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# UAS Safety and Risk Assessment

Presentation by : **Guy Maalouf**

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Let’s start simple:

***Are you sitting with your group?***

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# What is safety?

Tip: what is the difference between those 2 pictures?

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# What is safety?

Tip: what is the difference between those 2 pictures?

Environment

UAS

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# What is safety?

Tip: what is the difference between those 2 pictures?

Environment → Risk

UAS → Assurance & Integrity

# Why care about safety?

Story time …

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# Airspeeder Mk II

Goodwood Aerodrome

**Specifications:**

Footprint: 3m

MTOW: 95 kg


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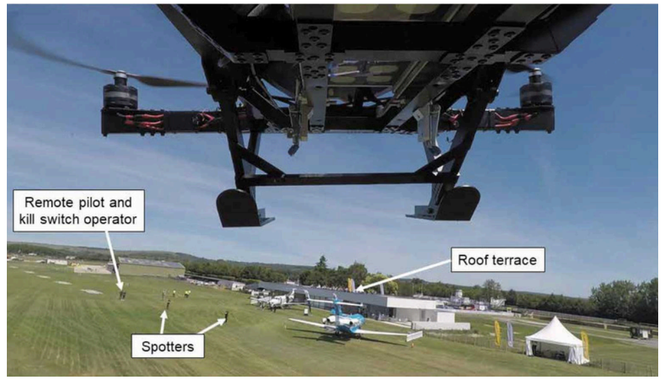
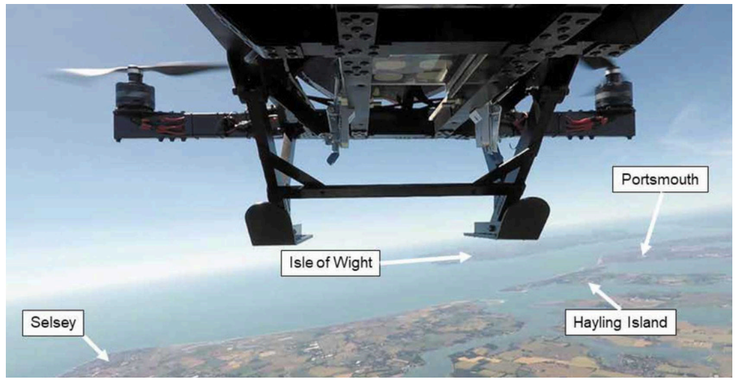
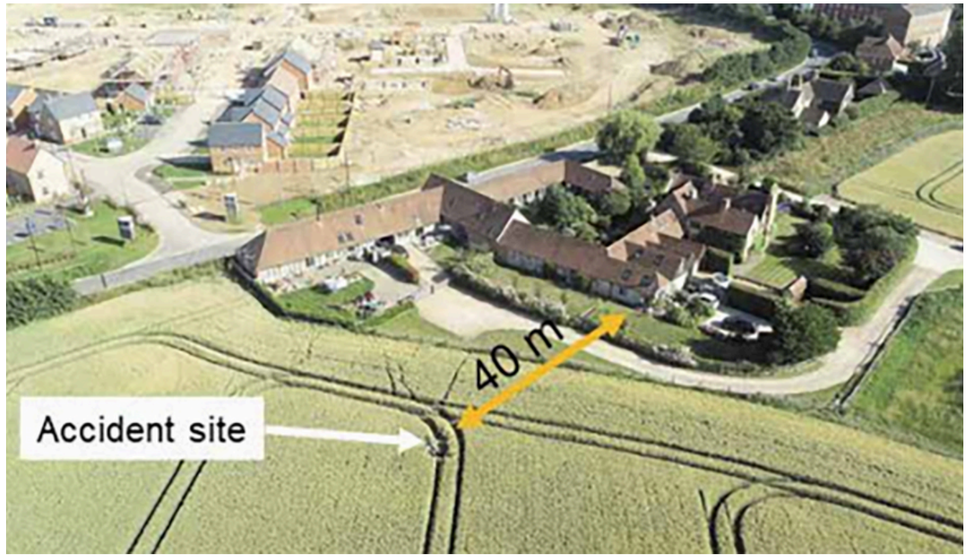
# What happened?




- Shortly after take-off and some planned manoeuvres (passes along the runway), the **remote pilot lost control**. The **drone levelled off** instead of following the control input.
- The operator **activated a "kill switch"** intended to cut power, but it **failed to work**.
- The drone then **entered an uncommanded climb**, ascending for about **4½ minutes**, reaching about **8,000 ft**. It drifted into **controlled airspace**, specifically part of the holding patterns for Gatwick Airport.
- Eventually the **battery depleted**, **control was lost** entirely, and the drone **fell to the ground**, crashing in a field of crops.

**Question:**
Can you guess how it happened?



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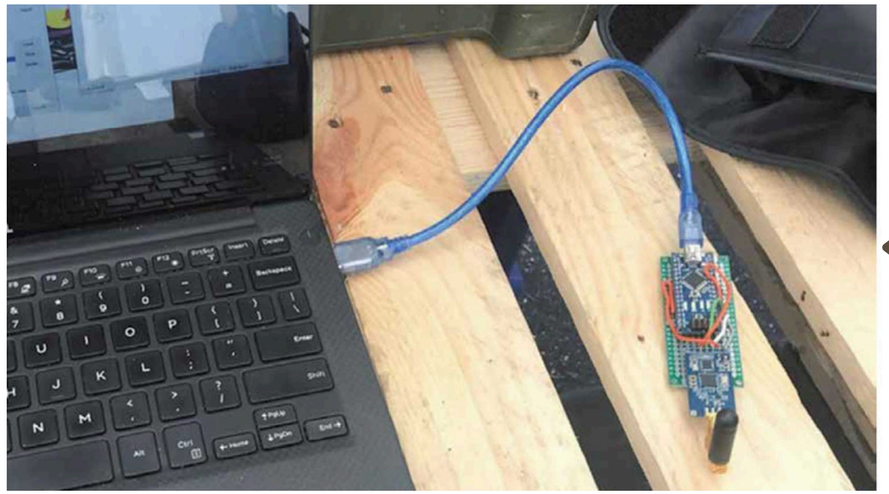
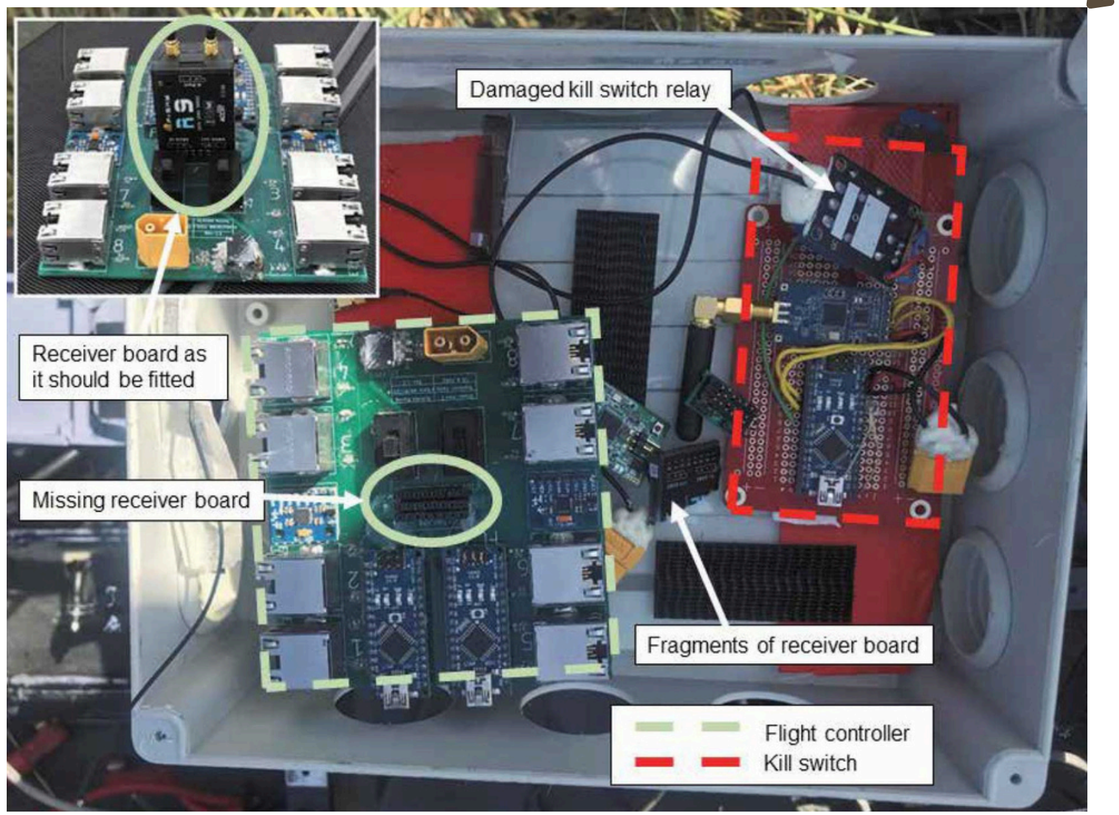
# How did it happen?

- Poor design & build quality
  - No Telemetry
  - No GNSS (No RTH or Geofence)
  - No on-board data recording
- Safety case misrepresentation
- Lack of testing
- Regulatory oversight
  - No inspection
- Software issues



Kill Switch

Flight Controller



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*"How do we ensure incidents like this (or even worse) don't happen**?**"*

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*"How do we ensure incidents like this (or even worse) don't happen?"*

# Safety & Risk Management

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# Safety Theory

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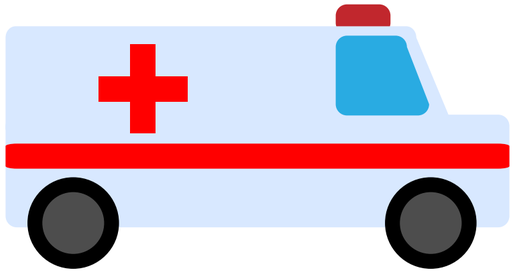
# Understanding safety concepts:

## Hazard

## Incident



## Accident

**Exercise: (5 minutes)**
Think about the difference between those 3 key terms.

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# Understanding safety concepts:

## Hazard

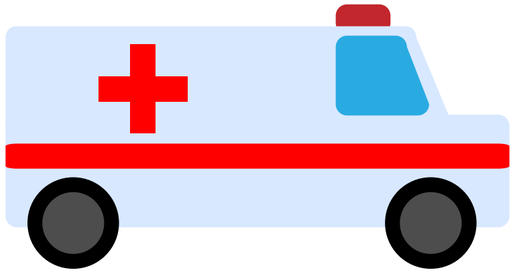
Source of potential harm

*ex: GPS, LiPo, Rx …*

## Incident

Hazard manifested but no major harm.

*ex: Loss of control*



## Accident

Hazard manifested with actual serious harm/damage.

*ex: Aircraft collision*

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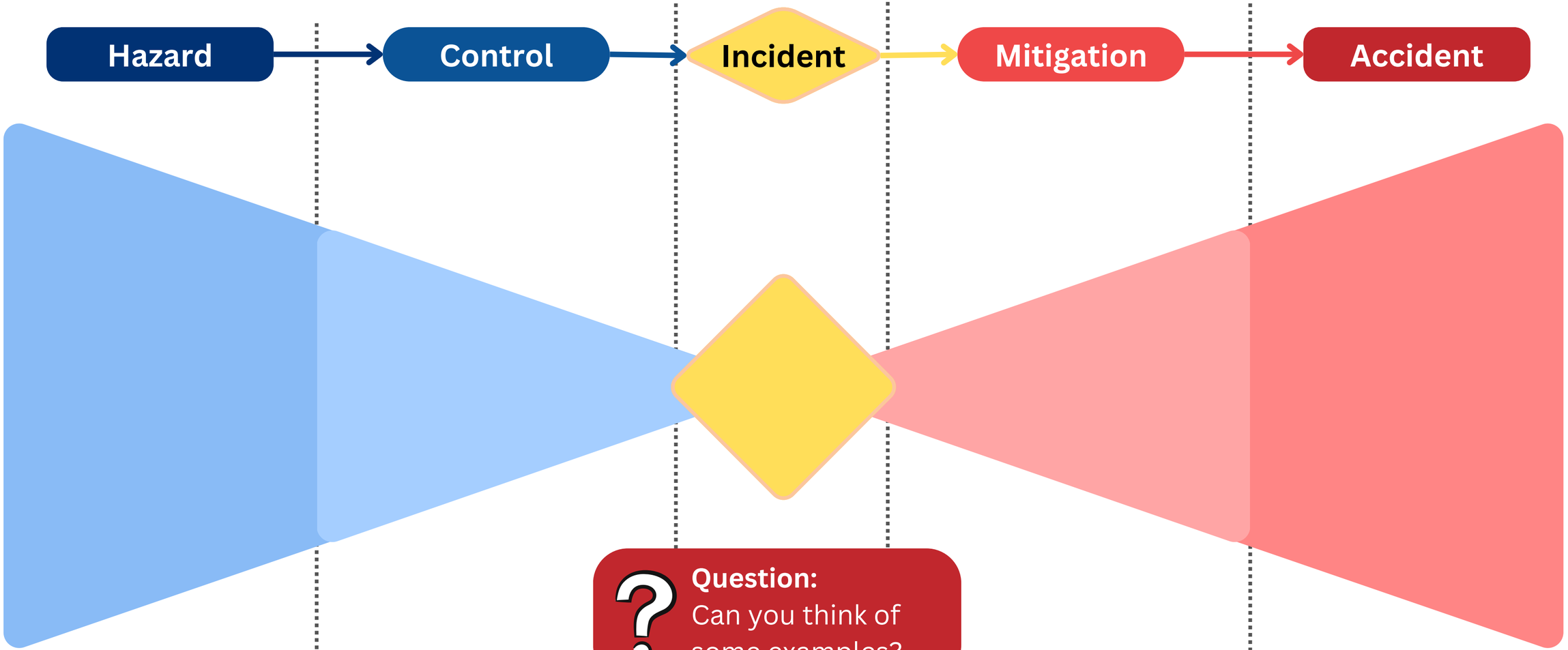
# The Bowtie Model:




