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Insight Report

Advanced Drone Operations Toolkit: Accelerating the Drone Revolution

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Preface

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Systems of mobility are fundamentally important to the health and sustainability of society. The movement of goods and people drives economies and greater interconnection. The supply-chain and logistics systems that have enabled rising prosperity and driven the success of digital commerce rely heavily on advances in communication, automation, and transport. While much of this innovation has been on land, we are now entering an era of rapid transformation – and disruption – in the skies. Unmanned and autonomous aerial vehicles are challenging traditional legal paradigms, while authorities that govern safety and security in the air are struggling to keep pace with technical innovation. Transport systems must adapt to meet the increasing demands of society, but without adding additional risks.

A unique opportunity exists today to harness the revolutionary power of drones and autonomous aerial mobility. Around the world, drones are already having a positive effect on human health, food production, environmental protection, and more. Drones are providing a vision from the skies that redefine how we see the world, identifying unhealthy or drought-stricken crops with granularity never possible with satellite imagery or crewed aircraft. Infrastructure is becoming more resilient through remote inspections and multi spectral imagery by drones acting as an interoperable platform capable of more frequent and precise measurements. Private citizens increasingly have access to capabilities that have historically been available only to governments or large corporations.

Transporting vital goods through the air has been a staple of international commerce for decades, but a revolution is taking place at low altitudes, on demand, for last-mile connectivity. Rural health clinics in Rwanda, bolstered by performance-based regulations, are receiving vital medical deliveries by drone and doing so in a way that is saving lives and reducing waste system-wide. Switzerland leads the world in urban deliveries of goods by drone. Other nations are beginning to explore similar approaches, adopting agile governance frameworks to support societal needs through the skies.

What is needed most today is leadership by those responsible for governing aviation. This toolkit has been co-designed with a wide spectrum of partners across government, industry, civil society and academia in collaboration with the World Economic Forum's Drones and Tomorrow's Airspace team at the Centre for the Fourth Industrial Revolution. While many emerging technologies proliferate in the absence of fit-for-purpose regulation, innovation in the application of drone technology is limited by governments' inability to update legacy rules to meet new possibilities. Thus, the goal of this toolkit is to enable regulators to learn from the innovative policy experiments occurring around the world and empower them to adopt these new governance models that accelerate the promise of drones for all.

Introduction

The Fourth Industrial Revolution is characterized by an unprecedented speed, scale and scope of technological change, with governments around the world struggling to adapt their approaches to policy and regulation in the face of these transformations. From artificial intelligence driving decision-making of autonomous controls to new materials and propulsion systems that will make flying cars a reality, ministries across the globe require the tools for creative governance that maintains the safety of the skies while enabling the increasing movement of people and goods.

One of the most impactful use cases for unmanned aircraft systems (UAS), commonly referred to as drones, is the transport of essential goods in a more rapid, efficient or less expensive manner than ground transport. Many areas of the world are poorly served by existing infrastructure. Advanced drone operations promise to bring both life-saving and economically important goods and services to these communities, with especially acute need after a disaster when the usual modes for transporting goods are no longer functioning. Currently, most governments around the world lack the oversight mechanisms to take advantage of what is possible in this area with drone technology.

To aid and advance the governance of autonomous aerial vehicle technology, the World Economic Forum has collected lessons from around the world that highlight the genesis and scaling phases of successful implementations and created a template of considerations for governments that are interested in implementing similar programmes. The status of drone operations across the globe fall into two categories – pilot projects (genesis) and expansion (scaling). Lessons from both experiences are being gathered in this toolkit to identify how to develop frameworks for enabling advanced drone operations alongside existing users of airspace and to understand the role of the regulator and government authority in scaling operations.

This policy toolkit has been developed in collaboration with the Drone Innovators Network (DIN), a community of leading civil aviation authorities and ministries, supported by industry leaders, that shares best practices to accelerate policy innovation around drones. Brought together by the Drones and Tomorrow's Airspace team at the World Economic Forum's Centre for the Fourth Industrial Revolution, this community was launched in Zurich, Switzerland, in June 2018. The toolkit draws on DIN members' pilot projects that have taken place across the globe, leveraging the lessons shared in Zurich. and complemented by ongoing project work being undertaken by the Forum. It also includes lessons discussed at the Lake Victoria Challenge event in Mwanza, Tanzania, co-hosted with the World Bank, that brought together regulators and pan-African aviation organizations to discuss drone use in Africa.

The intent of this toolkit is to help empower those in government seeking to bring the benefits of UAS to their countries, while mitigating the risks by showing them how other governments have tackled relevant challenges. Safe, clean, inclusive and scalable drone use has become the goal of many nations, recognizing the vast potential to disrupt outdated logistics systems, promote global health initiatives, save lives, minimize costs and to connect disconnected populations. This toolkit, developed not in theoretical dialogues but through comparative analysis of real projects, shares the lessons learned by governments and private players alike to enable the continued evolution of this new technological innovation.

Nation states are struggling to develop frameworks that enable socially and economically important use cases, while mitigating negative impacts, securing the skies from unlawful actors and enforcing the policies they do create. Drones are, by their nature, dispersed. They change the commercial flight model by not operating point-to-point between fixed airports but enabling a more dynamic use of airspace with limited physical infrastructure required. Many of the new players in the drone ecosystem do not come out of the traditional aviation community while seeking to accomplish tasks that would not have been possible with traditional aviation technology. Separating the intent and capability of the systems from pilots who are reliable and operating in the interest of society is a significant challenge to authorities previously tasked with overseeing well-understood and regimented communities. This is both the problem and the promise posed by drones.

> **We are witnessing the beginning of a logistics revolution; one that will redefine the way goods and people are moved around the world and one that will drive social change alongside societal impact.**

Timothy Reuter, Head of Drones and Tomorrow's Airspace, USA

What follows are insights and recommendations from the most successful projects, demonstrating what it takes to launch and oversee advanced drone operations. The stories and information were captured first-hand by the World Economic Forum speaking directly with policy-makers, entrepreneurs, regulators and technical experts who have fundamentally shifted the dialogue from what "may" be possible to what "is" possible, in a very short time.

The two case studies presented are great examples of how leaders in the field can revolutionize governance frameworks. Rwanda's first successful deployment of drone delivery for medical logistics is not the end of the story but the beginning. The success of the operation drove the Rwandan government to seek new methods of regulation to scale the contribution drones could make to their society and economy. Switzerland became the "Home of Drones" only after being fully embraced by the Swiss Federal Office of Civil Aviation (FOCA). Looking ahead, how does the government invest in enabling drone infrastructure and what role does the public play in determining the approval processes? The answers to these questions and the stories from these countries can help guide the decision-making of regulators from around the world.

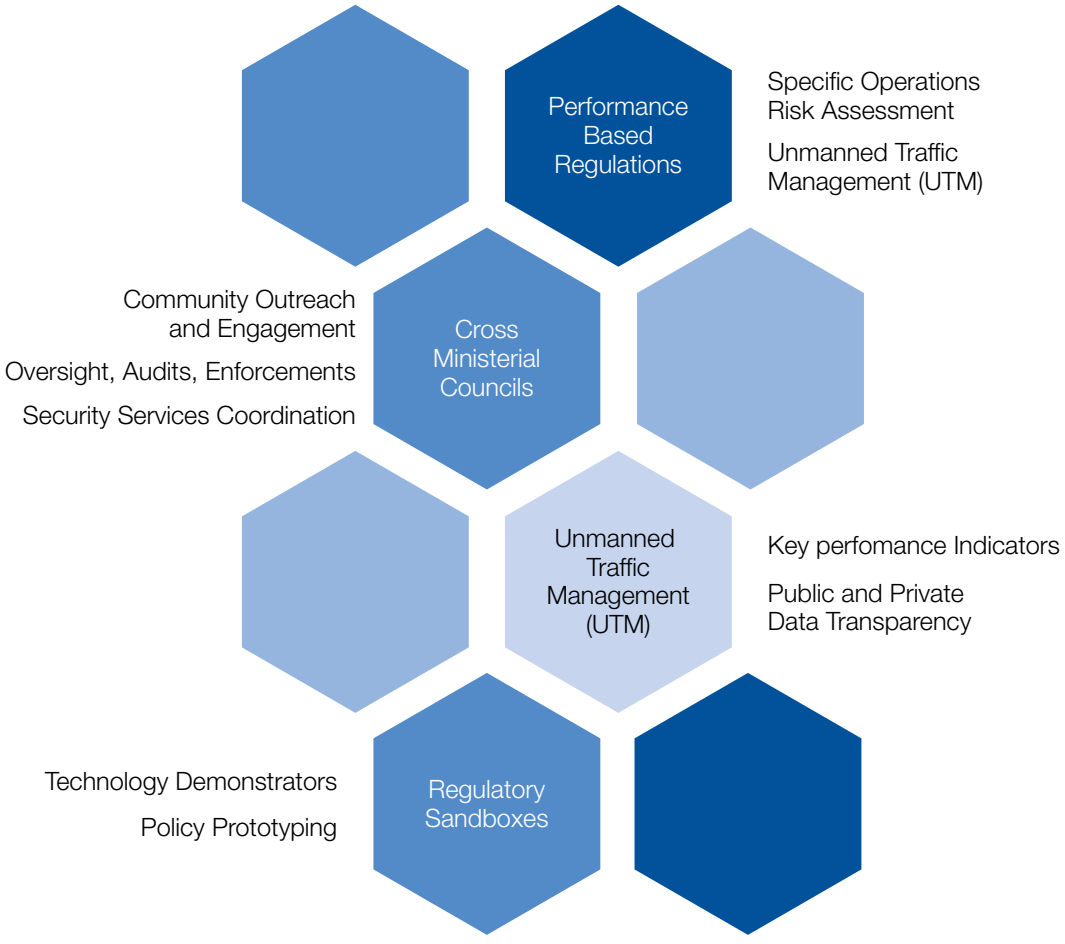
Tools for Governance of Advanced Drone Operations

The opportunity for countries to benefit from advanced drone operations is increasing as associated technologies continue to rapidly improve and evolve. Most countries are struggling to routinely enable beyond visual line of sight operations, multiple aircraft per operator or autonomous operations, and operations around people, all key conditions for realizing the full potential of drones. For the purposes of this paper, we consider operations that meet at least two of these three operational criteria to be advanced operations.

