Drones and Tomorrow’s Airspace
“Getting to Yes”
Committed to improving the state of the world

Our mission statement

The World Economic Forum, committed to improving the state of the world, is the International Organization for Public-Private Cooperation.

The Forum engages the foremost political, business and other leaders of society to shape global, regional and industry agendas.

Our motto

Entrepreneurship in the global public interest
Key areas of project focus include drone delivery, personal transport, aerial imagery, and the infrastructure that enables it all.
Infrastructure as an Example
Unique Challenges Require Novel Solutions

Africa needs $75 billion per year for infrastructure – we’re not replacing roads, we’re augmenting roads.

Road safety is the third largest killer in Africa behind Malaria, and HIV

In Asia, 90% of the population live near an all-weather road

In Africa, 34% of the rural population lives within 2km of an all weather road.

In Tanzania only 25% of the population lives within 2km of a road.

The African Union has identified three technological priorities for the coming year - malaria vaccine technologies, gene sequencing, and drones.
New Paradigms for Drone Regulation
How can regulators unlock the potential of drones for data, delivery, and transportation?

Goal
Outdated policies are impeding both life-saving and economically impactful uses cases for drone. This project is enabling regulatory innovation to keep pace with technical innovation.

Impact
• Co-Designed and Implemented national drone regulation in Rwanda, now being tested.

• Drone Innovator’s Network (DIN) established and the 1st Toolkit is being developed for publication.

• Iteration and Implementation of regulation and policy in second test.

Timeline
• September 2017: Government of Rwanda partners with C4IR to co-design new drone regulation.

• January 2018: Rwandan cabinet approves new regulation.

• June 2018: Drone Innovators Network launch event

• September 2019: Broad circulation of updated framework.
Draft Regulations were shared with WEF, by the Rwanda Civil Aviation Authority (RCAA)

Draft Regulations were co-curated by incorporating and evolving Best Practice Standards (ASTM), EASA Prototype Regulations, JARUS SORA, and energy based guidance from UK CAP 722.

Sets up a risk based framework with 3 major categories similar to EASA

• Basic – No authorization, just notification within operational scope
• Specific – Aligns with EASA specific category
• Complex – BVLOS, Multiple Vehicles per Operator, Highly Autonomous, etc.
Rwandan Pilot Project
Stakeholder Engagement & Learning

Core Stakeholders
- Rwanda Civil Aviation Authority (RCAA)
- Ministry of Infrastructure (MININFRA)
- Ministry of Youth & ICT (MYICT)
- Office of the President (OTP)
- Rwanda Utilities Regulatory Authority (RURA)
- Private Sector Federation – ICT Chamber

Direct Stakeholders
- Rwanda Bureau of Standards (RBS)
- Ministry of Local Government (MINALOC)
- Ministry of Justice
- Ministry of Health (MINISANTE)
- Ministry of Agriculture (MINAGRI)
- Rwanda Insurers Association (RIA)
- Smart Africa Secretariat
- Charis Drones
- FabLab Rwanda
How do you Operationalize it?
Permitting and Licensing Flowchart

- Registration (ConOps)
- Activity Permit (ORA)
- Basic
- Notification
- Specific
- Activity Permit
- Pilot License
- Complex
- Activity Permit (SORA)
- Pilot License
- Operator Certificate

FAST TRACK (STANDARD SCENARIO)
SOLUTION
What are the Requirements?

Toys – Under 250g

**Basic** – Size, Location, Affiliation with Sports Club.

**Specific** – Commercial, Medium Risk characteristics.
- speed, size, purpose,

**Complex** – Commercial, High-Risk characteristics.
- Autonomous, multiple vehicle per operator, BVLOS, urban environments, near airport

<table>
<thead>
<tr>
<th>Risk probability</th>
<th>Risk severity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Catastrophic</td>
</tr>
<tr>
<td>Frequent 5</td>
<td>5A</td>
</tr>
<tr>
<td>Occasional 4</td>
<td>4A</td>
</tr>
<tr>
<td>Remote 3</td>
<td>3A</td>
</tr>
<tr>
<td>Improbable 2</td>
<td>2A</td>
</tr>
<tr>
<td>Extremely improbable 1</td>
<td>1A</td>
</tr>
</tbody>
</table>

World Economic Forum ®
Policy Challenges
Past, Present, Future

Past (Accommodate)
- Pilotless Vehicles
- Low Altitude
- Rural Operations
- Small Drones
- Within Visual Line of Sight
- Data Capture Only
- Public Operations Only

Present (Integrate)
- Identification and Tracking
- Over People
- Beyond Visual Line of Sight
- Autonomous Flights
- Certification processes Re-imagined
- Multiple Vehicles per Operator
- Commercial Expansion
- Software Design Assurance Process