**Question:**
Can you think of some examples?

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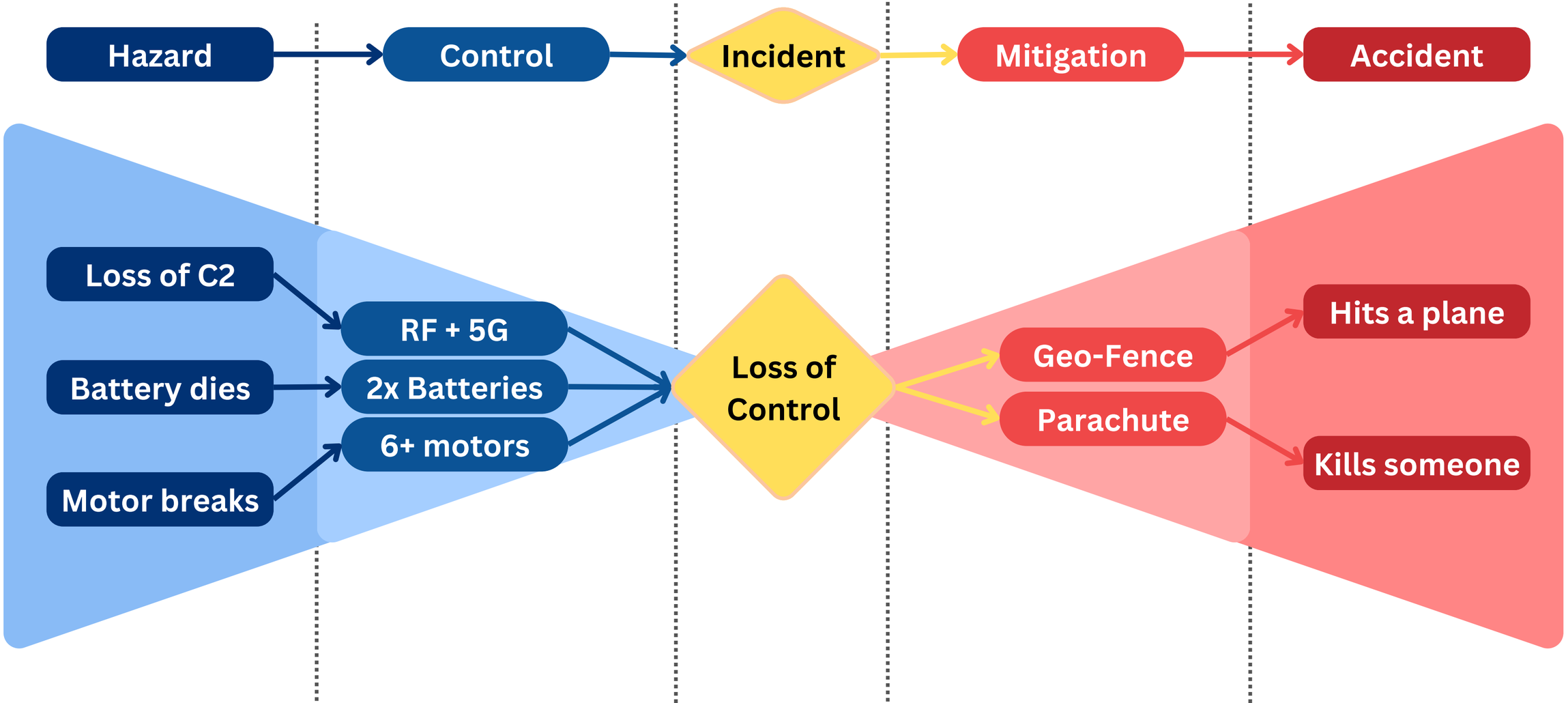
# The Bowtie Model:



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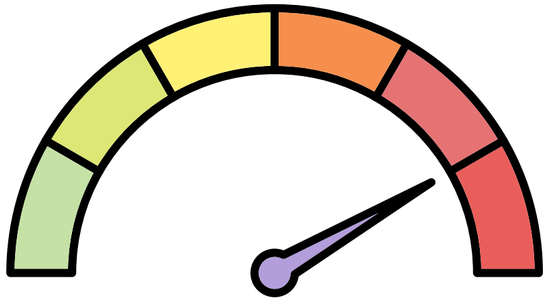
# What is Risk?

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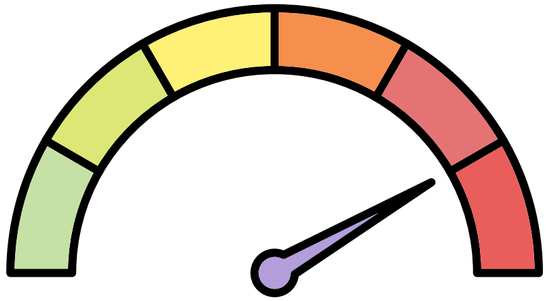
# What is Risk?



## Risk

Likelihood x Severity

*ex: The likelihood of a drone falling and the severity of its impact.*

Severity

| Likelihood | Negligible | Marginal | Critical | Catastrophic |
|---|---|---|---|---|
| Improbable | Low | Low | Medium | Medium |
| Remote | Low | Medium | Serious | Serious |
| Probable | Medium | Serious | Serious | High |
| Frequent | Medium | Serious | High | High |

Risk Assessment Matrix

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# UAS Regulations

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EASA
European Aviation Safety Agency

[easa.europa.eu](easa.europa.eu)

[Easy Access Rules]

Trafikstyrelsen
Danish Civil Aviation and Railway Authority

[trafikstyrelsen.dk]

[droneregler.dk]

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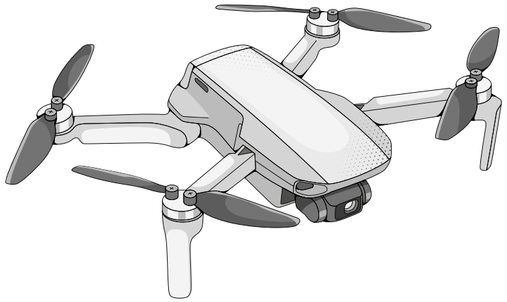
# Operational Categories



## OPEN 01

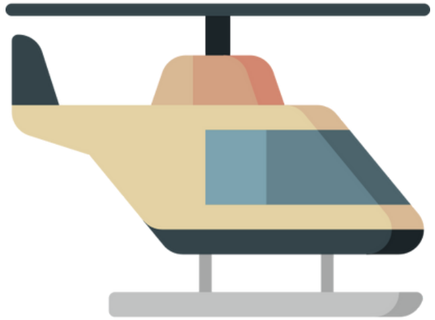
**Low** level of risk:

- Leisure activities
- Low-risk commercial activities (i.e. photography, inspection)

## SPECIFIC 02

**Medium** level of risk:

- National drone delivery
- Remote operations
- Heavy drones (> 25kg)



## CERTIFIED 03

**High** level of risk:

- International cargo drone flight
- Air taxis
- IFR (Instrument Flight Rules)

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# Open Category

**Low** risk operations

What are the limitations of the open category?

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| C-Class | Max Take off mass |
|---|---|
| Privately build | <250g  |
| legacy < 250g | |
| C0 | |
| C1 | <900g  |
| C2 | <4kg  |
| C3 | <25kg  |
| C4 | |
| Privately build | |
| Legacy drones (art 20) | |

EASA
European Aviation Safety Agency

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# Open Category

## Low risk operations

- VLOS (Visual Line of Sight) ~ 500m
  - **See the drone without any aids.**
  - **See and avoid any obstacles or other aircraft.**
- Altitude < 120m AGL (Above Ground Level)
- MTOM (Maximum Take-Off Mass) < 25kg
- Safe distance from public
  - **A1: Minimise overflying** uninvolved persons.
  - **A2: > 30m (1:1 ratio)** from uninvolved persons, or **5m in slow speed mode.**
  - **A3: 150m away** from residential, commercial or industrial areas.
- No-fly zones (dronezoner.eu)
- Pilot must be certified (A1/A3, A2)

| C-Class | Max Take off mass | Subcategory |
|---|---|---|
| Privately build | <250g  | A1 Not over assemblies of people (can also fly in subcategory A3) |
| legacy < 250g | | |
| C0 | | |
| C1 | <900g  | |
| C2 | <4kg  | A2 Fly close to people (can also fly in subcategory A3) |
| C3 | <25kg  | A3 Fly far from people |
| C4 | | |
| Privately build | | |
| Legacy drones (art 20) | | |

EASA European Aviation Safety Agency

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# Specific Category

**Medium** risk operations

- **Standard scenario (STS).**
  - STS-01: VLOS, < 120m, controlled ground area, populated environment, CE class C5 UAS.
  - STS-02: BVLOS, 2km from the pilot, airspace observers, < 120m, controlled ground area, sparsely populated environment, CE class C6 UAS.
- **Pre-Defined Risk Assessment (PDRA).**
  - PDRA-S01: VLOS, <150m *(Agriculture, Short-range cargo)*
  - PDRA-S02: BVLOS 2km, <150m *(Surveillance, Agriculture, Short-range cargo)*
  - PDRA-G01: BVLOS + Observer, <150m *(Surveillance, Long-range cargo)*
  - PDRA-G02: BVLOS, Segregated Airspace, <150m *(All range of ops)*
  - PDRA-G03: BVLOS, Close to obstacles *(Linear inspection, Agriculture)*
- **Specific Operation Risk Assessment (SORA).**
- **Light UAS operator Certificate (LUC).**
  - Safety management system
  - Remote pilot competencies
  - Documentation system
  - LUC safety manual

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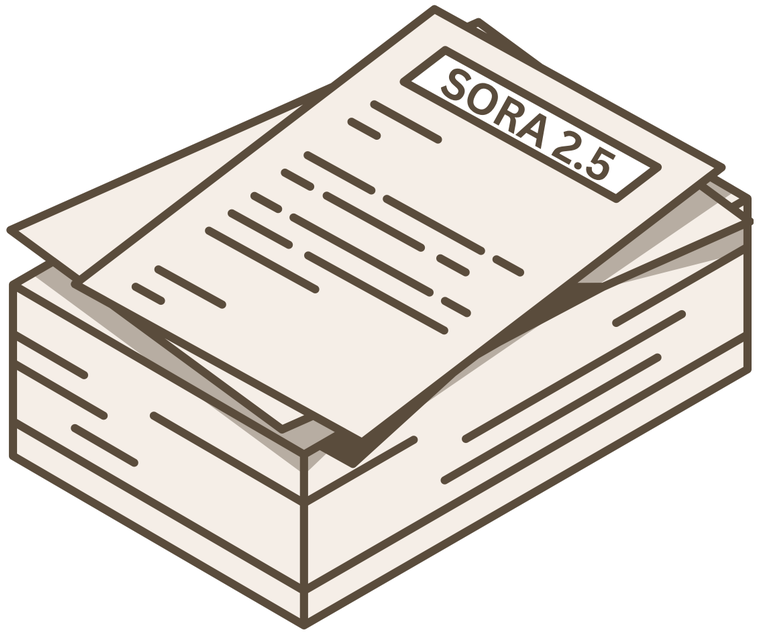
# Specific Operation Risk Assessment (SORA)




**Publication date:** 13/5/24

Joint Authorities for Rulemaking on Unmanned Systems

jarus-rpas.org

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# SORA Methodology

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# Example

**Mission:**

The WildDrone team need to **study animals** at the Ol Pejeta Conservancy.

In order to be safe, and to efficiently gather data, they **need to fly BVLOS**.

Help the WildDrone team **carry a risk assessment** of the BVLOS operations that they will submit to the KCAA.