In Switzerland, Swiss Post is connecting hospitals and medical labs by drones; lifting medical supplies and cargo into the skies to avoid transport gridlock and ensure the security of vital cargo. In Rwanda, the Ministry of Health is saving lives through aerial supply chains that bring blood products to clinics around the country, preventing stockouts and eliminating expiration of product and wastage from the system. The following elements are modular components of an overarching programme that regulators and the community identified as fundamentally important to enabling applications.

Performance-based regulation model– All over the world, governments have struggled with balancing their expertise in oversight through certification with the dynamism of rapidly evolving technologies. In early 2018, Rwanda passed a pioneering national scale regulation based on performance, not prescription. This regulation was developed by the Rwandan Civil Aviation Authority with support from the World Economic Forum's Centre for the Fourth Industrial Revolution, in consultation with experts from all over the world. Regulations based on dynamic risk mitigation enable authorities to approve new types of missions based on evolving technologies while keeping unsafe operations out of the airspace. Performance-based regulations (PBRs) are regulations developed to combine risk profile and safety performance, address the management of risk, and ensure compliance. These are regulations that focus on the actual risk presented by an operation, such as EASA's newly promulgated regulation, and are founded in international best practice and safety management doctrine. Rwanda's implementation of PBR for all category of unmanned aircraft has led directly to an increase in operations for its drone ecosystem, promoted expansion of domestic industry participants, and will enable the planned scaling of the Zipline blood delivery system to 95% of the country.

Cross-ministerial councils – Breaking barriers in communication across ministerial silos helps develop a broader understanding of the opportunities, challenges and solutions government officials face before operations begin. By engaging all relevant government departments



early, the opportunity for identifying socially meaningful and economically impactful use cases can ensure buy-in and a shared vision across the government as well as much greater societal adoption from community engagement through existing government channels. In Rwanda, the Ministry of Health set up and coordinated directly with the Drone Advisory Council and Zipline to integrate drones into their blood delivery system, which led directly to the national scale success that exists today.

Security service coordination – Without direct buy-in and consultation from the onset, security concerns will prevent the genesis and scaling of operations. When considering the development of drone operations, two concrete challenges must be first and foremost – safety and security. In Switzerland, direct and early coordination with security authorities that had oversight authority over critical infrastructure assets enabled FOCA and industry coordination in a collaborative manner.

Technology demonstrators – Fit for purpose events, bringing together the stakeholders that must be convinced the technology is mature enough for implementation or further experiments can be extremely effective for facilitating early drone operations. By identifying the national, regional, or municipal organizations and leaders that need greater awareness of technological capacity and including those individuals with the ability to influence communities, a technology demonstrator can provide a final push to expand into real operations. In Rwanda, operations took nearly 18 months to meet final approval for widespread operations, leveraging months of on-site inspections, training demonstrations, and two technological demonstrations of the communication protocols and payload management capabilities in worst-credible state scenarios.

Regulatory sandboxes – Governments can support a variety of significant drone developments by enabling small areas of operations, including specific corridors for flight. In Malawi, UNICEF and the Civil Aviation Authority of Malawi worked together to create a drone corridor where the national and international communities were invited to test, fly and learn in a real-world environment that promoted community engagement, operational expertise and government exposure leading directly to the expansion of drone operations for mapping, delivery, and multiple other use cases.

Community outreach and engagement – Without early, direct engagement with the public and groups that have concerns about privacy, data usage and applications of the drones, governments can find themselves working against the very groups who could ensure their positive impact. Specific campaigns to develop community engagement by governments, while working with company vendors that also want to operate, can address the concerns of the public when impact-driven use cases have been developed. Zipline, in collaboration with the Government of Rwanda, worked directly with the community to show that video collection from the drone was not taking place while also promoting domestic workforce capacity building and recruitment, leading directly to local acceptance and excitement about the operations.

Policy prototyping – Understanding that as drone technologies, including unmanned traffic management, are evolving rapidly, the policies that govern those technologies must also be able to consistently evolve. Providing a planned revision of the policy, or a continuous process for evaluating the implementation policies for drone technologies according to key performance indicators (KPIs) is a new approach to governance requisite to meet the challenges of the Fourth Industrial Revolution. Switzerland's Federal Office of Civil Aviation (FOCA) approaches oversight in this way, as it continuously adopts the evolved and updated specific operational risk assessment (SORA) from the international organization JARUS, the Joint Authorities for Rulemaking on Unmanned Systems. As more and more countries adopt it and new systems come online, the performance of those systems is better understood and the needs of communities or authorities evolve.

Public-private data transparency – Providing open-source data that can inform new technological development, while keeping communities of stakeholders engaged, helps promote domestic technology growth and enables innovation throughout the local economies. Tanzania's drone-based mapping project of Zanzibar, in collaboration with the World Bank, enabled open sharing of collected data with local communities and has since helped promote innovative approaches for data usage in disaster management.

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

Specific operations risk assessments– Implementing performance-based regulations requires policies and tools that reflect risk assessment protocols and a concept of operations, or operations centric, approach to oversight. The SORA is a rapidly evolving document developed by JARUS and helps facilitate PBR implementation. This tool enables governments to gain a clear and formal understanding of the most important factors that define more advanced drone operations within the context of international best practices and has demonstrated established successes in Rwanda, Switzerland, Spain, Australia, New Zealand and, more recently, the United States. The Matternet medical delivery operations was largely made possible through the oversight of FOCA through the implementation of the SORA, now being used to provide expansion into the US through the UAS Integration Pilot Program (UAS IPP).

Key performance indicators – Key performance indicators (KPIs), developed through ongoing collaboration from ministries, private stakeholders, academia and public interests provide much needed context for evaluating the success of enabling policy and the operations themselves. KPIs should be specific and tied to established goals and objectives, identify critical metrics that would meet the goals and objectives, and collect measures that relate directly

to the critical metrics which operationalize those goals. In Rwanda, the Ministry of Health, Zipline and the Rwanda Civil Aviation Authority (RCAA) have maintained data on the number of flights, number of incidents, numbers of lives positively impacted by the operation, and number of jobs created locally that all operationalize different goals of the process thereby making the long-term sustainability more concrete and understanding the various outcomes achieved through the implementation of advanced drone operations. Additionally, KPIs help understand whether other technologies may be more effective for achieving overall health outcomes (i.e. investing in supply chain, infrastructure, or training).

Oversights, audits and enforcements – The responsibilities of government offices to ensure safety, security and inclusion in the airspace will require different authorities to work together to enforce and oversee the advanced drone operations in their jurisdiction. Some technologies like unmanned traffic management (UTM) and automatic authorizations can help with this process, while other non-technical policies will need to be applied that ensure auditing and in-person assessments of skills meet the safety requirements of the operation. FOCA prioritizes in-person audits and oversight of ongoing and proposed operations to ensure the pilots and technology perform according to what is proposed; this is an opportunity for learning, adapting and collaborative development for long-term safety.

Unmanned traffic management (UTM) – While advanced drone programmes may not require wide-spread deconfliction if the operational mitigations are in place to ensure separation from air traffic, the scaling of a national drone programme will require technologically based deconfliction and constant awareness for central authorities. For airspace management to scale with the growth of manned aviation alongside the exponential increase in unmanned operations, enabling a national technology that aids in the registration, identification, authorization and deconfliction of all traffic will be a necessity for governments. UTM can play an important role in minimizing ground risk, as well as ensuring the appropriate level of involvement of all stakeholders. As Airbus' *Blueprint for the Sky*, its futuristic scenarios of air-traffic-management, illustrates: "The underlying principles and approaches of UTM schemes in development around the world are very similar, even though each region uses slightly different terminology and organization. Each one consists of systems run by regulatory authorities, independent services provider, data providers, operators, and aircraft."[1] The future of traffic management, for all vehicles, may look less like traditional air traffic management and be more akin to certified databases referenced through APIs that provide service through a variety of apps and software platforms.

Performance-based Regulations: A Proven Path to Drone Success

Performance-based regulation (PBR) is a new methodology introduced to meet the demands of the Fourth Industrial Revolution in the aviation sector. It is an evolution in governance for unmanned aviation, providing an agile framework for airspace access, focusing on actual risk rather than strict certification. When PBR is applied to the field of unmanned aviation, it enables the expansion, piloting and live-testing of new technologies through a holistic approach to risk management and redefines what operations are possible. By focusing exclusively on a strict certification approach to aviation technologies or waiting for other CAAs or international bodies to develop regulations that permit advanced drone operations, nations miss out on life-saving benefits that drones can provide. Social and economic demands that could be fulfilled through advanced drone applications are being left unfulfilled as governments struggle to move forward with flexible yet safe regulations.

