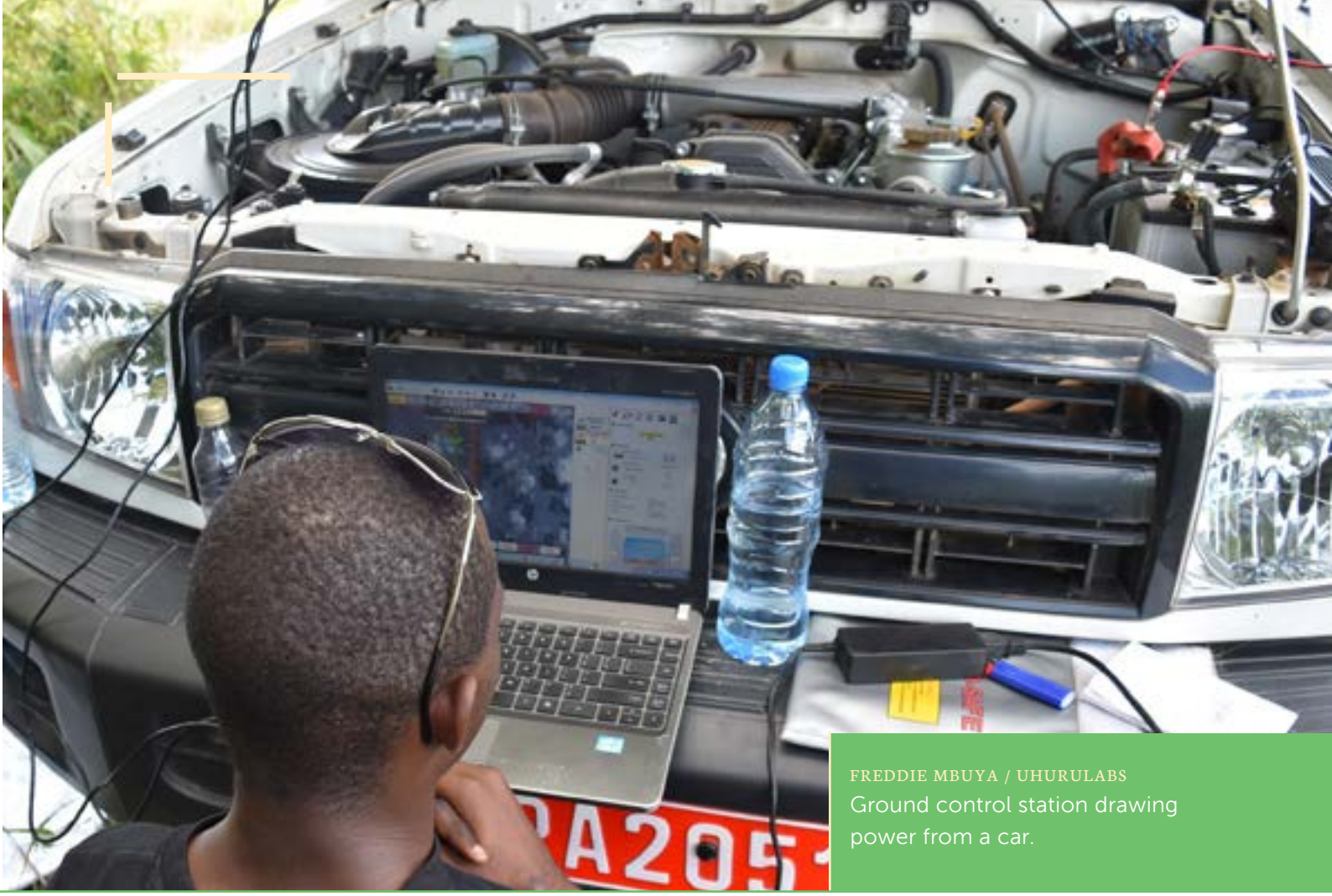

FREDDIE MBUYA / UHURULABS
Ground control station drawing power from a car.

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FREDDIE MBUYA / UHURULABS

Deogratias Minja signing the register at a ward office.

ANNEX C. WBG UAS OPERATIONAL CHECKLIST FORM

The purpose of this document is to facilitate a comprehensive pre-flight planning process to ensure that operations are conducted safely, with appropriate authority, and in accordance with existing regulation. This should be applied broadly across all nations in which tasks are being flown in support of WBG projects.