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# 1- Documentation of Proposed Operations

**What** you want to do?

**Where** you want to fly?

**Which** UAS you intend to use?

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# 1- Documentation of Proposed Operations

**What** you want to do?

BVLOS for wildlife conservation

**Where** you want to fly?

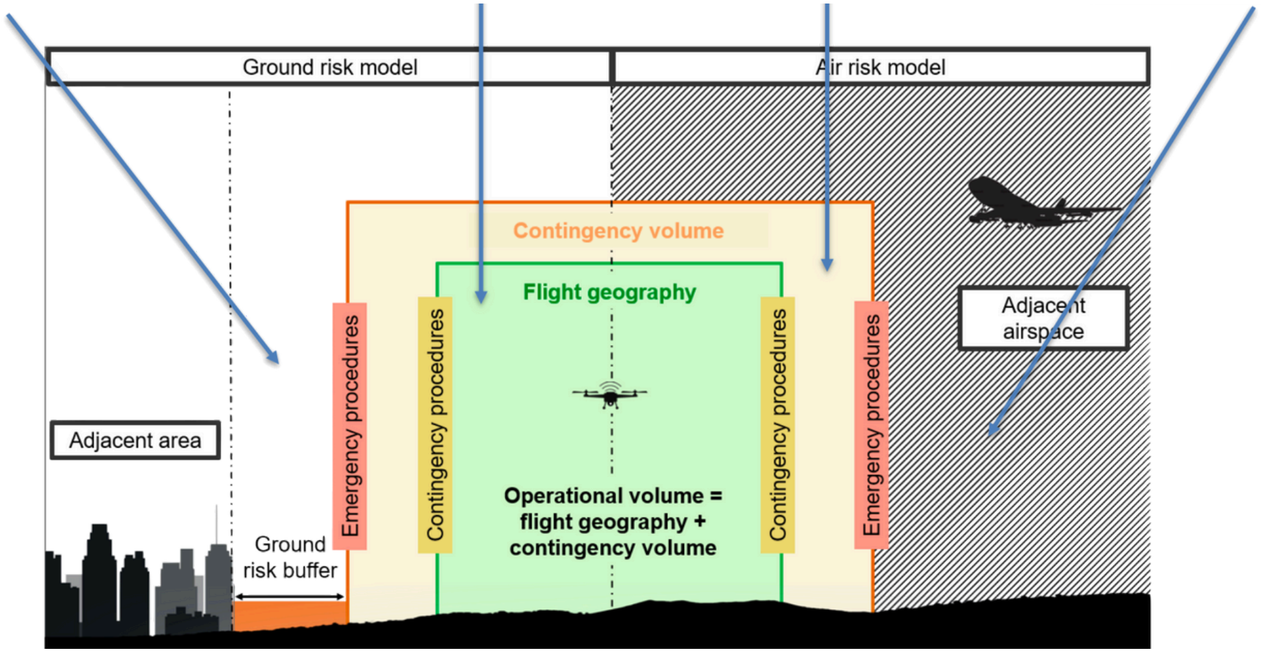
Ol Pejeta Conservancy, Kenya

**Which** UAS you intend to use?

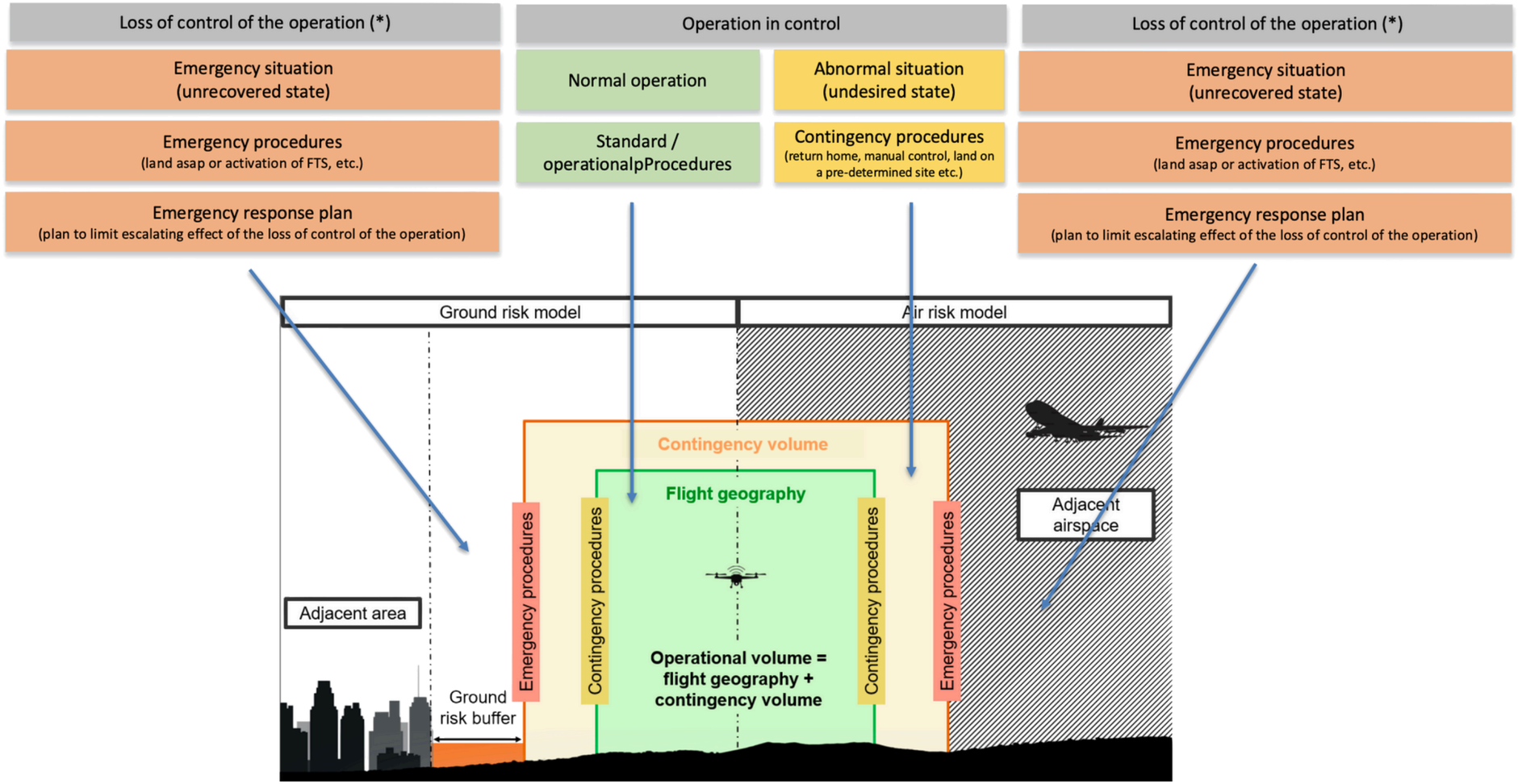
DJI Mavic 3 Pro

# SORA semantic model

**Exercise: (5 minutes)**
Think about the difference between those volumes.



# SORA semantic model



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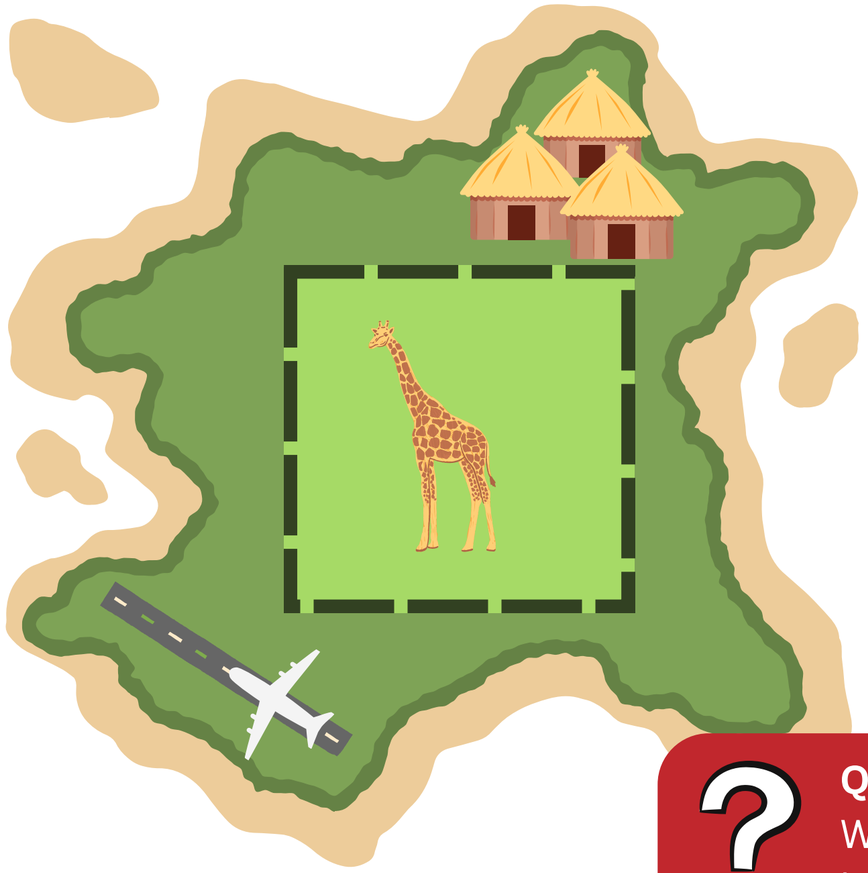
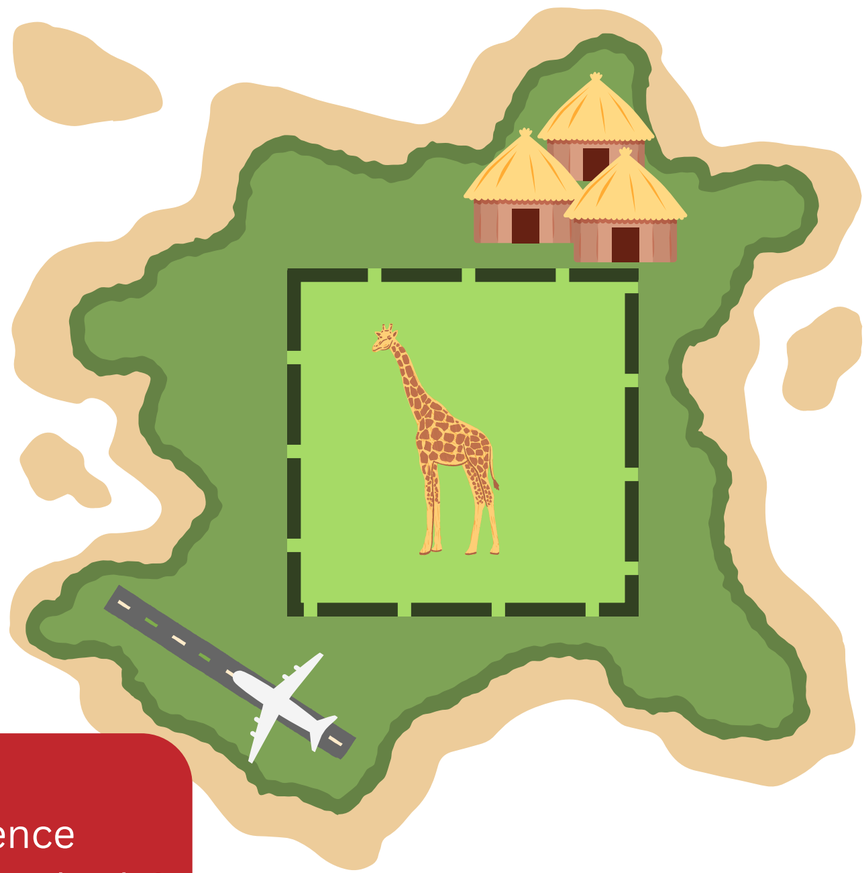
# Top-down vs Bottom up approach





**Question:**
What is the difference between those 2 methods?

Top-down

Bottom-up

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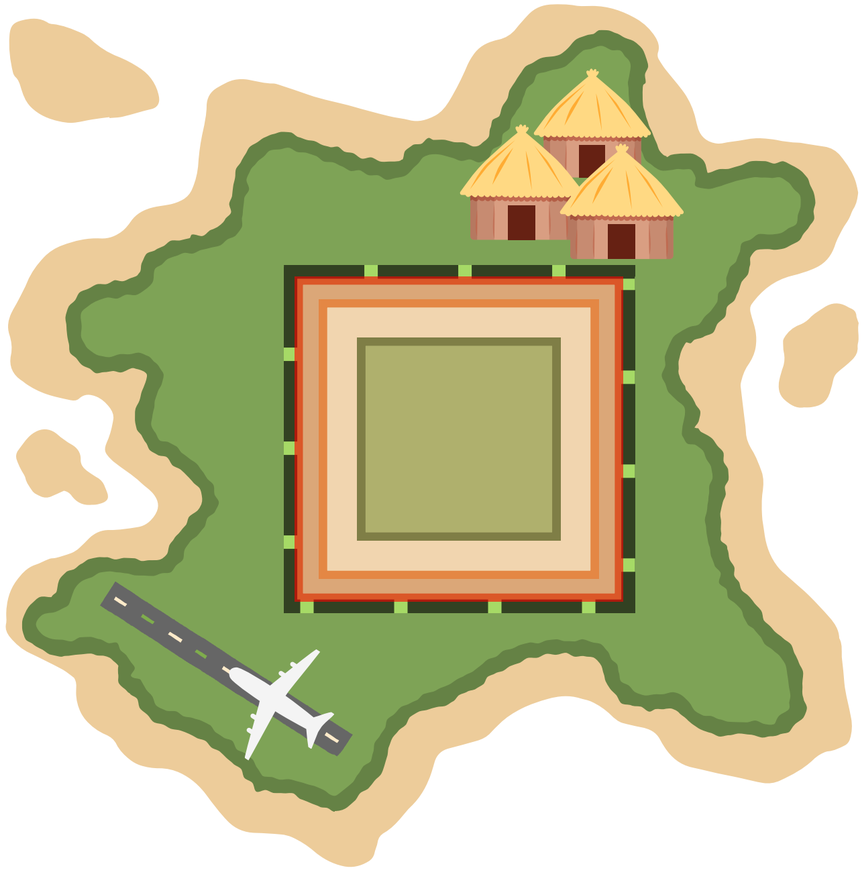
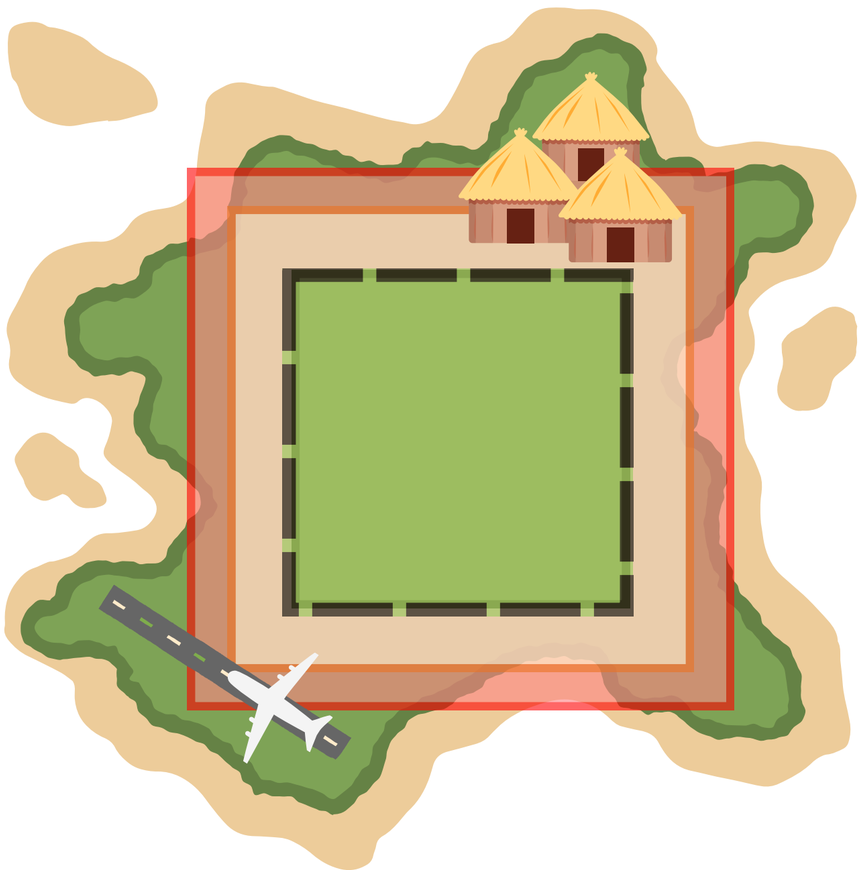
# Top-down vs Bottom up approach