Prior to the adoption and implementation of PBRs, CAAs often had trouble determining how to allow UAS access to broader airspace where private- and public-manned aviation operated. Without harmonized certification standards and lacking regulatory approval mechanisms for specific types of flight (autonomous control, multiple aircraft per operator, beyond visual line of sight, high gross take-off weights, etc.), UAS are constrained by process, institutional resourcing and not technological capability.

PBR transforms the prescriptive dynamic by creating a process-focused framework for approving the new technologies while considering operational context to mitigate risk. While more progressive organizations had discussed a need for PBRs, and some had created policies that reflect the underlying theory of PBR (Switzerland and the European Aviation Safety Agency's proposed regulation), the Forum has sought to synthesize a robust underlying theory that combines best practices and industry standards. This initial theory underpinned the collaboration with the Government of Rwanda, where leadership at the Rwandan Civil Aviation Authority saw the benefits of PBR and implemented one of the first national scale, performance-based, UAS regulation.

It is important to understand that PBR is not a pathway that will eliminate the need for certification for all types of unmanned aircraft or operations. However, PBR allows systems that have yet to, or are never intended to, attain airworthiness certification access to airspace by mitigating the risks associated with flight to an acceptable level through other means. In other words, PBR takes into consideration four separate elements that develop the overall concept of operations (CONOPS). These elements are:

1. Personnel who will operate the aircraft
2. Environment within which the operation will take place
3. Mission goals that are being proposed
4. System(s) that will be used for flight

These four elements are not new to the aviation community as they are a direct evolution of safety risk management defined by safety management system (SMS) theory. In concept, the approach is what takes place all around the world. A potential UAS (drone) operator outlines the mission they want to undertake (where, when), what aircraft system and specifications they will use to accomplish that mission (how, what) and the personnel intended to execute the mission (who). From there the government can authorize or reject the approval. PBR allows governments to ask the important questions without needing to ensure that a specific technology is included in the results, leading to greater innovation, a more inclusive economy and the ability to align safety goals with societal ones.

A good example of how PBR turns the model on its head relates to the drone delivery of goods that may fly over low-density rural areas or towns, with a high degree of autonomy, using multiple vehicles per operator. In many jurisdictions these elements that characterize flight approvals would be impossible as the regulations governing certain requirements for pilots, separation(s), altitude(s), or populations and the mechanisms do not exist to have a conversation on the reality of safety or the risk balance between the need for the flight versus the risk to society. PBR allows the authority to engage in a conversation with an applicant seeking approvals for flight. If the proposed flight uses a new technology or exists in an area classically deemed to pose a higher risk than otherwise acceptable, the applicants and the government may provide recommendations on how to meet the threshold of safety – perhaps additional redundancies, specific operational trainings, proof of reliability of the system, protected spectrum, or an additional pilot.

In a recent workshop held in Mwanza, Tanzania, government officials throughout Africa identified common, but important, risk mitigations that could go a long way to ensuring the safety in the sky and on the ground.

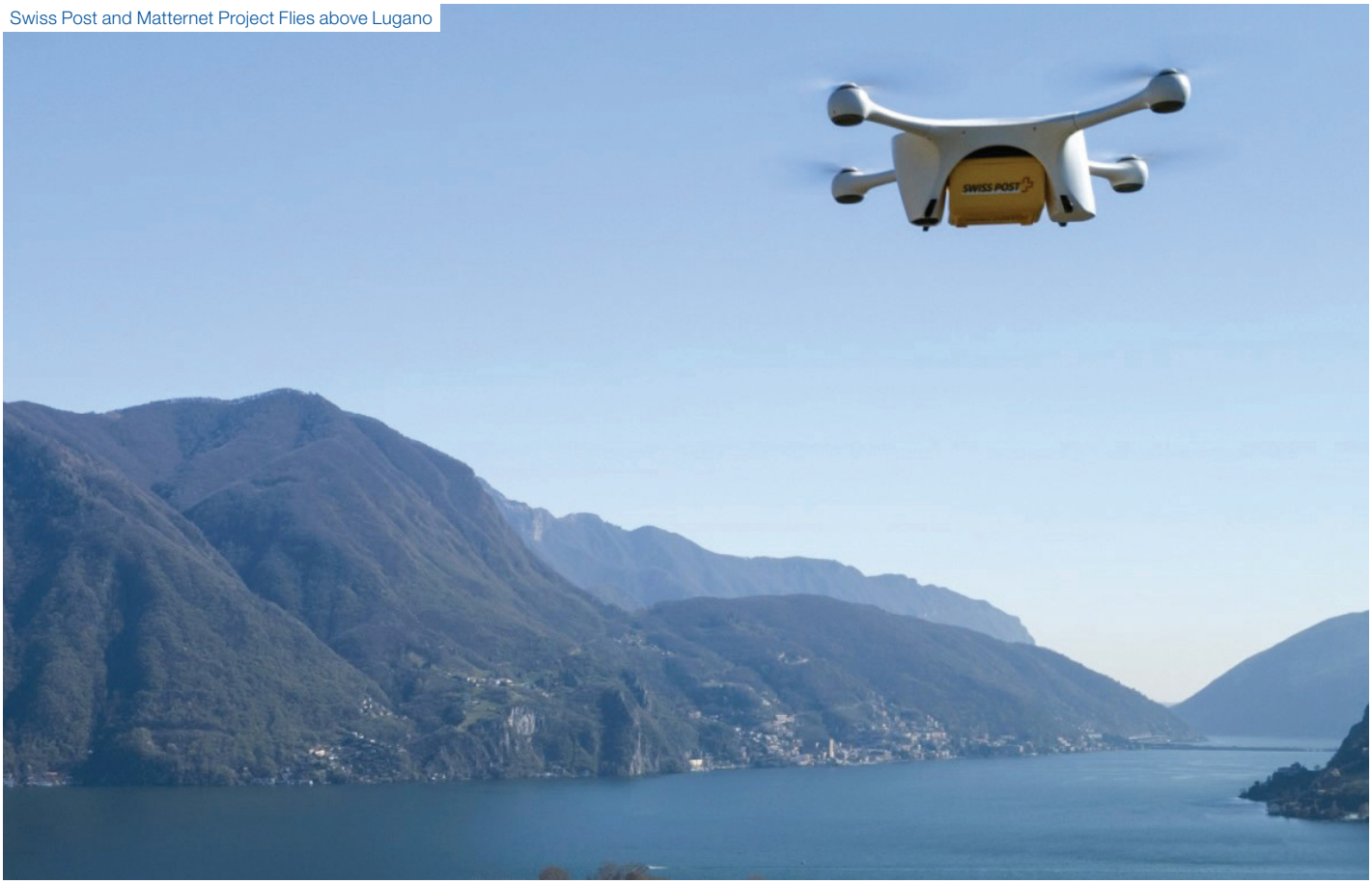
The latest efforts by European Aviation Safety Agency (EASA) and FAA UAS pathways to date are in conformity with this approach and are likely to develop a framework for regulatory oversight that correlate.[2] EASA, considered one of the foremost leaders in aviation oversight, allows that this newly proposed regulation shall "implement an operation-centric, proportionate, risk- and performance-based regulatory framework for all UAS operations…" The first national adoption of PBR, the outcome of the Forum's Drones and Tomorrow's Airspace collaboration with the Government of Rwanda, is a path-breaking implementation of what EASA, FAA and other progressive governments have examined, but have not yet implemented, thus providing a real-world model for how this approach can work.

Tanzania, a regional neighbour of Rwanda, has seen the dramatic benefits that drones present and recently turned

to Rwanda's regulatory framework for guidance. One senior aviation safety technician of the Tanzanian Civil Aviation Authority announced: "We have taken the regulatory framework that Rwanda has passed and the work that the Kenyan CAA had done as models for our work. We want to have a flexible, scalable regulatory framework."[3] While the world is beginning to adopt a framework that allows for exemptions or waivers to existing unmanned aircraft regulations, the goal is to create a framework that can fit all modes of flight, all systems of UAS, and consider both the risks and benefit to society.

Case Study: How Switzerland Pioneered Urban Drone Delivery

Swiss Post and Matternet Project Flies above Lugano



Switzerland recently became the first country in the world to have ongoing urban drone delivery through a collaboration between Swiss Post and Matternet, a drone company based in Palo Alto, California. These operations, somewhere between test and scaled commercial operations, are the output of work started in early 2015. "Demonstrations are over, pilot projects are over," says Janik Mischler, Head of Autonomous Delivery Operations for Swiss Post. "In Lugano, operators have flown over 2,000 flights. This is the right direction, but we still have technical people on site, in Lugano. For this to make sense, you need a fully autonomous operation, with someone overseeing everything from the flight operations centre. We need U-space[4] to automate the integration of our systems in a jointly used airspace system." While the business case is still being proven, the Swiss government has demonstrated flexibility, agility and leadership; empowered by a regulatory framework that enables them to consistently update their rules and a CAA willing to manage risks.

What FOCA is perhaps best known for in the unmanned aircraft world is its leadership internationally in the development of implementation strategies based on its initial operational risk framework known as the GALLO. The GALLO, or Guidance for Authorization for Low-Level Operation, was the initial implementation policy that the Swiss CAA created to provide a framework for accessing airspace in lieu of system certification. The GALLO became the first standardized risk management framework which would meet the needs of a CAA to ensure safety. While some may see this as an incremental step in the evolution of aviation risk management for drones, it was a crucial step from a perspective of agile governance. Previously, the question had been, "how do we certify the aircraft for airspace?" Under the new system, the question became, "how do we maintain aviation safety?"