The form is divided into a number of sections and designed to serve as a record of operational planning. It should be retained and presented to relevant authorities if requested. The form should be completed fully with comprehensive notes and answers to the principle questions.

Download and print a copy of this form here: www.bit.ly/UASWBGChecklist.

PROJECT INFORMATION

Project reference number	
Date	
Name of originator	
Name of operator	
Name of remote pilot	

CLIENT INFORMATION

Name of client	
Address	
Contact details	

TASK INFORMATION

Date / time		
Country		
Task location		
Coordinates		
Vehicular access	YES	NO
Access notes:		
Brief task description		

EQUIPMENT INFORMATION

UA type	
Fixed wing / rotary wing	
Flight time	
Range	
Redundancy modes	

AUTHORITY, REGULATION, INSURANCE, ENVIRONMENTAL, AND SECURITY (ARIES) - PLANNING

Consideration	Questions	Findings / notes
UAS operating regulations	Is a UAS operating permission required? Is one in place? https://www.droneregulations.info/	
Local authority	Do you need local authority permission to operate? Is authority in place?	
Social / community perceptions	How will the community react to UA operations? Are they supportive? Will they require some education on the impact/ benefits of UA operations? How will education be delivered?	

Environmental / wildlife	Are there environmental regulations to comply with? Is the task in close proximity to special scientific sites? Will operations be affected by wildlife? If so, how can you mitigate to reduce impact? Have you educated relevant authorities on the impact to wildlife and how the task will be adapted to reduce this?	
Privacy / data	Does a privacy/data protection regulation apply? What measures must be applied to comply with regulations? What data capture requirements must be met before flight? What data due diligence must be undertaken?	
Insurance	Are you adequately covered for flying operations in this area? (This should include public liability and professional indemnity.) Are there additional insurance considerations needed for the task?	

Security	Are there any existing security threats to the operating team or to UAS equipment?	
Cyber security	What are the potential cyber security risks to your system in this area? What control measures does your UAS have in place to mitigate cyber security risks?	
Reputational	Does the task present any reputational risk to WBG? If so, how will that risk be mitigated?	

PRE-DEPLOYMENT OPERATIONAL TASK PLANNING

Consideration	Questions	Findings / notes
Airspace classification	What is the airspace that you intend to operate in? Does it require liaison with ATC?	
Congested area? **YES NO**	Consider proximity of general public, buildings and roads, extra equipment/ mitigation needed, team size. (Complete onsite survey with site diagram)	
EVLOS? **YES NO**	Are you compliant with national EVLOS regulations (if they exist)? EVLOS: how many air observers are required and what is the estimated maximum range of the flight to complete the task?	
Night operation? **YES NO**	(Consider extra equipment, surveys and air observers required to complete a night operation)	
Other airspace restrictions	Control zone (CTR), aerodrome traffic zone (ATZ) military/civilian danger areas, restricted areas...	
Local ATC	(If applicable) Who is the local ATC unit for the area of operations?	

ATC frequency	(If applicable) What frequency does local ATC unit operate on?	
Proximity to other air users	Gliding clubs, power gliding, micro-lights, kite flying, model aircraft clubs, private helicopter pads…	
Potential air hazards	Small arms ranges, gas venting sites, high-intensity radio transmission area, bird sanctuaries…	
Land permission	Local authority, land owner, military	
Restrictions	Nuclear power station, prisons, school areas, hospitals, elderly homes, government buildings…	
Sensitivities	As above, with the addition of nature reserves, livestock (farms), protected species…	
Terrain	What is the terrain? (farmland, forest, desert, marshlands, mountainous…)	

Ground hazards	Lakes, rivers, motorways, railways...	
Public access	Public right-of-way, gates, footpaths, bridle paths...	
People	Congested areas	
Risk reduction	Can the job be done at another time to avoid crowds, i.e., school leaving times, rush hours, etc.	
Weather	(Consider prevailing weather patterns for the task area)	

NOTIFICATIONS (IF APPLICABLE)

Establishment	Date notified	Contact name	Contact details
Local ATC unit			
Military control			
Police			
Hospital			
Fire			

GUIDANCE NOTE:

Managing the risks of unmanned aircraft operations in development projects

UNMANNED AIRCRAFT SYSTEMS TECHNOLOGY

BACK: FREDDIE MBUYA / UHURULABS

Recovering a UA from a field where it landed.

WORLD BANK GROUP

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