Top-down



Bottom-up

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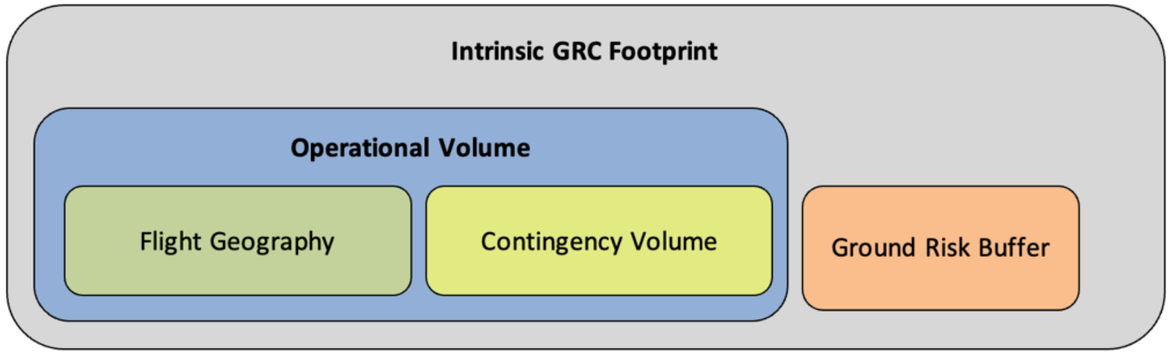
# 2- intrinsic Ground Risk Class (iGRC)




**Alternatively, use the equations described in Annex F (python package, online calculator)**

| Intrinsic UAS Ground Risk Class | | | | | | |
|---|---|---|---|---|---|---|
| **Maximum UA characteristic dimension** | | 1m / approx. 3 ft | 3 m / approx. 10 ft | 8 m / approx. 25 ft | 20 m / approx. 65 ft | 40 m / approx. 130 ft |
| **Maximum speed** | | *25 m/s* | *35 m/s* | *75 m/s* | *120 m/s* | *200 m/s* |
| **Maximum iGRC population density (people/km²)** | **Controlled Ground Area** | 1 | 1 | 2 | 3 | 3 |
| | **< 5** | 2 | 3 | 4 | 5 | 6 |
| | **< 50** | 3 | 4 | 5 | 6 | 7 |
| | **< 500** | 4 | 5 | 6 | 7 | 8 |
| | **< 5,000** | 5 | 6 | 7 | 8 | 9 |
| | **< 50,000** | 6 | 7 | 8 | 9 | 10 |
| | **> 50,000** | 7 | 8 | **Not part of SORA** | | |

- A UA weighing less than or equal to 250 g and having a maximum speed less than or equal to 25 m/s is considered to have an iGRC of 1 regardless of population density.
- A UA expected to not penetrate a standard dwelling will get a -1 GRC reduction in Step 3 from the M1(A) sheltering mitigation when not overflying large open assemblies of people, see Annex B for additional details.

# Step 2: iGRC

| Intrinsic UAS Ground Risk Class | | | | | | |
|---|---|---|---|---|---|---|
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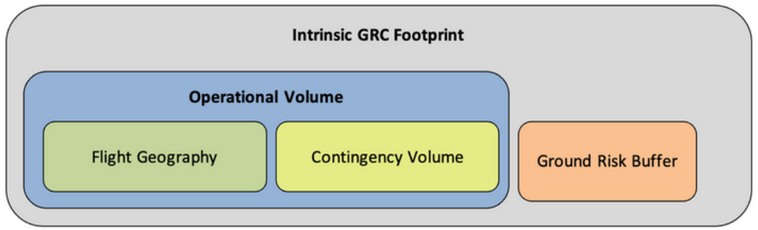


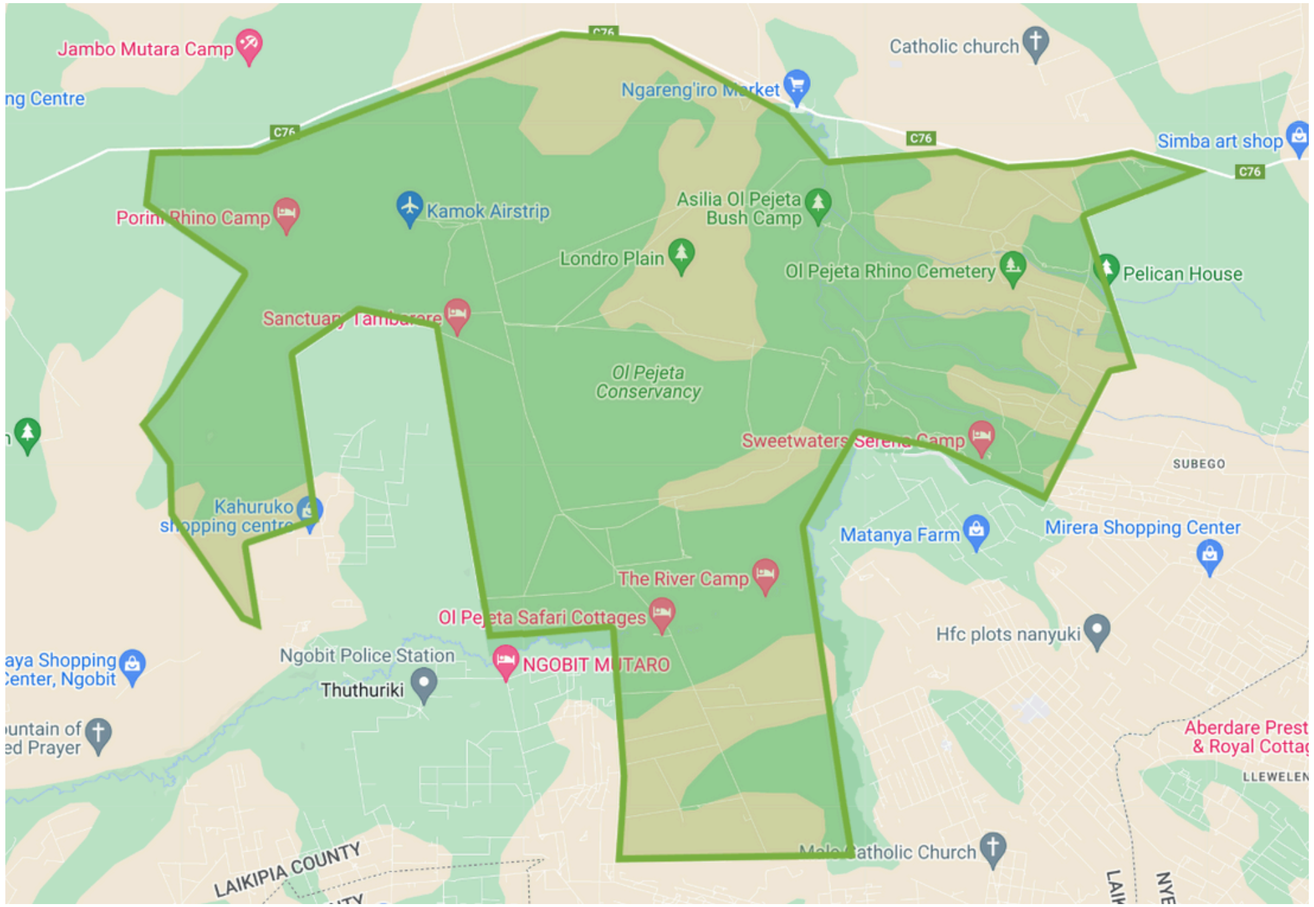

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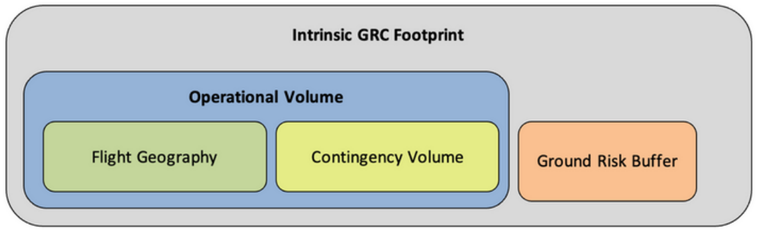


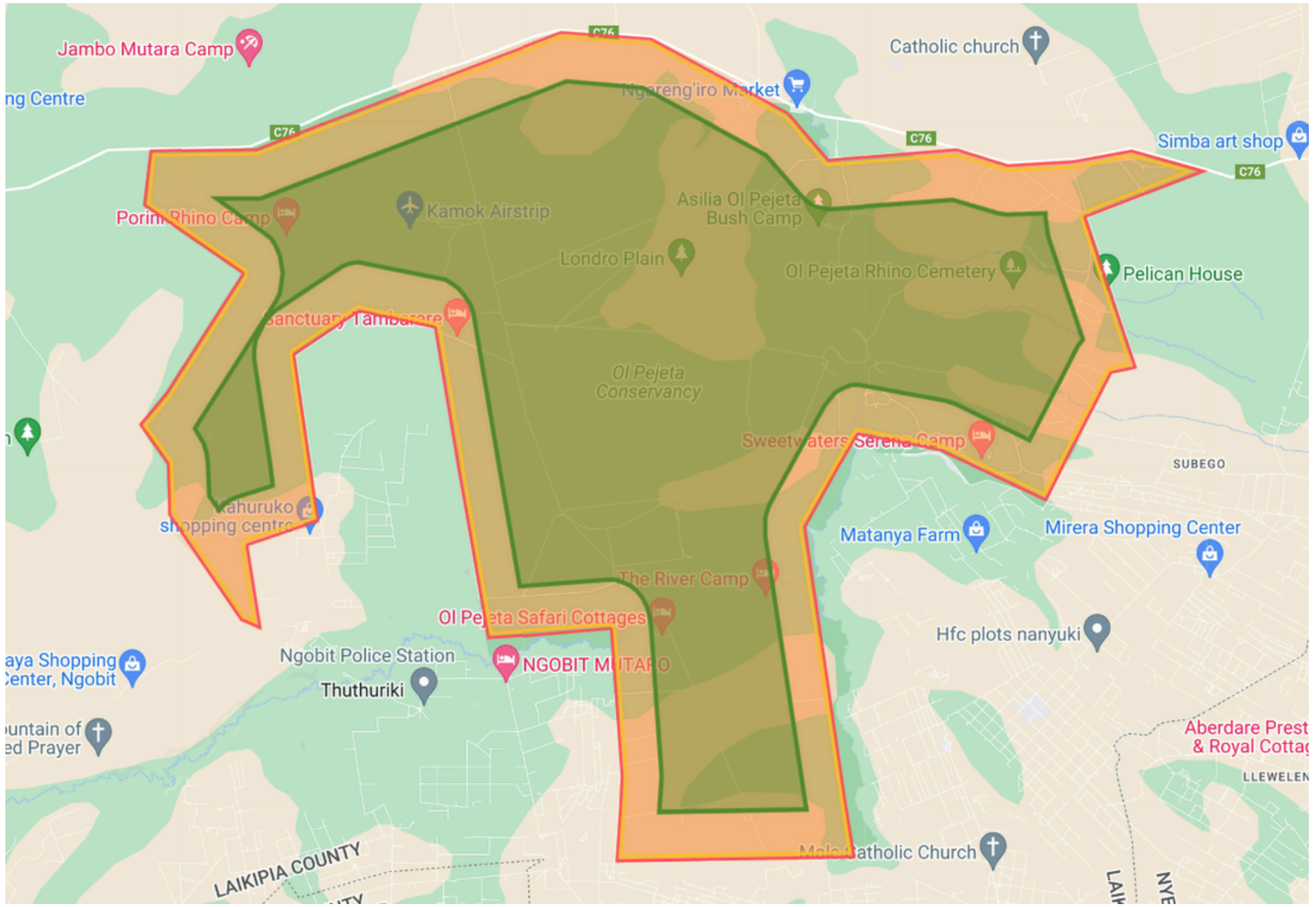

# Step 2: iGRC

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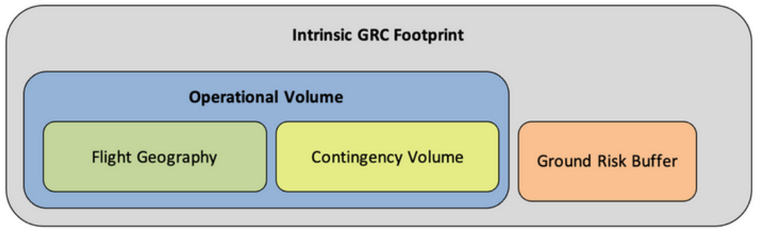