Two seemingly unrelated events led directly to development of the SORA now being used in Switzerland, soon to become a

key enabler of new regulations from EASA and implemented around the world. The first event came from manned aviation, when a new electric aircraft, *Solar Impulse*, required FOCA to assess the airworthiness of a system with advanced battery and propulsion systems, remote pilot back-up controls, and an intent to fly first in rural operations (which was more easily approved) and then over urban settings like San Francisco, Zurich and Abu Dhabi.

"The *Solar Impulse* project demonstrated the need to incentivize CAAs," Markus Farner and Lorenzo Murzilli, of FOCA's Innovation and Digitalization Unit (ID), acknowledge. "We worked with *Solar Impulse* and it was the project that helped us understand new innovative things. Twelve years before the around-the-world flight, they came to FOCA. At the time we saw them as explorers, only seeking to operate in rural areas and not near many people. It was really a basic safety case." In other words, though the operation was using an experimental aircraft with no certification, the operation was low-risk and could be authorized. "However," they went on, "they came back with a similar aircraft and wanted to fly over people. They proposed flying over New York, San Francisco and around the world and wanted to do it with a Swiss certificate over any number of countries." The question soon became, "how could FOCA authorize this?" It was perceived as a huge risk. What it eventually came down to was leadership and flexibility.

"We had to look to see if there were any ways to ensure basic air safety" Murzilli goes on, "…but there were no standards. We had to examine it from a holistic view. At the time, they had a lot of elements that were like a drone operation; a remote-control station that backed up the pilot, for example. We had to build the entire safety approach from scratch – the analysis and approvals." In Switzerland, Murzilli says: "We cannot say, 'it is not safe' simply because we do not have the right procedures to determine if it is safe. We cannot say, 'no you cannot fly', unless we have a justification for that 'no'. In manned aviation, you must justify your 'yes' through the certification processes. You check boxes for each requirement. With this, there were no boxes to check. This is a clear directive from our leadership."

If there is one reason that the SORA started first in Switzerland, this is probably it. In terms of process, Farner says:

> **"You cannot tie safety to your way of doing things. You cannot argue that it is the only way of achieving safety. For us, it went beyond work with *Solar Impulse*. It became emotional. We had to build trust with the *Solar Impulse* guys and they learned to trust us not to just say 'no'. We had the power to approve or decline a mission. This was someone's life goal we had in our hands. That is an important responsibility."**
>
> **Lorenzo Murzilli**, Switzerland

Just as *Solar Impulse* drove FOCA to examine approvals in a holistic fashion, Jean-Pierre Heckman, of Airbus, was presenting a new model of holistic risk evaluation for a project known as ASCOS. This holistic approach to aviation safety focused on the harm CAAs want to prevent; specifically, at those events that lead to death. The presentation examined a new approach to looking at both sides of the model: threats, hazards, harms and barriers. The project was not about identifying the barriers but rather understanding how barriers can fail and what is the mechanism to strengthen the barrier being employed. By imparting an evaluation of "robustness" or "reliability" for the harm barrier, a CAA can more easily trust the mitigation being employed and grant increased access to airspace. The bow-tie risk model – named for its unique graphic interpretation showing both sides of the risk equation meeting in the middle like a bow-tie – is fundamental to the SORA.[5]

The first FOCA working group on drones took place in 2007 in reaction to demand from universities and tech companies seeking to experiment with new, unmanned aircraft. However, it was not until 2013, when Swiss Post approached the CAA with the intent to explore drone delivery of medical samples, that a need for some new process was clear. "At this time," Farner and Murzilli explain, "…we had some BVLOS operations going on. The first BVLOS 'swarm' flight was actually authorized on 24 April 2010 for EPFL, one of the two Swiss Federal Institutes of Technology, but it was small in scope."[6] Until then, flights had been evaluated for low risk, and if they were in rural areas with minimal risk, then the operation could be approved.

After extensive review by Swiss Post of the drone landscape in Switzerland, Matternet was identified as a likely partner. The first operation by Matternet in Switzerland used the GALLO approach, identifying operational mitigations for an uncertified aircraft system. The Swiss Post innovation team brought Matternet to the attention of FOCA to begin coordinating demonstrations with an intent for medical deliveries with drones as soon as possible. In 2015, one such demonstrator, began. Matternet came over from the US and, in a field, the first BVLOS flights took place in coordination with the GALLO approval process. With each additional successful test, the CAA could move forward with longer and longer flights throughout 2015.

As Christoph Derrer, Matternet's UAV Compliance and Regulatory lead, explains: "You don't just wake up and say you want to do something; it can take years to prove it out." At the time, all parties acknowledge, the aircraft was not adequate to meet the vision. Operationally, FOCA would not even let them fly over cows. There were a lot of requests to change the technology, even to the point where the business cases changed, and Swiss Post looked for other manufacturers and service providers. Eventually, finding no other partners that could meet the requirements of FOCA and as Matternet's airframes and supporting system continued to evolve, Matternet returned to conduct the next steps. "What mattered most to us…" Murzilli points out, "… is that the Matternet leadership always listened to our concerns and adjusted their system, operations or trainings. They were a true partner and we felt we could trust they cared about safety."

Trust is a key element in all drone operations. “This is the case for every approval…” Farner and Murzilli are sure to make clear, “It is difficult to put into a checklist or toolkit. When you just put it into a prescriptive regulation you don’t get the personal interaction, back and forth. There is so much you don’t know; it’s impossible. You must trust the team. The FAA used to say we have a partnership for safety and that is something we must do. Propose and verify. If I find that needs change, you must work with us to evolve and change because this is a partnership.”

Meanwhile, the European Commission, through JARUS, had begun to define unmanned aircraft classifications in a way that would enable operational risk management rather than strict certification. The “three pillar models” began to be formulated around three classifications – open, specific and certified. The GALLO, which enabled operations beyond basic or low risk, clearly was well suited to help approve the “specific” category according to this new model. Thus, the GALLO became the SORA – the specific operations risk assessment. As of December 2018, the SORA is being finalized by JARUS WG-6 for direct reference in EASA’s proposed regulation. It will become the means of compliance to meet EASA’s specific category of flights.

Just as with Solar Impulse, FOCA saw a need to develop a methodology that gave a high level of confidence for safety. It began with the GALLO, which was being used and tried to build something else around it using the bow-tie model with robustness as a risk framework. This became the SORA. Internally, the innovation management office invited representatives from throughout FOCA’s aviation safety to provide input and reflection. “When we were building the SORA or the GALLO,” Farner explains, “…we brought together all aspects of the CAA into one room to look over the building blocks... Different competencies drive different results to different problems.” They also sought input outward, bringing together those who were having similar challenges and addressing them in a similar, if not concrete, way. The JARUS WG-6, in charge of developing the SORA model internationally, grew from a two-member group to what is today an 80-member group with representations from countries and industry stakeholders from all continents. Many other countries started to use the SORA framework and through continuous feedback from real-life operations the SORA continued to evolve and improve.

As Matternet and Swiss Post began their operations, other entrants started inquiring how they could also access airspace the SORA, then, became much more defined and began to be shared with many operators. “One of the major challenges,” Mischler says, “...was the uncertainty to operate because we didn’t know what it was going to take to fly in urban areas … at the time it was a moving target and the initial process was not done. We were all learning how to do it. Now we have the SORA, which is the outcome of the initial process.”

A good example for how the SORA is different from a certification approach to air safety is the way parachutes were included into operations. FOCA, rather than requiring certification to a standard that did not exist, engaged in an extensive review of the parachute system, culminating with first-hand tests of the system. Farner says: “You realize very quickly that if you use the same approach for drones that you do for manned aviation, you will fail.”

Skyguide, the Swiss Air Navigation Service Provider (ANSP), exemplifies a company founded in traditional aviation mindsets, and without direct competitors in its jurisdiction, but nevertheless beginning to explore and invest in aviation technologies as well as innovative mindsets. Florent Beron, Senior Corporate Strategist for Skyguide and a former air traffic controller, explains that their interest and work in UTM, or U-Space in Europe, started in the exploration of technologies that may have a direct impact on Skyguide’s long-term future, in December 2016.

At this same time, Swiss FOCA was undertaking the same analysis, asking the question: “What is happening and how do we track drones?” As enabling technologies go, UTM is a clear need in the industry for the challenges it solves, including a need for registration, identification, deconfliction, air traffic coordination and authorizations or communication with local authorities beyond FOCA or the ANSP. Beron was so convinced that U-Space would “transform the aviation industry forever” that Skyguide had to do “something.”

Over the next year, Murzilli and FOCA challenged Skyguide to do more than just “talk about it,” which was something that seemed to be the status in Europe. There were many organizations discussing U-Space but no viable technology solutions. “We want to be doers,” Beron reiterates, “not talkers.”

Skyguide began building out the needs and requirements with FOCA over the next year and sought out technology providers as partners. As an ANSP, Skyguide saw its responsibility as managing the airspace and resources between manned and unmanned aviation, while U-space service providers (USSPs) would provide the interface and service layer on top of it. Initially, registration and identification were the main focuses – to identify those drones in the airspace who should be there separate from those that should not. As a close partner with FOCA, the two began searching for those companies who could demonstrate their capability live.