Future (Evolve)
- Full-Scale Delivery
- “Autonomoation”
- Hybrid Designs
- Certification Processes
- Data Ownership, Migration, Consumption
- Privacy
- Mixed-Traffic (UTM)
- V2V, V2I, V2x
The Challenge According to Government

**Government Perspective**

- Safety – What safety data do I need?
- Security – How do you maintain security?
- Reliability – Are these systems capable?
- Resilience – What are the cyber threats?
- Enforcement – How can regulations be enforced?
- Reality vs. Fiction – What is real and what isn’t?
The Challenge According to Industry & Academia

**Societal Perspective**

- Access to Airspace – Where can I fly legally?
- Standards and Best Practices – What will be accepted by CAAs?
- Licensing and Training Requirements – What licenses are recognized?
- Opportunities – Which use cases are approvable?
- Stability – Are the rules today the same as tomorrow?
- Transparency – Decision making should be easy to understand
# Getting to Yes – Step 1
## Regulations and Compliance

<table>
<thead>
<tr>
<th>Regulatory</th>
<th>Compliance</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Performance Based Regulations</td>
<td>• ASTM Operational Risk Assessment for sUAS</td>
</tr>
<tr>
<td>• Classifications by Size</td>
<td>• Specific Operational Risk Assessment (SORA)</td>
</tr>
<tr>
<td>• Standard Scenarios</td>
<td>• Concept of Operations Registration</td>
</tr>
<tr>
<td>• Exemptions/Approvals</td>
<td>• Safety Management Systems (SMS)</td>
</tr>
<tr>
<td>• Sandbox environments</td>
<td>• Technological Enforcement (UTM)</td>
</tr>
<tr>
<td>• Corridors for Operations</td>
<td>• Recreational Clubs &amp; Community Organizations</td>
</tr>
</tbody>
</table>
## Operational Risk Assessment for sUAS Standard (ASTM WK4679-16)
### FAA Recognized AMOC for Authorizations

<table>
<thead>
<tr>
<th>Severity Level</th>
<th>Definition</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Catastrophic</td>
<td>Non-sUAS Equipment destroyed (such as electrical transmission lines, substation, water treatment facility, etc); multiple fatalities</td>
<td>5</td>
</tr>
<tr>
<td>Hazardous</td>
<td>Large reduction in safety margins; vast reduction in ability to complete duties accurately; single fatality or serious injury; major equipment damage.</td>
<td>4</td>
</tr>
<tr>
<td>Major</td>
<td>Significant reduction in safety margins; reduction in the ability of pilots to cope with adverse operating conditions as a result of increased workload; serious accident; injury to persons.</td>
<td>3</td>
</tr>
<tr>
<td>Minor</td>
<td>Nuisance; minor incident;</td>
<td>2</td>
</tr>
<tr>
<td>Negligible</td>
<td>Little or no negative consequence</td>
<td>1</td>
</tr>
</tbody>
</table>
## Likelihood of Hazard Occurring During an Operation

<table>
<thead>
<tr>
<th>Likelihood Level</th>
<th>Definition</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequent</td>
<td>Likely to occur many times</td>
<td>5</td>
</tr>
<tr>
<td>Occasional</td>
<td>Likely to occur sometimes</td>
<td>4</td>
</tr>
<tr>
<td>Remote</td>
<td>Unlikely, but possible, to occur</td>
<td>3</td>
</tr>
<tr>
<td>Improbable</td>
<td>Very unlikely to occur</td>
<td>2</td>
</tr>
<tr>
<td>Extremely Improbable</td>
<td>Almost inconceivable to occur</td>
<td>1</td>
</tr>
</tbody>
</table>
Concept of Operations

<table>
<thead>
<tr>
<th>Environment</th>
<th>Personnel</th>
<th>System</th>
<th>Mission</th>
<th>??</th>
</tr>
</thead>
</table>

Rural
Urban
Sparsely Populated
High Altitude
Low Altitude
Medium Altitude
Below 250g
Medium sized drone
Visual line of sight
Visual Meteorological conditions
No training
Certified trained pilot
Geofencing capable

Data tracking
Inspecting high-voltage power lines
Spraying crops with fertilizer
Spraying crops with pesticide
Delivering medicines to remote hospital
Visual observer and pilot
Safety officer, VO, and pilot
1 pilot only
Training flights
Recreation club certified
First flight of aircraft
Over water
Near powerlines (sensitive infrastructure)
## Specific Operational Risk Assessment