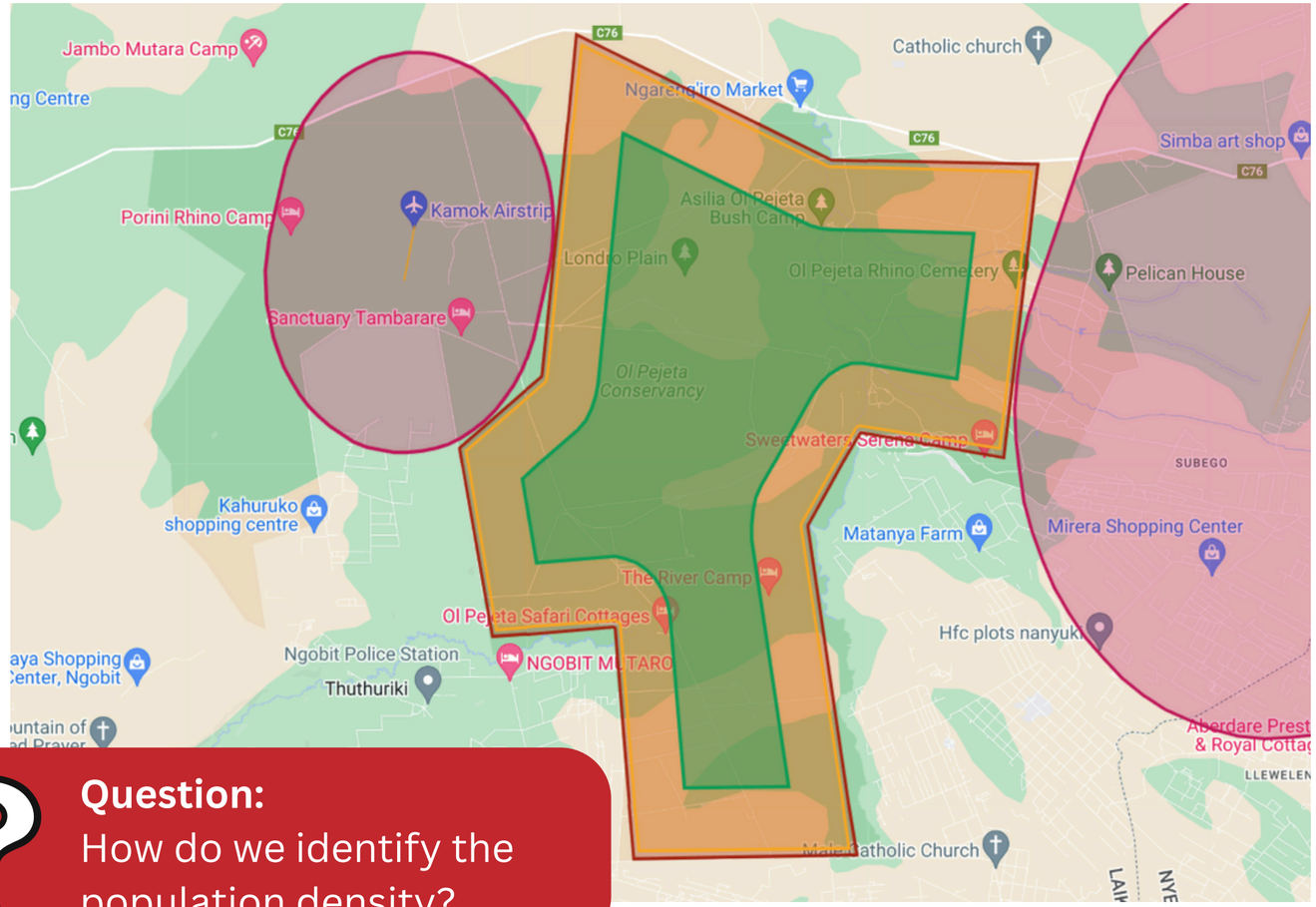


**Question:**
How do we identify the population density?

# Step 2: iGRC

| Intrinsic UAS Ground Risk Class | | | | | | |
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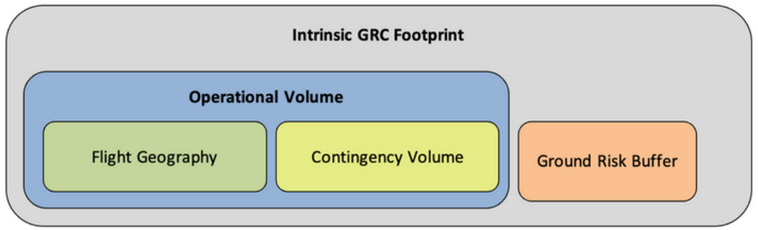


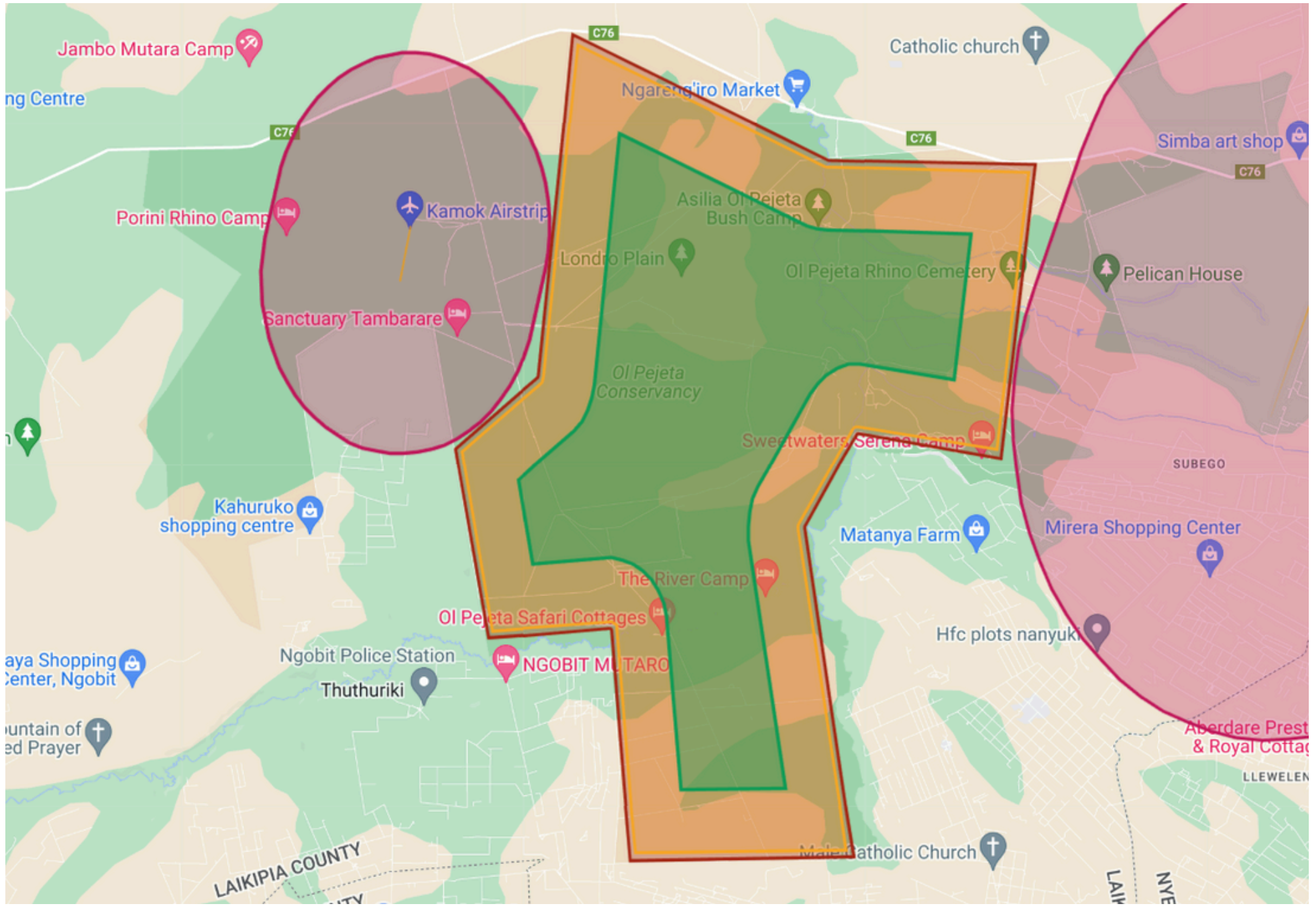

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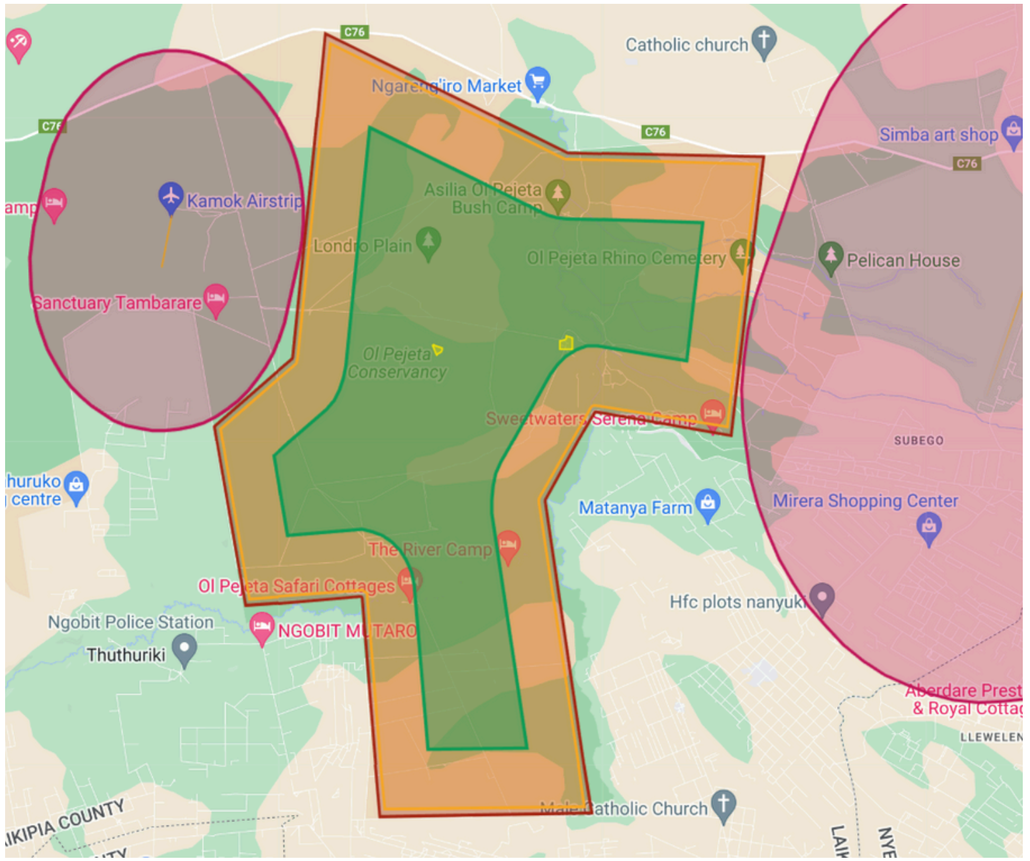
# 3- Final Ground Risk Class (GRC)

| | Level of Robustness | | |
|---|---|---|---|
| **Mitigations for ground risk** | **Low** | **Medium** | **High** |
| M1(A) - Strategic mitigations - Sheltering | **-1** | **-2** | **N/A** |
| M1(B) - Strategic mitigations - Operational restrictions | **N/A** | **-1** | **-2** |
| M1(C) - Tactical mitigations - Ground observation | **-1** | **N/A** | **N/A** |
| M2 - Effects of UA impact dynamics are reduced | **N/A** | **-1** | **-2** |

# 3- Final Ground Risk Class (GRC)

| | Level of Robustness | | |
|---|---|---|---|
| **Mitigations for ground risk** | **Low** | **Medium** | **High** |
| M1(A) - Strategic mitigations - Sheltering | **-1** | **-2** | **N/A** |
| M1(B) - Strategic mitigations - Operational restrictions | **N/A** | **-1** | **-2** |
| M1(C) - Tactical mitigations - Ground observation | **-1** | **N/A** | **N/A** |
| M2 - Effects of UA impact dynamics are reduced | **N/A** | **-1** | **-2** |