In April 2017, Skyguide signed a Memorandum of Understanding (MoU) with AirMap and senseFly, which had just adopted AirMap’s platform solution, to provide a demonstration in June of registration, identification and aerial deconfliction. Members from leading technology companies all seeking to be involved in unmanned systems joined the demonstration where the first implementation of U-Space in Europe was shown in operation in less than three months’ preparation. “Skyguide really started building U-Space out after this demonstration…” Beron explains. “It gave us credibility and reliability. It showed how the ANSP can work directly with the regulatory bodies, new technology providers and manufacturers of drones and software. We want to create an open market of users, service providers, manufacturers and the public.” By demonstrating the technological identification of drones and steps toward airspace deconfliction, a significant hurdle was overcome.

Francine Zimmermann, an officer with Swiss FOCA, continues: “When the World Economic Forum approached us with the idea of creating the Drone Innovators Network (DIN), and our minister, Federal Councillor Doris Leuthard, decided that its first meeting would take place in Switzerland, it was clear for us that we were in the position to contribute something to the greater good. This event helped motivate all involved stakeholders to set up a Swiss-wide U-Space demonstration. It showed how U-Space can be used to enable advanced drone operations by mitigating both air- and ground-risk.”

In June of 2017, FOCA invited the many organizations responsible for local and cantonal emergency response and police activity to one location for consultations. Though FOCA, as a federal organization, knew aviation was in its domain, it believed that ensuring that these other organizations were supportive of the operations would be important. At the cantonal and local community level, representatives can have the right to block, or severely slow, activities until they support them or until legal challenges have been made. “If you want to do something in a reasonable timeframe” Farner says, “you must bring everyone together.”

This meeting included the cantonal Office of Transport, city police forces, cantonal police, several departments of each of these police organizations, including emergency coordination (dispatchers) and media/communication groups responsible for all of them. “Looking back…” Farner goes on, “this meeting was very important. They made important recommendations to applicants as how to inform the public to a high-quality standard. Everyone who came had an open mind. Nasty questions were asked, but it was their job to ask them and ours to answer.” At the outset, the stated goal of the meeting was to have everyone’s agreement for the operation to move forward. In the end, all participants learned a great deal. Direct outcomes that FOCA recall of that meeting for any organization looking to develop drone operations are:

– All police need a detailed knowledge of the project, including emergency concepts, routes, altitudes, times, distances and emergency procedures

Solar Impulse flying Above Swizterland

Source: REUTERS / Christian Hartmann

– Clear and direct knowledge of who the contact point will be for the operation should be available
– If blood is being transported, a clear definition of custody needs to be developed for accident responders

Constant interaction with the cantonal police, as well those responsible for planning critical infrastructure, has been important since early in the drone operations inception. Dominik Schwerzmann, an officer of the Zurich Cantonal Police, says: “Drones represent an innovation and technology. It’s a new threat, an unknown that people, even police, don’t understand and cannot assess quite yet. It will be a similar process with every technological innovation in a society. With the railways it was the same discussion. With electrical power we had the same arguments. With cellphone, same concerns. I think it’s a task for federal and local authorities to help people understand what’s going on to develop an environment of trust.”

While it may seem that this evolution occurred smoothly and with no challenge, especially when it comes to Matternet and Swiss Post, such is not the case. In October 2017, all approvals were stopped because of a lack of resourcing, just as Swiss Post was promising its customers that medical deliveries would begin within three months. Suddenly, an environment open to demonstrations and a lack of business case or direction devoid of specific customer pressure became highly pressurized and political. When approvals stopped, politicians and CEOs became involved. It became very clear that drone operations were a serious business and resources had to be unlocked.

As Matternet’s drone operations in Lugano continue to evolve, reaching 2,000 flights since October 2017, roughly five flights over the city per day for commercial deliveries, the recognition that Switzerland is the “Home of Drones” continues to grow. What started with single demonstrations in rural areas, with a prohibition to fly over cows, led directly to the first demonstration of coordinating air traffic operations with Skyguide and AirMap at Geneva airport. Murzilli says: “For FOCA, the question is not, ‘How to integrate into the airspace in a completely scalable way for all aircraft?’ The question is, ‘How do I bring things in the air, for which I don’t have a certification framework, so that they can be eventually certified later?’” This is a distinction that is problematic for much of the drone industry.

CAAs are concerned that by authorizing one ongoing, medium- or high-risk operation others will follow and they will be swamped by applications. FOCA sees this problem as a challenge, but not one that cannot be overcome. “There shouldn’t be a prescriptive limit between specific and certified operations – with few notable exceptions such as passenger aircraft,” Murzilli is quick to explain, “Sooner or later, companies intend to export all over the world and they need to think about how to do that. For flights all over the world, ICAO can create standards and recommended practices (SARPs) for certified aircraft. The SORA will only take you so far. For scaled operations across many countries, you will need to certify your systems when the process becomes clear. It is mainly a business requirement.”

Some scepticism has persisted as to the level of adoption of the SORA internationally, but FOCA sees Matternet's selection for two of the United States Federal Aviation Administration's (FAA) Unmanned Aircraft System Integration Pilot Project (UAS IPP), largely based on the experience of using the SORA, as a clear indication that it is the right way forward. As Matternet seeks airspace access under the FAA's Part 135 UAS lightweight category, it will show that the SORA leads directly to certification. To FOCA, this is not about conflicting approaches where one must win, it is about supplementing the evolution and integration of drones. As Murzilli says: "This is about helping a company go from 10 people to 5,000 people without killing them in the process. In two to three years' time maybe even a start-up can try to do scaled drone delivery."

While innovation may seem sporadic and new technologies may seem to arise quickly, agile policy-making and supportive technology governance requires intentionality. Institutions that are focused on safety exclusively will not be inclined to try new and innovative operations where they present risk to the status quo. As Murzilli and Farner point out: "For those who want to enable drone operations, sometimes it feels like you are an outpost behind enemy lines. You need air support from the top; leadership must understand the importance of what you are doing. If your leaders don't want it to happen, it won't happen. The first question to answer is, do you have top-level support? Does your director, or minister, understand that this will be a challenge? If you have leadership support, it can be done."

For Skyguide, the message is the same. Beron gives his company's leadership credit for understanding that innovation drives constant change, and that it is important to examine new ideas and support new ways of thinking. He says: "Before, we were just airspace managers focusing on separating traffic and keeping the airspace safe. Now we're looking at how to enable a whole ecosystem of new entrants who all want to access the airspace. We're even looking at augmented reality for police and integrating gliders, balloons and other special flights into the system." What could have been an existential threat to Skyguide is now "integrated completely into the corporate strategy of the company, not just for 2020 but through 2035".

Most importantly though, Beron says, is that, "without the support from each other – the regulator, the ANSP, other authorities, and technology partners like AirMap – nothing could happen. We're all working on aviation safety together."

With leadership support, and the SORA in hand, any country can begin to develop a framework that will enable advanced drone operations. It will take trust-building with the community, engagement of those who oversee critical infrastructure and technological solutions that will help coordinate air traffic. As Farner and Murzilli both confidently explain: "What you actually need is to build a sufficient level of confidence that your operation will be safe enough to approve it. When we approve a drone operation, we don't look for an arbitrary number, we look to see if we have sufficient level of confidence that the operation is safe. As of today, there has not been a single intolerable outcome when using the SORA. There have been incidents or occurrences, but zero intolerable outcomes."

Five key takeaways from drone operations in Switzerland

1. Technology demonstrations for key stakeholders drive knowledge-building, engagement with leading providers, and allow opportunities to create ongoing relationships that will drive faster and more resilient development of drone programmes.
2. Developing regulation frameworks from ongoing experiences (like the GALLO becoming the SORA) and being able to update the frameworks allow for agile governance that embraces dynamism and can lead to much greater safety and security than a more rigid regulation that cannot change without lengthy review and adjudication.
3. Unmanned traffic management (UTM) is a digital infrastructure that can help tremendously in the identification, authorization and awareness of safety and security organizations as well as private companies looking to operate. It also provides scalable solutions for mitigating risk within the SORA framework.
4. Cross-ministerial councils that bring together the myriad stakeholders with direct and indirect interests in proposed drone programmes are a vital element of any operation and can be the singular item that leads to success or failure if neglected.
5. Community engagement at the local, municipal and regional levels are fundamental steps to engage the public for wider support.

Safe, Secure and Inclusive: Developing a Drone Ecosystem that Works for All

Developing a drone ecosystem does not happen overnight, but there are steps that a governing authority can take to advance the innovative applications of drones in their jurisdiction. The first, and most important, ingredient that will begin the development of long-term and sustainable drone industry is an enabling regulatory environment that provides legal use of commercial, and non-commercial, operations. Just as a flower may not bloom without soil for its roots to take hold, neither can a drone economy take root without a stable regulatory environment. Beyond a regulatory environment that enables legal flight, the following tools for implementation have been developed in consultation with 12 CAAs around the world.[7] By developing a community of regulators, relevant government ministries, private industry, academia and civil society, lesson-sharing with coordination by the World Economic Forum's Drones and Tomorrow's Airspace team led to developing the following ecosystem ingredients.

Regulatory flexibility: One constant frustration voiced across industry participants is the lack of clarity among regulatory frameworks that limit the scope and scale of potential autonomous operations. Prospective industry participants saw the regulatory climate as a barrier to entry that could not be overcome, while CAAs continue to seek guidance from the International Civil Aviation Organization (ICAO) to avoid negative perception of their airspace. *By providing regulatory policy frameworks that allow for commercial operations with minimal barriers to entry and providing a "regulatory sandbox" for new entrants to thrive, the industry promotes sustainable growth through knowledge sharing and flight data*. Providing small areas to test the very frameworks of regulation, allow governments and private industry to demonstrate what works, what does not, and how to enable further operations.