<table>
<thead>
<tr>
<th>Event</th>
<th>Formula</th>
<th>Likelihood of having UAS operation out-of-control</th>
<th>Likelihood of person struck by the UA if the operation is out of control</th>
<th>Likelihood that, if struck, person is killed</th>
<th>Likelihood of the other A.C. struck by the UA if the operation is out of control</th>
<th>Likelihood that, if struck, the other AC cannot continue a safe flight and landing</th>
<th>Likelihood of the critical infrastructure struck by the UA if operation is out of control</th>
<th>Likelihood that, if struck, the critical infrastructure is damaged</th>
</tr>
</thead>
<tbody>
<tr>
<td>Likelihood of Fatal injuries to third parties on ground</td>
<td>= Likelihood of having UAS operation out-of-control</td>
<td>X</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Likelihood of Fatal injuries to third parties in the air</td>
<td>= Likelihood of having UAS operation out-of-control</td>
<td>X</td>
<td>Likelihood of the other A.C. struck by the UA if the operation is out of control</td>
<td>X</td>
<td>Likelihood that, if struck, the other AC cannot continue a safe flight and landing</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Likelihood of Damage to critical infrastructure</td>
<td>= Likelihood of having UAS operation out-of-control</td>
<td>X</td>
<td>Likelihood of critical infrastructure struck by the UA if operation is out of control</td>
<td>X</td>
<td>Likelihood that, if struck, the critical infrastructure is damaged</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
## Getting to Yes – Step 2

### Implementation (CONOPS focused Mitigations)

<table>
<thead>
<tr>
<th><strong>System</strong></th>
<th><strong>Environment</strong></th>
<th><strong>Mission</strong></th>
<th><strong>Personnel</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Certification</td>
<td>Weather reporting</td>
<td>Data management rules</td>
<td>Training</td>
</tr>
<tr>
<td>Parachute</td>
<td>Flight Plan</td>
<td>Operations manuals</td>
<td>Pilot licensing</td>
</tr>
<tr>
<td>Redundancies</td>
<td>UTM</td>
<td>Training on mission types</td>
<td>Company training requirements</td>
</tr>
<tr>
<td>Size limitations</td>
<td>Airspace zoning</td>
<td>Safety management systems</td>
<td>Background checks</td>
</tr>
<tr>
<td>Speed limitation</td>
<td>Guidelines for location</td>
<td>Community membership requirements</td>
<td>Security team engagement</td>
</tr>
<tr>
<td>Geofencing</td>
<td>Safety requirements</td>
<td>Registration and approvals</td>
<td>Flights hours</td>
</tr>
<tr>
<td>Tethering</td>
<td>Reporting requirements</td>
<td>Payload</td>
<td>Flight records</td>
</tr>
<tr>
<td>Signal repeater</td>
<td>Location authorizations</td>
<td>Separation from vehicles and property</td>
<td>Crew size</td>
</tr>
<tr>
<td>Fail-safe</td>
<td>Population density</td>
<td></td>
<td>Visual Observer</td>
</tr>
<tr>
<td>Strobe lighting</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Licensed Spectrum</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Third party Software?</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Illustrations

1. ![Drone Image 1](image1.png)
2. ![Drone Image 2](image2.png)
3. ![Drone Image 3](image3.png)
4. ![Drone Image 4](image4.png)
# Getting to Yes – Step 3
## Advanced Operational Oversight

### System Failures Modes

<table>
<thead>
<tr>
<th>Failure Mode</th>
<th>Effect</th>
<th>Technical Resolution</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Failure of the transmitter</strong></td>
<td>Connection between transmitter and receiver is jammed, pilot is not able to interfere with the flight path</td>
<td></td>
</tr>
<tr>
<td>e.g.: power supply transmitter, antenna intermittent, failure in electrical system</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Thermal overload of the battery</strong></td>
<td>Decrease of battery capacity, thermal overload of surroundings in the aircraft</td>
<td></td>
</tr>
<tr>
<td>e.g.: internal failure of LiPo accumulators, overload through high current/ unbalance</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Fishbone Analysis

How a credible failure leads to harm (damage)

- Battery Failure
  - Limited battery capacity
  - Limited flight time/mission inconsistency
- Thermal runaway (overload)
  - Thermal termination premature
  - Flight failure, chemical fire
- Damage to person or property
Drones for Good
Make it Meaningful

SUSTAINABLE DEVELOPMENT GOALS

1. NO POVERTY
2. ZERO HUNGER
3. GOOD HEALTH AND WELL-BEING
4. QUALITY EDUCATION
5. GENDER EQUALITY
6. CLEAN WATER AND SANITATION
7. AFFORDABLE AND CLEAN ENERGY
8. DECENT WORK AND ECONOMIC GROWTH
9. INDUSTRY, INNOVATION AND INFRASTRUCTURE
10. REDUCED INEQUALITIES
11. SUSTAINABLE CITIES AND COMMUNITIES
12. RESPONSIBLE CONSUMPTION AND PRODUCTION
13. CLIMATE ACTION
14. LIFE BELOW WATER
15. LIFE ON LAND
16. PEACE, JUSTICE AND STRONG INSTITUTIONS
17. PARTNERSHIPS FOR THE GOALS
Drones and Tomorrow’s Airspace

Harrison Wolf Harrison.wolf@weforum.org
Thank you!