**Question:**
Which mitigations are applicable here?

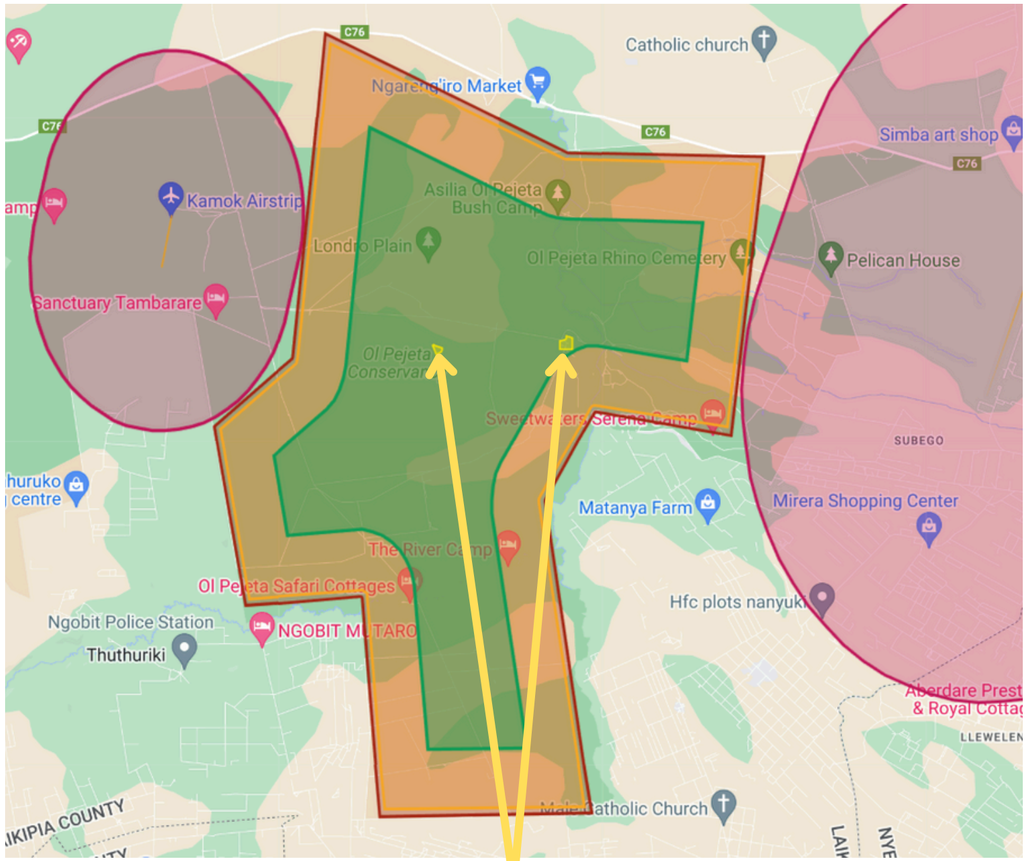


SDU

# 3- Final Ground Risk Class (GRC)

| | Level of Robustness | | |
|---|---|---|---|
| **Mitigations for ground risk** | **Low** | **Medium** | **High** |
| M1(A) - Strategic mitigations - Sheltering | **-1** | **-2** | **N/A** |
| M1(B) - Strategic mitigations - Operational restrictions | **N/A** | **-1** | **-2** |
| M1(C) - Tactical mitigations - Ground observation | **-1** | **N/A** | **N/A** |
| M2 - Effects of UA impact dynamics are reduced | **N/A** | **-1** | **-2** |

- No overflight of camps & lodges
- Perpendicular road crossings



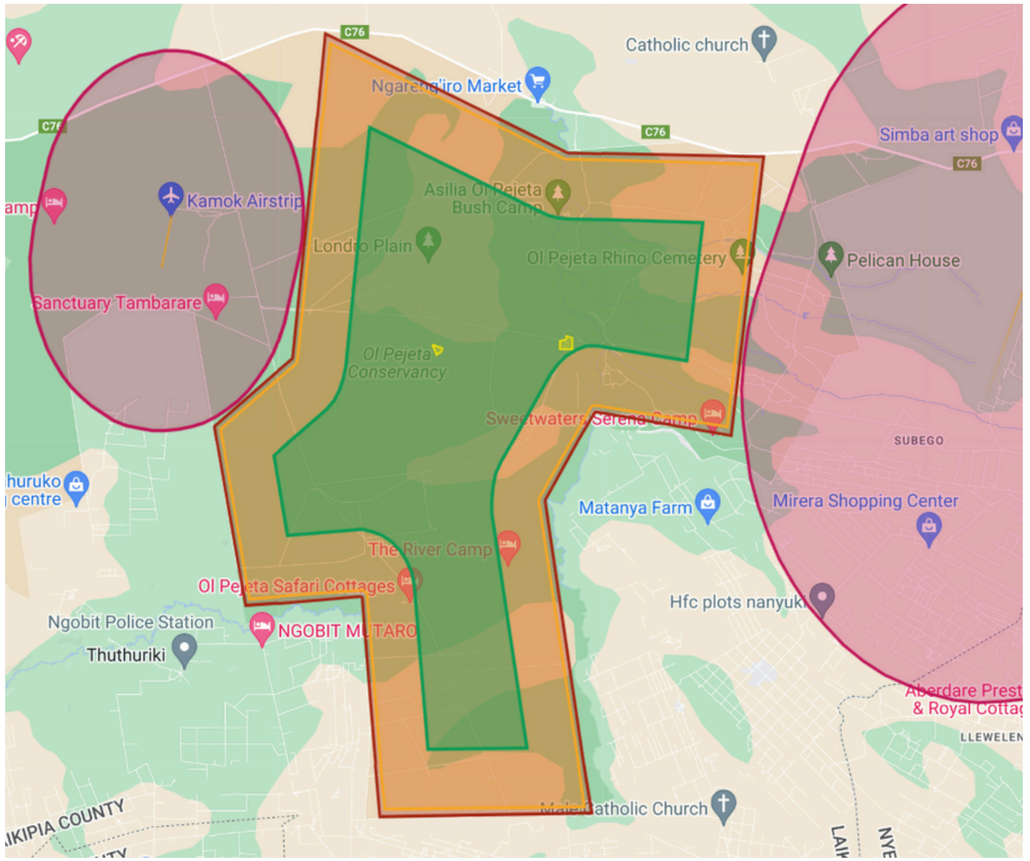

Campgrounds & Lodges

SDU

# 3- Final Ground Risk Class (GRC)

| | Level of Robustness | | |
|---|---|---|---|
| **Mitigations for ground risk** | **Low** | **Medium** | **High** |
| M1(A) - Strategic mitigations - Sheltering | **-1** | **-2** | **N/A** |
| M1(B) - Strategic mitigations - Operational restrictions | **N/A** | **-1** | **-2** |
| M1(C) - Tactical mitigations - Ground observation | **-1** | **N/A** | **N/A** |
| M2 - Effects of UA impact dynamics are reduced | **N/A** | **-1** | **-2** |

| **Intrinsic UAS Ground Risk Class** | | | | | | |
|---|---|---|---|---|---|---|
| **Maximum UA characteristic dimension** | | 1m / approx. 3 ft | 3 m / approx. 10 ft | 8 m / approx. 25 ft | 20 m / approx. 65 ft | 40 m / approx. 130 ft |
| **Maximum speed** | | *25 m/s* | *35 m/s* | *75 m/s* | *120 m/s* | *200 m/s* |
| **Maximum iGRC population density (people/km²)** | **Controlled Ground Area** | 1 | 1 | 2 | 3 | 3 |
| | **< 5** | 2 | 3 | 4 | 5 | 6 |
| | **< 50** | 3 | 4 | 5 | 6 | 7 |
| | **< 500** | 4 | 5 | 6 | 7 | 8 |
| | **< 5,000** | 5 | 6 | 7 | 8 | 9 |
| | **< 50,000** | 6 | 7 | 8 | 9 | 10 |
| | **> 50,000** | 7 | 8 | **Not part of SORA** | | |



SDU

# 4- Initial Air Risk Class (iARC)

## 1- Rural area

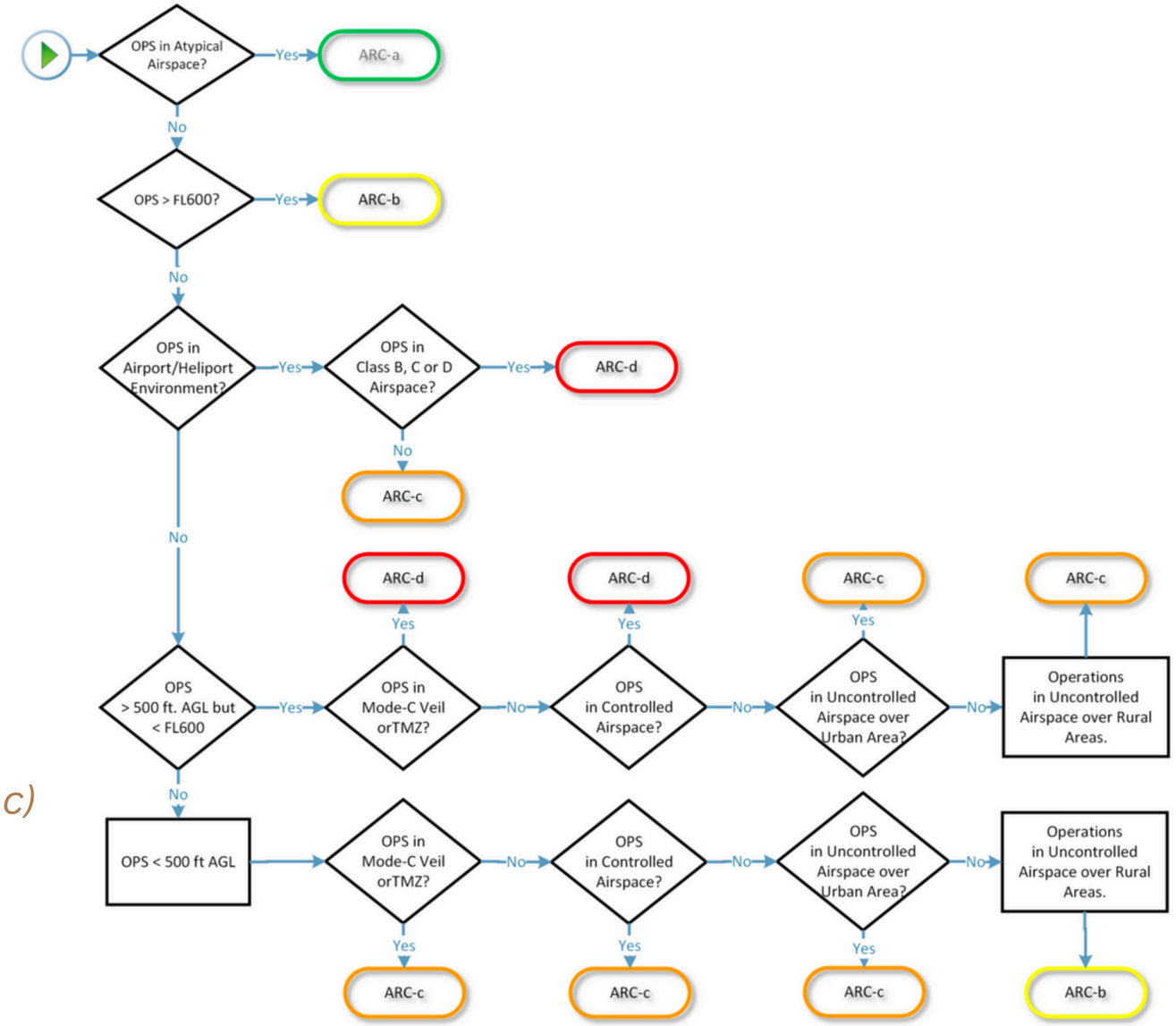
*Medium encounter rate above 150m (ARC c), lower below 150m (ARC b)*

## 2- Urban area

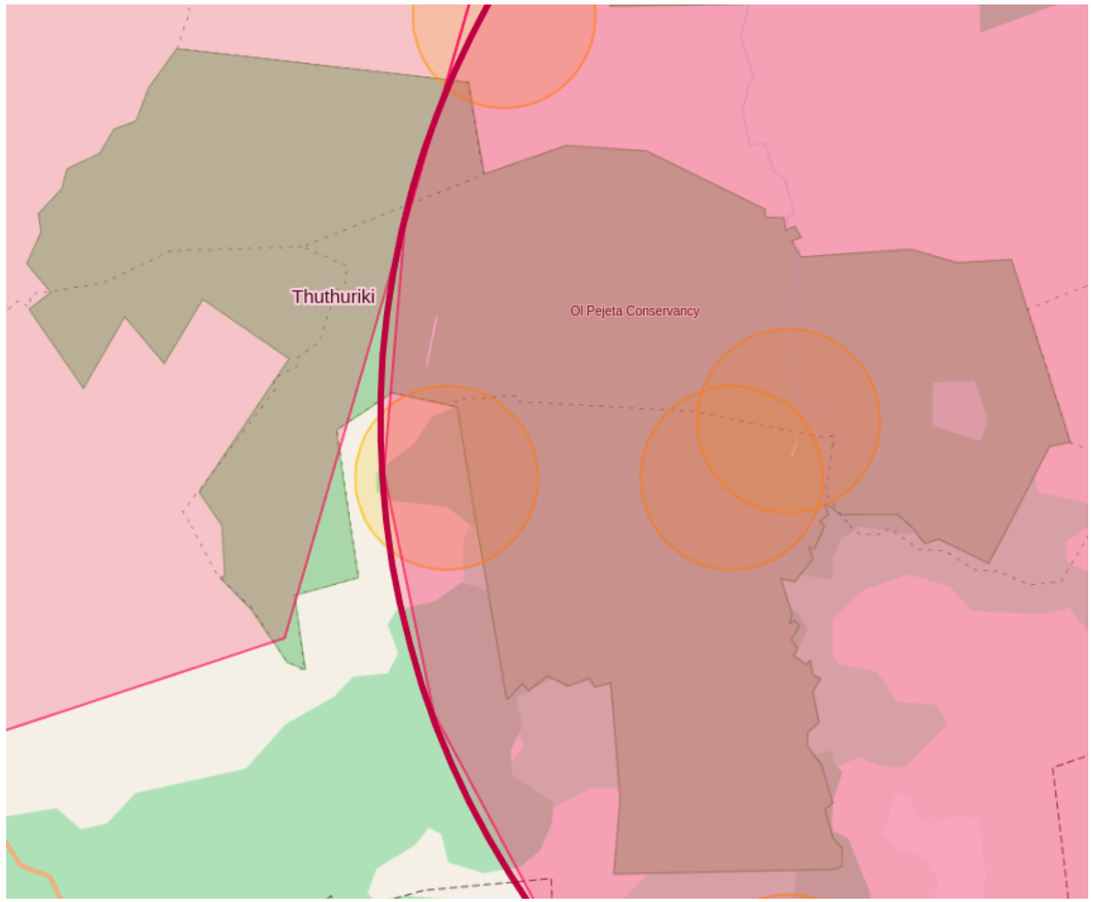
*Medium encounter rate even at low level (ARC c)*

## 3- Proximity of airport

*Very high encounter rate (ARC d)*



# 4- Initial Air Risk Class (iARC)




https://dronesafetymap.com

WHERE YOU CLICKED

**AIRSPACE** : Prohibited Area
HKP2 NANYUKI

**SUMMARY**

Red zones are regulated high-risk areas and operation of your drone may be hazardous or prohibited.