A prototypical demonstration of how sandbox regulatory environments can enable sustainable, long-term growth for social impact is the UNICEF-managed drone corridor in partnership with the Government of Malawi. From the beginning, the vision was not necessarily to enable drone activities in Malawi but rather to explore the possibility of finding a more effective way to move blood samples in the fight against HIV/AIDS. [8]

In 2014, UNICEF engaged the Ministry of Health and the CAA to provide "preliminary approval and in the absence of national regulations…" develop locations for testing that might "kickstart the regulatory process."[9] UNICEF programme leaders began meeting several government ministries, including "Home Affairs and Internal Security, Local Government, Foreign Affairs, Information, and Defence… all those ministries responsive to the need to improve children's access to early HIV diagnoses and treatment". By engaging ministries who felt a shared mission – saving lives for children – UNICEF developed strong partners on the ground. Though aviation safety concerns tempered some of the initial support, community engagement and training of those with concerns moved the mission forward.

Source: UNICEF. https://blogs.unicef.org/innovation/government-malawi-unicef-announce-first-humanitarian-drone-testing-corridor-africa/

At the time, not much real data existed as to the use of drones in medical supply chains, especially in areas with a limited footprint. UNICEF implemented a study examining the use of drones as a "feasible and affordable way" to reduce the turnaround time between HIV testing of children and the delivery of results to health facilities. For the study, two major considerations helped to identify the best-case locations for the study – wireless connectivity and power availability. The Kamuzu Central Hospital Laboratory and the Area 25 Health Centre were chosen as the initial service area; the two facilities are both located within Lilongwe and are separated 17km by road and 9.7km directly by air.[10]

After achieving national approval for test flights, UNICEF met key stakeholders and community leaders; a key lesson for any drone delivery advocate. Among those consulted were the Mayor's Office, Lilongwe Police, District Council, District Health Officer and Traditional Authorities. In December 2016, UNICEF, in close collaboration with the Malawian CAA, developed a testing environment near Lilongwe, 50 NM North East of Kamuzu International Airport. This corridor was developed in conjunction with air traffic control (ATC) experts to ensure that it did not conflict with departure or arrival paths of the major international airport. While the corridor is active, NOTAMs are issued for drone activities and all operations must begin with a call to ATC. While the drone activities could have remained constrained just to the corridor itself for testing and operations of drones in Malawi, the purpose today of the corridor is as a testing gateway to the rest of the country.

Operations are tested in the corridor, and then authorizations beyond the corridor can take place as the safety of the systems and operators are demonstrated. By providing a testing environment, supported by "flexible regulations" that are focused on actual "risk of the operation", Malawi, through UNICEF support, has accomplished extensive mapping of the Lilongwe region for urban sanitation, conducted crop surveillance, integrated UAS into national disaster preparedness and response frameworks, facilitated flood assessments with UAS, and is planning to integrate drones into the management of the HIV and health supply chain.

Domestic technological development and deployment: Without government-led demand signals and a clear regulatory environment, the unmanned aviation industry may fail to grow from a lack of investment. An entire ecosystem supportive of these technologies – flight operations, data acquisition, data processing, data delivery – may need to develop. Limitations in the technology sector could be overcome by domestic and international investment, with companies providing training and technology solutions so long as the government supports applications for flight. *Collaborations with domestic investors are the most likely to provide long-term growth through partnership with government ministries and foreign-direct investment*. The technology interface between government and operators is one of the most important technology investments a government can make and, therefore, requires great attention. Preferably the portal will be developed in consultation with a variety of stakeholders and inclusive of those who are most likely to have the greatest challenge in its use.

By providing a web-based interface for the application of drone operations, authorities create and implement a single digital application for all drone operations in the country. At this intersection of public and private cooperation, the government can require the fundamental information needed to promote safe and secure operations. With intentionally designed elements, the system can also bolster inclusive qualities on licensing fees, insurance provision and community development. This technology portal can include registration, authorization forms akin to those found in the ICAO UAS toolkit,[11] the remote identification tracking information for unique identifiers, communication notifications, and even initial risk assessments to align with categorization or performance-based resource allocation.

In Rwanda, before any technology service providers had entered the country, the government set up a Drone Advisory Council that included members of the Ministry of Health, Ministry of Transportation, Ministry of Infrastructure, Office of the President, Security Organs and Ministry of Agriculture to understand the landscape, opportunity, challenges and knowledge gaps facing the adoption and integration of drone technologies. The Ministry of Health, recognizing the need for fortifying and improving the supply chain of blood, worked with the President's Office and the CAA to develop an initial trial opportunity and attracted the drone operator Zipline.

Institutionalized skills and training: Developing the skills, knowledge and abilities for drone operation, data collection, processing and value delivery is a fundamental need in promoting an ecosystem that is yet undeveloped. These objectives can be addressed by international and domestic

partners as they leverage experience with manufacturing, flight, processing and delivery. Clear standards driven by government and industry partners who can identify requisite skills to attain licensure and authorization for flight are needed to meet industry and government trust in operations. *Partnerships with local universities, international training organization, non-profit and civil societies and a nation's CAA are ideal for developing the requisite training and knowledge-building domestically*. It is vital that the CAA set a bar for required levels of skill (performance)(while the industry establishes the curriculum and testing necessary to demonstrate that compliance. By enabling industry participation in the training and compliance, it allows the government to set targets and certify schools without having to allocate extensive resources in prescribing curricula, providing training or testing.

In Australia, the Civil Aviation Safety Authority (CASA) has divided training and licensing for commercial operations into two separate categories: requiring individuals to obtain a remote pilot licence (RePL) to be qualified to fly drones beyond their "excluded" category of aircraft (drones between 100g and 2kg); and a remote operator's certificate (ReOC) to companies that intend to operate drones of any size for commercial operations. As CASA points out: "A remote pilot licence (RePL) is your individual permission to fly. If you hold a RePL, you will need to be employed by someone who holds a certificate to fly. These operators hold a remotely piloted aircraft (RPA) operators' certificate, or ReOC."[12]

Perhaps the most important element of enabling designated entities to provide training to support licensing and skills development is that it can create a local community around universities and high schools, technology accelerators, fabrication labs and community hubs. WeRobotics is co-creating a network of "Flying Labs." These are locally owned and operated knowledge hubs, which focus on social good applications for aid, health, conservation, agriculture and development sectors in Africa, Latin America, Asia and Oceania. They localize the use of robotics technologies such as drones and AI in collaboration with local communities to address local social challenges through a bottom-up approach. Flying Labs provide hands-on training to individuals and local organizations to build local capacity, convene knowledge-sharing and stakeholder events, support local organizations and entrepreneurs in implementing pilot projects and share hard/software resources and mentorship. They provide "drones as a service" business incubation programmes and reach out to communities through various community engagement initiatives.

Market-driven sustainability: The most important long-term objective, beyond ensuring safety, is to promote an industry with local citizens, serving local needs, for the economic well-being of local populations. Long-term solutions will be driven by a stable regulatory environment, supported by industry players as they develop continued expertise, investment and sustainable business models. This requires significant, market-driven demand that will only be developed over time. I*n the short term, government-signalled demand provides access to operational business models necessary for the industry to drive the skills, knowledge and abilities of industry participants*.

Both private and public leaders have begun to invest in the opportunities that drones present. Recently, in the US, the Department of the Interior became the manager of one of the largest civil fleets of unmanned aircraft, using an estimated 301 aircraft made up of three different vehicles (as of 2018)[13] to add value to its operations in wildfires, wildlife monitoring, hydrology, geological surveys, geophysical surveys and volcanic activity.

The new field of cargo drone delivery is still in its early days and defined almost exclusively by expensive, top-down, foreign-based interventions. These interventions may be appropriate for a specific set of use-cases, partners and regions. Understanding the limitations of affordable solutions in relevant social, geographical and environmental contexts is one of the overarching goals of a bottom-up approach that can be achieved through field tests. The focus of such field tests is not on a specific drone itself but on testing a variety of drone solutions.

The principle purpose of these field tests is to develop the local standard operating procedures to enable local partners to learn how to implement regular delivery services to remote communities. WeRobotics has been field-testing such readily available and locally affordable and repairable drones for cargo use in the Peruvian Amazon rainforest as well as the remote mountains of the Dominican Republic and is continuing such tests in other challenging environments in the coming months. The field tests seek to better understand the failure points and failure rates of the technology while developing streamlined workflows to enable the safe and regular delivery of essential items such as urgent medical supplies like anti-venoms and vaccines or the delivery of samples from remote communities to regional clinics.

Openly publishing reports of such field tests allows for transparency and the sharing of learnings more widely, which can inspire other local stakeholders who cannot invest in multi-year and multi-million-dollar cargo projects to find appropriate solutions for their communities.

Case Study: Demonstrator to Delivery in Rwanda, Scaling a Drone Ecosystem

HE President Paul Kagame examines a blood delivery package delivered via drone

The biggest success story in global drone operations started with a devastating problem. Certain remote areas of Rwanda's mountainous country are difficult to reach, especially during the rainy season. In rural hospitals, healthcare providers struggle to provide adequate blood supply to mothers during childbirth and blood delivery from central hospitals and inefficiencies in the blood cold chain trucks exacerbate wastage of vital supplies.

To address this challenge, the Government of Rwanda brought in Zipline, a California-based drone start-up, to improve delivery of blood. Given the novelty of drone delivery as part of national infrastructure, Zipline was authorized as a state aircraft to allow operations for emergency deliveries only. Traditional aviation certification requirements would be developed in line with risk evaluation as every route and hospital to be served required the regulator's approval. It was an initial step, to enable demonstrations of capability built on trust that would evolve into a national scale drone delivery programme leading the world in its impact and scope.

With the opportunity to improve healthcare service delivery, and for the Rwandan Civil Aviation Authority (RCAA) to pilot, test and learn from new drone opportunities, an appropriate regulatory framework would be developed based on lessons learned to enable advanced drone operations. Lives were saved, and blood wastage nearly eliminated, while demonstrating the vital role that drones could play. Since its inception, the Rwandan blood delivery project has provided emergency blood supplies to more than 1,200 women, greatly reducing the risk of maternal mortality, and reduced wastage in the blood logistics network of Rwanda by 4% that is serviced by Zipline. To some, this would mark the end of a journey with drones, but to Rwanda, this set the stage for a revolutionary approach to regulatory oversight. Rwanda's experience with Zipline had been so successful that regulators were motivated to expand the impact drones could provide.

Rwanda's economy faces challenges of capacity, cost and scale with respect to drone integration and development, requiring a robust framework of engagement, policy development and market creation. At the time, only two UAS operators in the country had successfully accessed the airspace – Zipline and Charris UAS. Charris UAS, a domestic Rwandan operator, with a commercial licence and operator certification, had only some operational experience. Without a robust regulatory framework that could oversee a spectrum of drone shapes, sizes and uses, only small drones for photography and low-altitude, visual line-of-sight operations could be approved.

In Rwanda drones are not synonymous with military operations or invasion of privacy as is the case in many other parts of the world, but rather as life-saving tools that can be trusted in their appropriate operations. This intentional stewardship began in early 2015 when Zipline and the Rwandan Ministry of Health first began meeting to discuss the possibility of including drones in the supply chain and management of blood stores. From the beginning, presidential leadership was behind the project which, as former Minister of Information Technology and Communication Jean Philbert Nsengimana explains, is

extremely important. “For success there must be higher authority that backs this type of project. Without it, people will not move beyond their comfort zone and innovative approaches will not be sought. The fact that the Office of the President was engaged throughout the process, to ensure things were well understood and done on time, made it happen.”

Will Hetzler, Chief Operating Officer of Zipline, explains how they look to the potential for impact first. “We always try to identify the potential of the end beneficiary – in this case, the Ministry of Health.” Zipline looks to identify the areas where the clearest return from the end-user, those who need the technology the most, can benefit the greatest. This helps to find advocates domestically. “We don’t want to have Zipline approach a CAA as a foreign company. Instead, we engage local institutions to become advocates to the CAA, to say, ‘this is something we need, and we want to champion it’. In the case of Rwanda, it was the leadership at the Ministry of Health who really championed it, having it driven by a peer government institution helped the CAA put in place a willingness to work with Zipline.”[14]

“The Initial proposal [to the RCAA],” Andrew Mutabaruka, Head of Aviation Safety and former aviation safety inspector with oversight over drone operations, says, “…was made to the Government of Rwanda through the Ministry of Health and Ministry of ICT by a drone [port] company called Redline, to create drone ports and to deliver blood to remote health facilities such as district hospitals that are not easily serviced due to inadequacy of surrounding infrastructure. RCAA was contacted to investigate how to approve the drone operation about regulation and accommodation into the airspace. The timely supply of lifesaving medical supplies was an immediate draw.”

By enabling the stakeholder community that would benefit the most to become advocates internally, Zipline was able to start more quickly than if it had gone first to the civil aviation authority and to seek out approvals. Once the Ministry of Health was onboard, the RCAA became engaged to determine what approvals and regulatory environment would be necessary. “In 2015,” as Mutabaruka says, “Rwanda began developing UAS regulations due to the emergence of the UAS technology globally, the cheap availability of the drones on the market, interest from various local institutions to use the technologies and a desire not to be caught off guard by new challenges arising from these technologies.” The RCAA looked outward for guidance and feedback, developing awareness campaigns with the local leadership, the police, hospital employees and others.

Engagement of the public, from both the government side and Zipline, continues to be a critical element of the success of the Rwandan drone delivery projects. Minister Nsengimana, who directly engaged in this outreach work, remembers: “This touched many departments and so I was the one coordinating all the initiatives among the various stakeholders. We worked with the RCAA, Ministry of Health, ICT, within the medical centre and the biomedical centre who was the operational entity. It was important to coordinate with the local government as the road to greater citizen awareness. We also then coordinated with local government and security institutions because of their clear need and interest. It was a real challenge that required a tremendous amount of engagement just to begin the projects.”

In 2015, Rwanda published the first set of regulations, which were quite prescriptive and not yet ready to embrace advanced operations. When Zipline launched in 2016 it operated as a state aircraft for emergency deliveries and, therefore, with different rules. These rules required each operation to be approved in real-time by the RCAA based on location, certification and a previously developed and restrictive categorization schema. For new applications, a 20-day waiting period was cited as a major hindrance to registration and operational approval, with no other approvals identified. Non-approved flights were nearly non-existent as security and police enforcement conducted a thorough and immediate interdiction.

While the Rwandan UAS regulations may have helped to govern drone usage for small or non-commercial aircraft, and with a focus on security oversight, they were not sufficient to oversee the Zipline operation. Hetzler recalls: “In late 2015, there weren’t any precedents for what we, or the government were trying to accomplish. At the time, the focus was making the flights as close to ‘manned operation’ as possible. As many do, the RCAA started with the ICAO RPAS manual. Eventually, we all came together to develop a platform that would answer the question, ‘What is an operation that could be reasonably accommodated and would serve the need while ensuring we have a good sense of what the risks are and how to mitigate them?’ After six months developing the initial project with the Ministry of Health and working in earnest with the CAA for one year, we were ready to fly. Altogether, the process took about 18 months from the concept to first flights.”

By approaching the governance of the airspace holistically, the RCAA, partnering with the Ministry of Health and a nationwide Drone Advisory Council (DAC) that included a variety of government and expert stakeholders, set a series of performance-focused requirements that would reduce or eliminate risk to other participants in the sky. “We took a long time going back and forth creating an operation everyone was comfortable with,” Hetzler explains. “…relying on air traffic control to provide separation (deconfliction services) by installing a very bare bones UTM with ATC to allow them use it deconflict all traffic (including civil and commercial operations)”. This, perhaps, was one of the earliest commercial implementations of the systems that would eventually become UTM – identification, deconfliction and coordination with ATC. If the Rwandan government had required a fully developed and robust UTM system – as some still seek today – it would have taken over two years or more, and the “thousands of emergency flights which have impacted thousands of lives” would have never been flown.

Skills and training were of utmost importance to the project development and the RCAA had to work with Zipline to outline the requirements. “As we were getting toward the flights going live,” Hetzler says, “…we conducted a few site inspections where the RCAA came to see the safety protocols and procedures. They were really interested in

the training protocols, especially for the Zipline controller, who is our person who is always 'on the loop' and the link with air traffic control." By working together to develop a way forward, the RCAA and Zipline rapidly iterated working protocols to drive a safer and more effective airspace project.

Perhaps the greatest unknown that the RCAA had to quantify, assess for risk and mitigate accordingly was the inability to take over the drone directly; a situation vastly different from manned aviation where a pilot should almost always be able to take control of an aircraft. "The RCAA had a really forward vision," Hetzler notes. "…The concern was never specifically on continuous control of the aircraft. They did want to understand how to 'detect and avoid' and 'how to avoid collisions'. Zipline built a safety case on the other mitigations it had available to them. Two sets of risk – air and ground traffic – were considered the most important. For air traffic, we demonstrated that even if there were no deconfliction whatsoever, flying completely blind, the air traffic density is so low the risk of air traffic collision was negligible."

By addressing the concerns of the RCAA, and demonstrating, in spring 2016, that system capabilities met what Zipline had stated through video demonstration, flight data, on-site safety inspections, training reviews, communication protocol development and an internally developed operator certification it could teach to, the final elements before larger approvals were demonstration flights in Rwanda and a demonstration in true operating environment how the communication with ATC would work. The first demonstration had to meet the system expectations of the RCAA: to be able to hold to altitude slots assigned, not just follow the contour of the terrain, and to ensure they stuck to the planned flight routes using visual observers along the short route of 10km.

The second demonstration was to illustrate the integration with the Ministry of Health's cold chain for keeping blood optimal even in worst-case scenario, long-distance flights. For this, Zipline demonstrated it could enter a holding pattern of one hour and still be able to deliver the blood.

The Rwanda drone delivery project began with 21 district hospitals, all receiving blood deliveries from a central point, just beyond a 20km circumference outside Kigali. As the deliveries proved reliable, and the blood supply system became more resilient, the belief that the programme would expand nationally became more concrete. As of 2018, the contract negotiations have been finalized to expand this project from 21 locations to 473 serviced locations; a 20-times increase in scope that will truly test the digital and human-centric systems in place. While the new regulations, promulgated in early 2018, temporarily slowed the Zipline work in Rwanda, the formalization of the process and the implementation of digitally based approvals are intended to help ease the time constraints that it takes for the applications to be processed. As Hetzler says: "That's nearly 500 new SORA reviews for the routes, which will take five years."