**VERTICAL LIMITS**

This piece of airspace is in effect between Surface and 99900ft SPS

**PROHIBITED AREA**

The flight of aircraft within this area is prohibited. Danger, Prohibited and Restricted Areas are defined according to ICAO International Standards. Regulations governing the flight of drones vary from country-to-country, therefore these areas are included for your information. It is your responsibility to check the applicability of any local, state and/or national laws and regulations which may permit or otherwise restrict the operation of your drone in this area. Unless regulations in your region explicitly permit the operation of your drone in this area, we recommend you do not operate your drone here.

SDU

# 4- Initial Air Risk Class (iARC)

## 1- Rural area

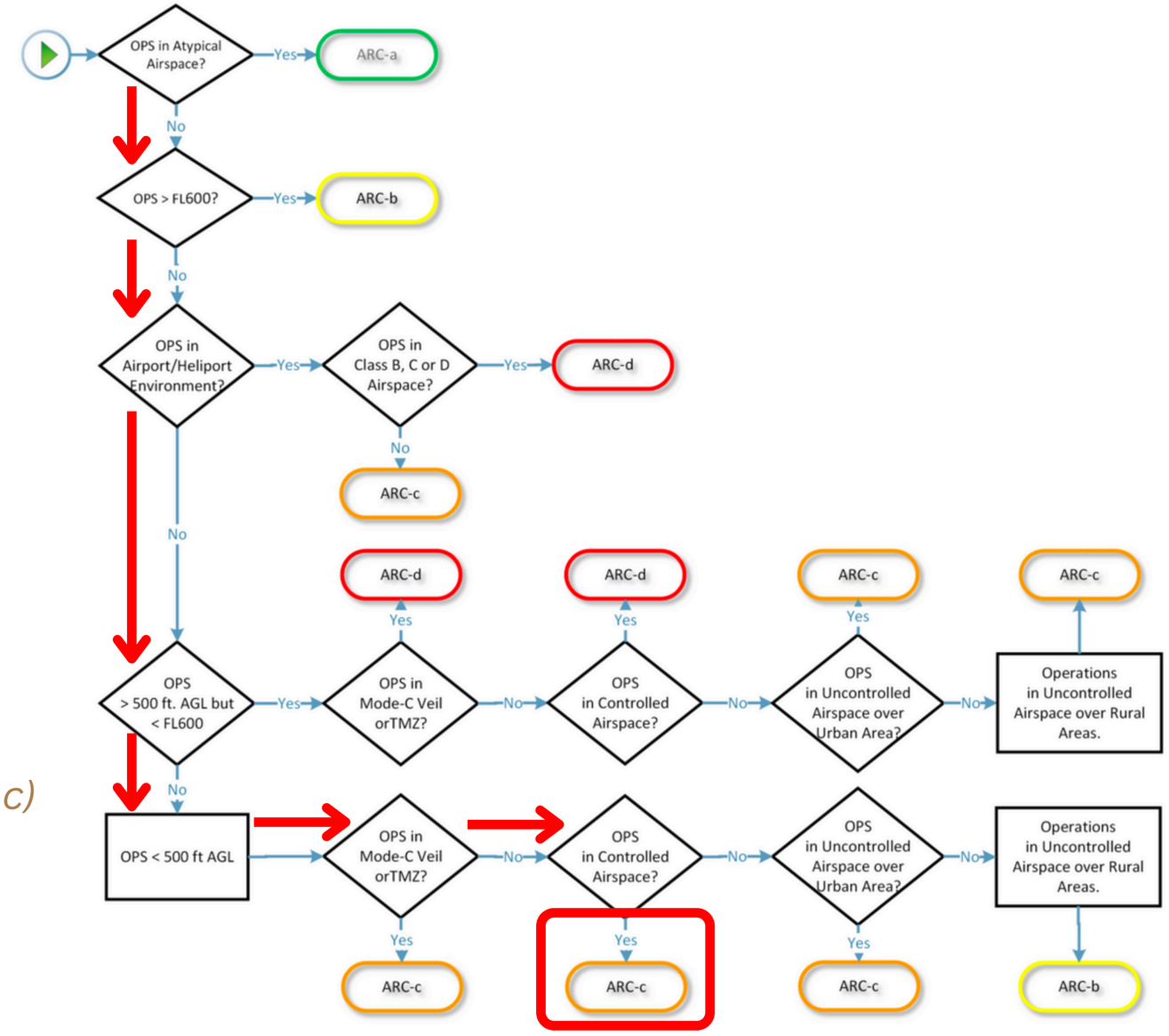
*Medium encounter rate above 150m (ARC c), lower below 150m (ARC b)*

## 2- Urban area

*Medium encounter rate even at low level (ARC c)*

## 3- Proximity of airport

*Very high encounter rate (ARC d)*



SDU

# 5- Strategic Mitigations

**1. Operational Restrictions**

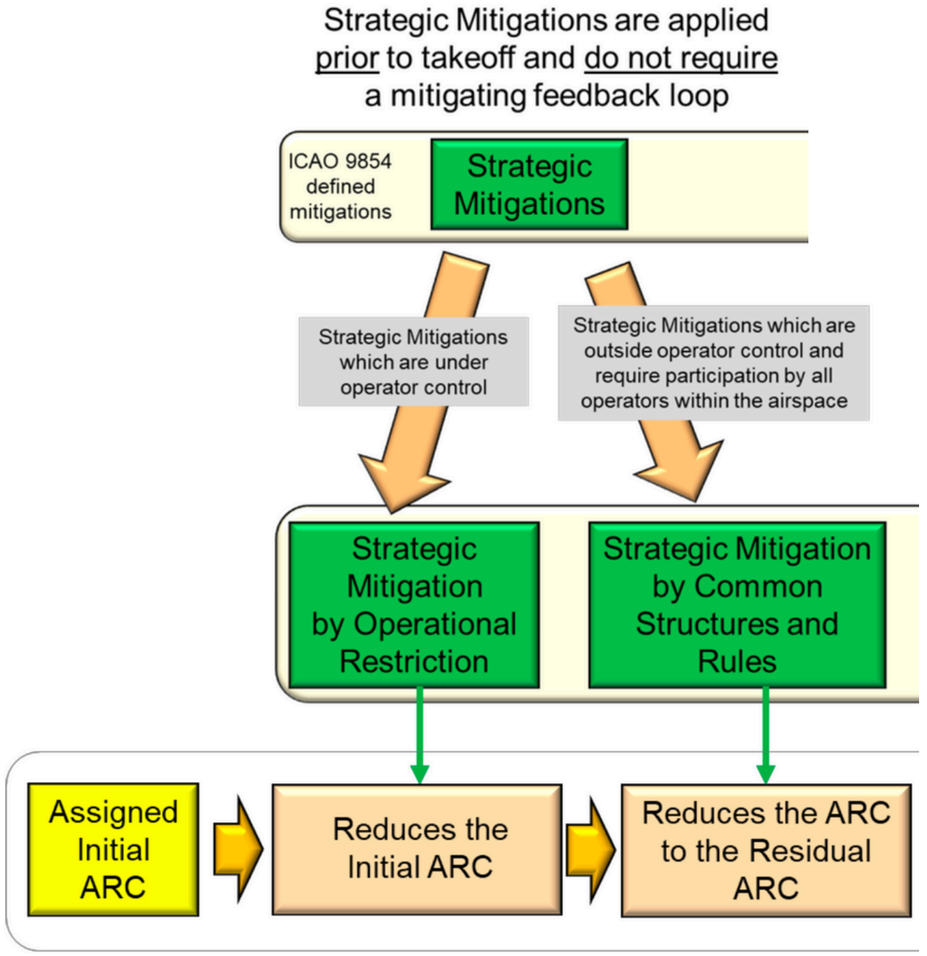
a. Boundary (i.e., low-altitude)
b. Chronology (i.e., time of day)
c. Exposure (i.e., high risk for a limited time)

**2.1. Common rules**

a. Electronic conspicuity
b. Anti-collision lighting
c. File a flight path (UTM/ANSP/...)

**2.2. Airspace structures**

a. Drone corridors
b. Procedural controls by UTM (take-off windows, reporting points, ...)



SDU

# 5- Strategic Mitigations

**1. Operational Restrictions**

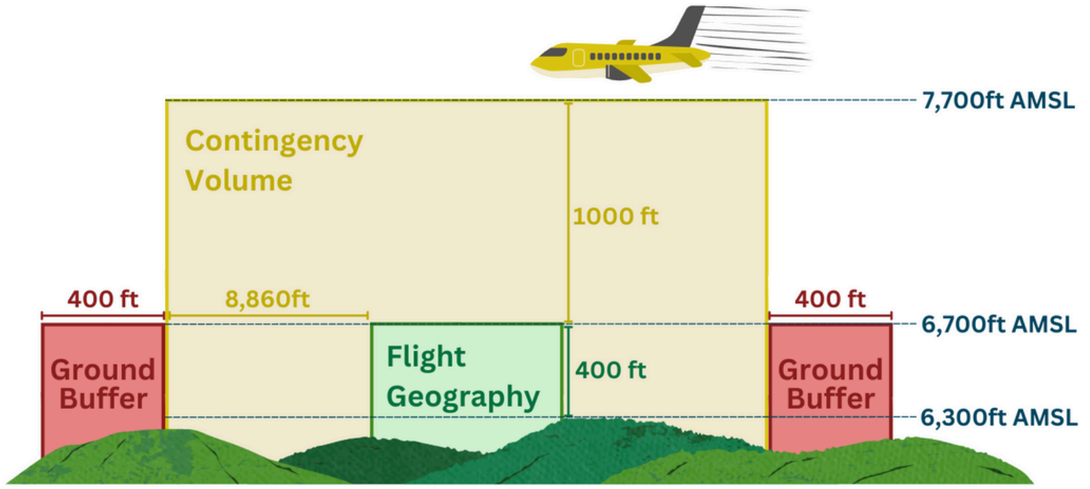
a. Boundary (i.e., low-altitude) Set flight-ceiling + buffer with ATC
b. Chronology (i.e., time of day)
c. Exposure (i.e., high risk for a limited time)

**2.1. Common rules**

a. Electronic conspicuity
b. Anti-collision lighting
c. File a flight path (UTM/ANSP/...)

**2.2. Airspace structures**

a. Drone corridors
b. Procedural controls by UTM (take-off windows, reporting points, ...)




*Dimensions not to scale

SDU

# 5- Strategic Mitigations

**1. Operational Restrictions**

a. Boundary (i.e., low-altitude) Set flight-ceiling + buffer with ATC
b. Chronology (i.e., time of day) 5 km at night - 2 km during the day
c. Exposure (i.e., high risk for a limited time)

**2.1. Common rules**

a. Electronic conspicuity
b. Anti-collision lighting
c. File a flight path (UTM/ANSP/...)

**2.2. Airspace structures**

a. Drone corridors
b. Procedural controls by UTM (take-off windows, reporting points, ...)

SDU

# 5- Strategic Mitigations

**1. Operational Restrictions**

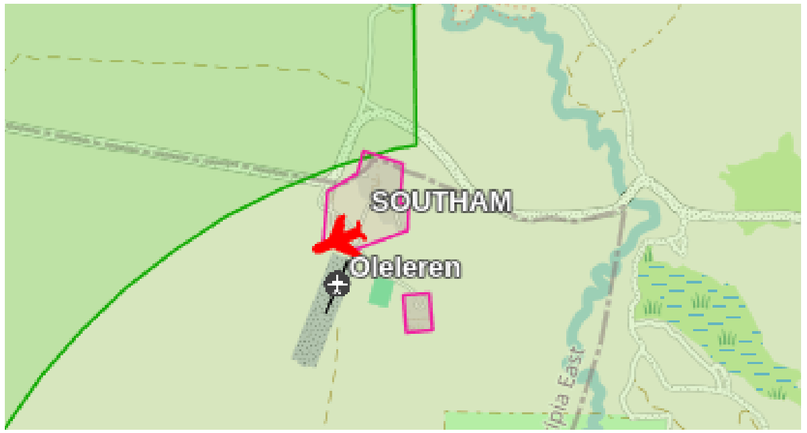
a. Boundary (i.e., low-altitude) Set flight-ceiling + buffer with ATC
b. Chronology (i.e., time of day) 5 km at night - 2 km during the day
~~c. Exposure (i.e., high risk for a limited time)~~

**2.1. Common rules**

a. Electronic conspicuity Monitor ADS-B
b. Anti-collision lighting
c. File a flight path (UTM/ANSP/...)

**2.2. Airspace structures**

a. Drone corridors
b. Procedural controls by UTM (take-off windows, reporting points, ...)