As the Zipline pilot project looked to scale throughout the country and the success of the initial test was apparent, the Government of Rwanda entered into a partnership with the World Economic Forum's Centre for the Fourth Industrial Revolution in 2017. This new partnership would look to foster a broader ecosystem of unmanned aircraft systems, to build on the success of domestic and international operators in Rwanda. The regulatory development and implementation strategies designed by the RCAA in collaboration with the World Economic Forum Drones and Tomorrow's Airspace team are the outcome of that partnership. These strategies are intended to accelerate and expand the types and benefits of drone operations while mitigating risk, and create a model that can be used by other regulators and policy makers around the world.

The RCAA and other stakeholders demonstrated exemplary vision that brought together agile government with real buy-in and leadership. With a need to "run where others can afford to walk," described by President Paul Kagame of Rwanda, it became clear that it might be possible to co-curate a framework and ecosystem development plan around advanced technologies for the good of the Rwandan people. The collaboration project in Rwanda outlined the following components to scale up the drone ecosystem:

1. Develop a regulatory environment that is replicable, scalable and sufficiently customized for Rwanda, amenable to ICAO standards and recommended practices, and considerate of industry best practices based on risk and/or performance metrics

2. Promote and grow a domestic drone-focused industry with the requisite skills and expertise for long-term sustainability beneficial to the Rwandan people

3. Address the needs of non-commercial drone operators who need a place to simply "crash", grow enthusiasm for drones, and test their projects as a foundational component of innovation-based technology industries

4. Implement long-term technology layers that support and broaden the impact of unmanned aircraft systems for digital communication, authorizations and approvals, remote identification and tracking, and scalable traffic management

In 2017, a Drone Taskforce composed of RCAA, Ministry of Information Communication and Technology (ICT), and the Drones and Tomorrow's Airspace team members met weekly to address concerns and develop new regulatory proposals based upon leading risk management strategies from both manned and unmanned aviation communities. This resulted in the regulations, implementing a performance-based regulatory model, being approved by the Rwandan Cabinet in January 2018.

While the regulation was announced during the World Economic Forum's Annual Meeting 2018 in Davos-Klosters, Switzerland, there was still a long journey ahead for implementation. Engagement of stakeholders was an ongoing process, including a user-focused risk mitigation workshop led by the RCAA in partnership with the World

Economic Forum team. Each of these meetings enabled participants to gain a better understanding of how the policy would be implemented, what stakeholders would need to be included for testing and iterating the user-experience for drone approvals, and how the government would be able to communicate risk with applicants. Through these conversations, stakeholders gained a common understanding of how the performance-based regulation that could enable beyond visual line of sight, highly autonomous, and delivery operations would be implemented at scale.

With the systems in place for interaction between the government and drone operators, the next step became determining if industry needs were being adequately addressed when balanced against government responsibilities. Recognizing the importance of "user experience" involvement, and to collect feedback from the public, the RCAA called a meeting of private companies to discuss the new regulations. This meeting consisted of more than 20 representatives, from 15 entities: four international drone operators; two domestic companies with some drone experience; four academic institutions; and five government ministries were represented, with the participation of the World Economic Forum. One of these entities, Charis, a Rwandan developed, and operated drone service provider, demonstrates what is possible as regulations become more flexible and enable broader adoption.

Charis was founded in 2014 by Eric Rutayisire. Rutayisire developed his first drone in Rwanda and started exploring various applications. He began by providing aerial photography at weddings and concerts prior to the initial drone regulations being promulgated. To generate demand, and to demonstrate their usefulness, Rutayisire explains they "had a period where we offered our services for free just so people could see the value proposition". By demonstrating the value of data acquisition in agriculture, "especially plant health assessment and crop yield prediction", and as the company grew, the vision for service offerings expanded. After their focus on agriculture, since agriculture was "… one of the biggest industries in Rwanda", they began adding "construction monitoring, mining, mapping, surveying for constructions, environmental monitoring, inspection, and spraying against insects."

It can be difficult to determine in the short term how much impact a new regulatory environment can have on a domestic industry, especially for those stakeholders who have already found success. For Charis UAS alone, its operations have expanded dramatically in 2018 – since the regulatory environment evolved into a risk based, or PBR-based, model. "The drone regulations in place made sure that we put in place safety measures so that we operate safely and produce good quality services," Rutayisire says. "This forced us to continue increasing our knowledge in the drone technology and become better every day." In 2018 alone[15], Charis UAS mapped more than 20,000 hectares during over 1,200 total flight operations. Charis is now present in three countries and is looking to expand to over 10 countries by 2019.

While some feared that a new regulatory approach to drone operations may hinder growth of the industry, Charis UAS has been able to continue, if not accelerate, its growth. From the perspective of the RCAA, there has been significant benefit. Mutabaruka says: "Rwanda is gaining knowledge in emerging technology and plans to continue to innovate and improve upon the provision of air navigation services, enabling young innovators to look at the sky as the highway of the future." It is clear that Rwanda has a vision that leverages advanced technology for societally impactful use cases, and, as Nsengimana concludes: "It is important that communication emphasizes the benefits of new technologies, rather than this new shiny innovation, removed from the impact. People must be at the heart of any project."

Minister Nsengimana and other leaders discuss Internet for All at the World Economic Forum on Africa 2016, in Kigali, Rwanda.

Source: Copyright by World Economic Forum / Benedikt von Loebell

Conclusion

Specific steps must be taken early to ensure safe, secure and inclusive implementation of drone technologies. Governments all over the world are faced with the challenge of providing oversight of these rapidly evolving technologies in a way that supports the benefit they can provide, while mitigating the risks they can pose. To meet their responsibilities, transport ministries are being asked to move beyond legacy regulatory approaches and develop new paradigms for drone regulation. By approaching this task of opening airspace to new entrants without aircraft certifications through operational risk assessments and policy innovation, authorities are being asked to overcome the institutional pressures that have evolved over the past century. While safety must always come first, the new opportunities created by advanced drone operations to save lives, improve well-being, and reduce risk in areas such as inspections and security operations must also be considered.

Many of the recommendations made in this paper look to the importance of cross-ministerial engagement that can provide the high level political support needed to try something new and which can balance concerns by traditional regulators concerned about introducing unfamiliar risks into the airspace. While CAAs will ultimately decide access to airspace, ministerial champions providing a holistic view for social good is crucial to early success. Having the Ministry of Health in the lead in Rwanda helped provide the societal acceptance and high-level support for testing drone delivery. The evolution of Rwanda's drone programmes continues to focus on opportunities to service government stakeholders and private industry alike, reflecting the importance of ongoing drone advisory councils, and security service coordination, to encourage knowledge building.

Technology demonstrations, regulatory sandboxes and policy prototyping provide an opportunity for states to experiment with new frameworks and new enabling infrastructure like UTM that can further support and accelerate positive integration into the airspace. Automated approvals, initiated through registration and identification mandates, set a basis for safe and familiar operations while also making possible real-time data exchange for monitoring and authorization/permitting by the state. Coupled with a robust process for operational risk permitting, any state can begin developing robust and safe advanced drone programmes for social good.

The Drones and Tomorrow's Airspace team at the World Economic Forum continues to evolve policy-making in support of socially impactful operations throughout the world. We believe that nations where the need is greatest can truly lead the Fourth Industrial Revolution by moving quickly to experiment, iterate and embrace technological innovation in the skies, on the ground and under the sea. If you are interested in encouraging and supporting the expansion of what is possible with autonomous aerial mobility, we encourage you to participate in future meetings of these projects and to engage in the project community that will inform and drive new policy prototyping and framework development.

Nine foundational experiences came out of this pilot project, which informs the rest of the Drones and Tomorrow's Airspace approach to ecosystem development:

1. In-person fact-finding with multistakeholder representation is vital to understanding the challenges and opportunities facing local, regional and national scale drone operations
2. Have clear understandings of what is required to get advanced drone operations standardized
3. International authorities with oversight of an industry, such as the ICAO for aviation, must be included and consulted early and often throughout the policy period
4. If the local technology leaders are working with you, the policy implementation and evolution phases will go much more smoothly and successfully
5. Efforts must be taken to ensure that regulatory changes have a grace period for implementation so that disruption to ongoing operations can be minimized
6. Community engagement is vital for the survival, expansion and success of any drone projectLocally created and integrated workflows with robust and expansive standard operating procedures are key for success
7. The local size of a market and cost of each delivery will be key to sustainability, coupled with the societal need for the operation
8. Prototyping and learning in iteration cycles are needed to find the fitting solution for local needs and most adapted technology choice

The World Economic Forum's Drones and Tomorrow's Airspace team in collaboration with the Drone Innovators Network will continue to update this toolkit based on feedback and intends to include additional case studies in the future.

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About the World Economic Forum, Centre for the Fourth Industrial Revolution, Drones and Tomorrow's Airspace

The World Economic Forum, Drones and Tomorrow's Airspace team, is working incollaboration to accelerate the adoption of beneficial drone technologies while mitigating the risk to society. Working with leading experts and industry innovators convened through workshops in Zürich, Switzerland, and San Francisco, California, this portfolio combines the platforms, networks, and convening power of the Centre for the Fourth Industrial Revolution and the World Economic Forum to design and implement new approaches to the governance of autonomous aerial robotics. By working with key government partners, complemented by academic experts, private sector technologies, and inclusive of civil society concerns, the pilot projects that arise from these collaborations drive iterative and revolutionary change. Together with other interested stakeholders, this partnership is exploring how Fourth Industrial Revolution innovations can help drive positive systemic transformation in a manner that supports rapid implementation of new mobility in safely, cleanly, and inclusively.

Endnotes

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