SDU

# 5- Strategic Mitigations

**1. Operational Restrictions**

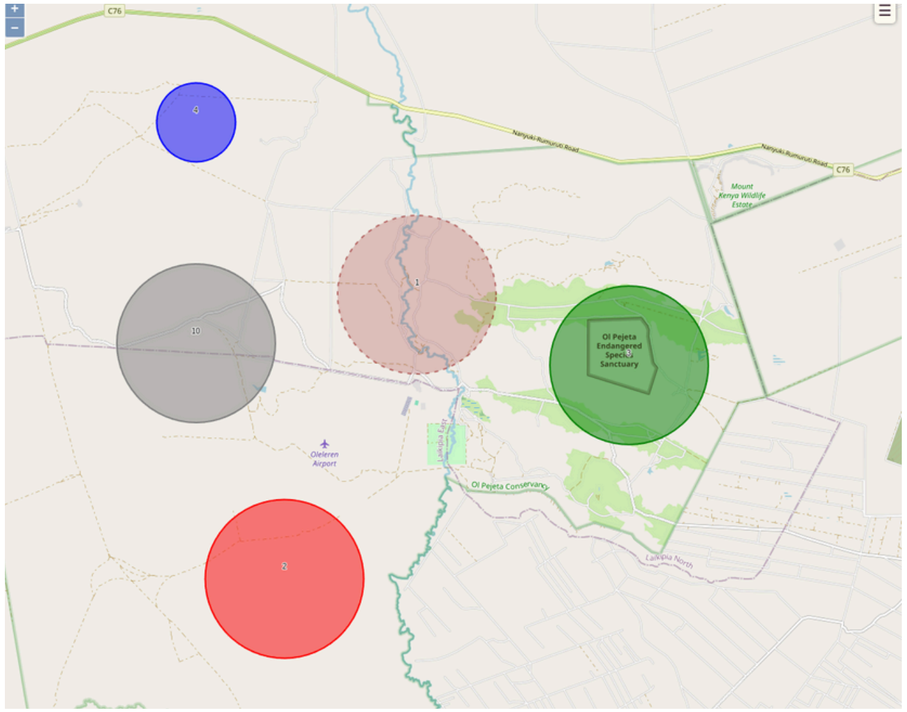
a. Boundary (i.e., low-altitude) Set flight-ceiling + buffer with ATC
b. Chronology (i.e., time of day) 5 km at night - 2 km during the day
~~c. Exposure (i.e., high risk for a limited time)~~

**2.1. Common rules**

a. Electronic conspicuity Monitor ADS-B
~~b. Anti-collision lighting~~
c. File a flight path (UTM/ANSP/...) Flight Cylinders

**2.2. Airspace structures**

a. Drone corridors
b. Procedural controls by UTM (take-off windows, reporting points, ...)



SDU

# 5- Strategic Mitigations

**1. Operational Restrictions**

a. Boundary (i.e., low-altitude) Set flight-ceiling + buffer with ATC
b. Chronology (i.e., time of day) 5 km at night - 2 km during the day
~~c. Exposure (i.e., high risk for a limited time)~~

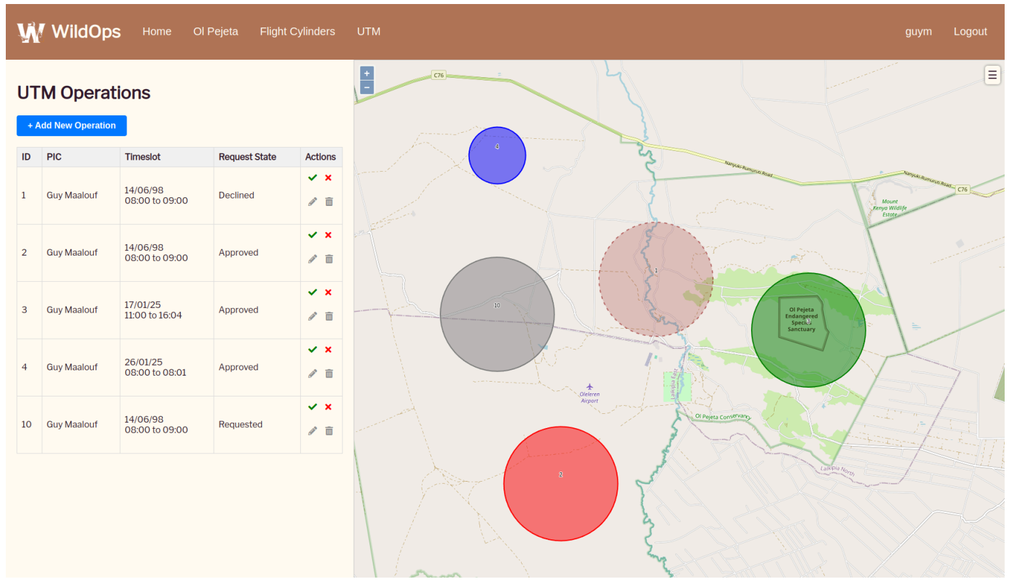
**2.1. Common rules**

a. Electronic conspicuity Monitor ADS-B
~~b. Anti-collision lighting~~
c. File a flight path (UTM/ANSP/...) Flight Cylinders

**2.2. Airspace structures**

~~a. Drone corridors~~
b. Procedural controls by UTM (take-off windows, reporting points, ...)
Flight Windows

| ID | PIC | Timeslot | Request State | Actions |
|---|---|---|---|---|
| 1 | Guy Maalouf | 14/06/98 08:00 to 09:00 | Declined | |
| 2 | Guy Maalouf | 14/06/98 08:00 to 09:00 | Approved | |
| 3 | Guy Maalouf | 17/01/25 11:00 to 16:04 | Approved | |
| 4 | Guy Maalouf | 26/01/25 08:00 to 08:01 | Approved | |
| 10 | Guy Maalouf | 14/06/98 08:00 to 09:00 | Requested | |



SDU

# 5- Strategic Mitigations

**1. Operational Restrictions**

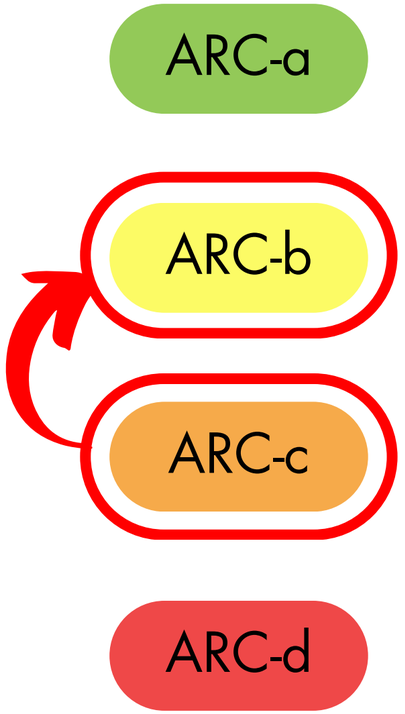
a. Boundary (i.e., low-altitude) Set flight-ceiling + buffer with ATC
b. Chronology (i.e., time of day) 5 km at night - 2 km during the day
~~c. Exposure (i.e., high risk for a limited time)~~

**2.1. Common rules**

a. Electronic conspicuity Monitor ADS-B
~~b. Anti-collision lighting~~
c. File a flight path (UTM/ANSP/...) Flight Cylinders

**2.2. Airspace structures**

~~a. Drone corridors~~
b. Procedural controls by UTM (take-off windows, reporting points, ...) Flight Windows

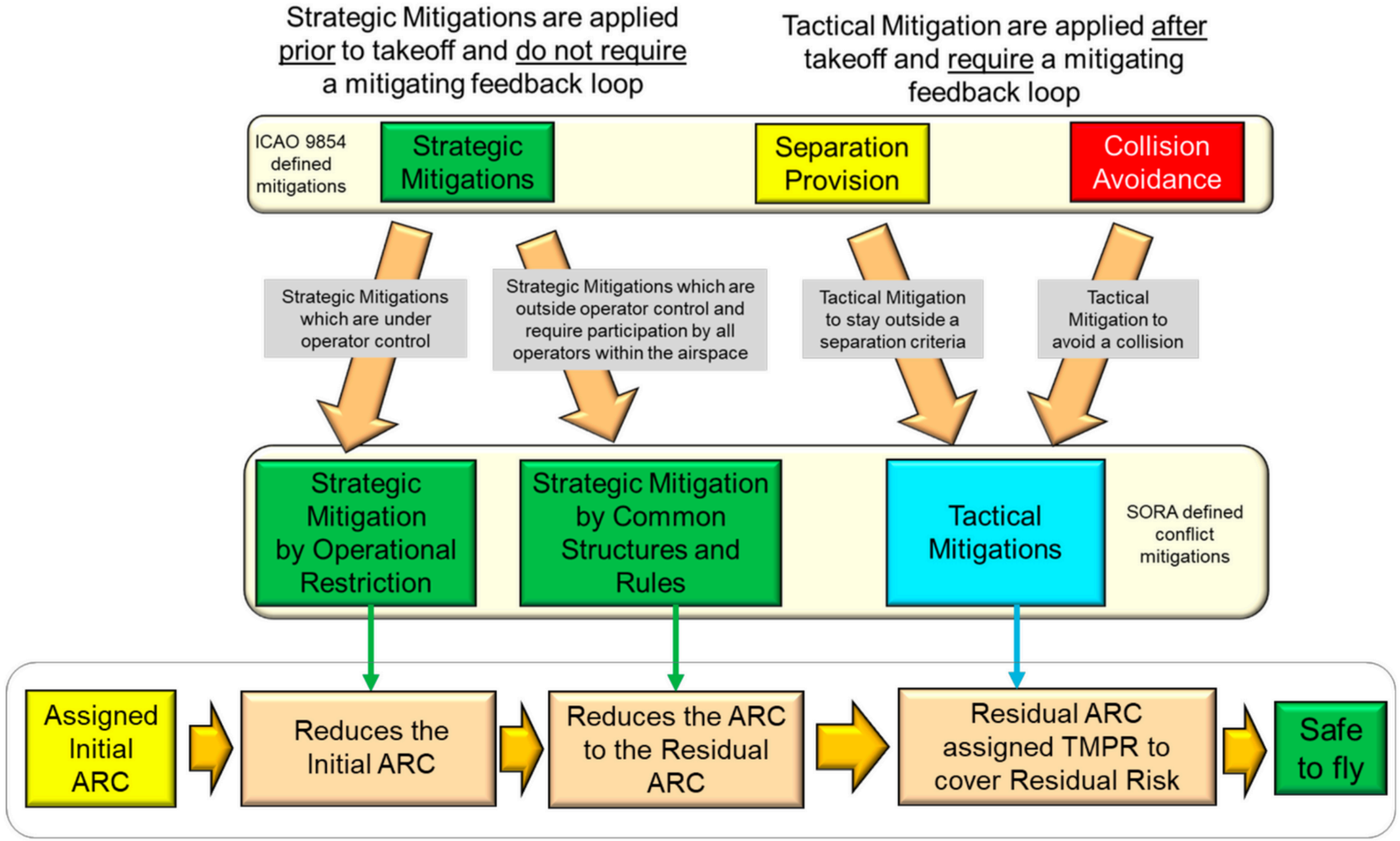


SDU

# 6- Tactical Mitigations

## Performance Requirements (TMPR)

1. **Detect** other aircraft.
2. **Decide** how to separate.
3. **Command** the UA.
4. **Execute** the separation.
5. **Feedback loop.**



SDU

# 6- Tactical Mitigations

## Performance Requirements (TMPR)

1. **Detect** other aircraft.
2. **Decide** how to separate.
3. **Command** the UA.
4. **Execute** the separation.
5. **Feedback loop.**

| | Function | TMPR Level | | | | |
|---|---|---|---|---|---|---|
| | | VLOS | No Requirement (ARC-a) | Low (ARC-b) | Medium (ARC-c) | **High (ARC-d)** |
| Tactical Mitigation Performance Requirements (TMPR) | Detect[1] | No Requirement | No Requirement | The expectation is for the applicant's DAA Plan to enable the operator to detect approximately 50% of all aircraft in the detection volume[2].<br>This is the performance requirement in absence of failures and defaults.<br>It is required that the applicant has awareness of most of the traffic operating in the area in which the operator intends to fly, by relying on one or more of the following:<br>• Use of (web-based) real time aircraft tracking services<br>• Use Low Cost ADS-B In /UAT/FLARM[3]/Pilot Aware[3] aircraft trackers<br>• Use of UTM Dynamic Geofencing[4]<br>• Monitoring aeronautical radio communication (i.e. use of a scanner)[5] | The expectation is for the applicant's DAA Plan to enable the operator to detect approximately 90% of all aircraft in the detection volume[2]. To accomplish this, the applicant will have to rely on one or a combination of the following systems or services:<br>• Ground based DAA /RADAR<br>• FLARM [3/6]<br>• Pilot Aware [3/6]<br>• ADS-B In/ UAT In Receiver[6]<br>• ATC Separation Services[7]<br>• UTM Surveillance Service[4]<br>• UTM Early Conflict Detection and Resolution Service[4]<br>• Active communication with ATC and other airspace users[5].<br>The operator provides an assessment of the effectiveness of the detection tools/methods chosen. | A system meeting RTCA SC-228 or EUROCAE WG-105 MOPS/MASPS (or similar) and installed in accordance with applicable requirements. |

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# Step 6: TMPRs

| Detect | Decide | Command | Execute | Feedback loop |
|---|---|---|---|---|
| Low (ARC-b) | Low (ARC-b) | Low (ARC-b) | Low (ARC-b) | Low (ARC-b) |
| The expectation is for the applicant's DAA Plan to enable the operator to detect approximately 50% of all aircraft in the detection volume[2].<br>This is the performance requirement in absence of failures and defaults.<br>It is required that the applicant has awareness of most of the traffic operating in the area in which the operator intends to fly, by relying on one or more of the following:<br>• Use of (web-based) real time aircraft tracking services<br>• Use Low Cost ADS-B In /UAT/FLARM[3]/Pilot Aware[3] aircraft trackers<br>• Use of UTM Dynamic Geofencing[4]<br>• Monitoring aeronautical radio communication (i.e. use of a scanner)[5] | The operator must have a documented de-confliction scheme, in which the operator explains which tools or methods will be used for detection and what the criteria are that will be applied for the decision to avoid incoming traffic. In case the remote pilot relies on detection by someone else, the use of phraseology will have to be described as well.<br>Examples:<br>• The operator will initiate a rapid descend if traffic is crossing an alert boundary and operating at less than 1000ft.<br>• The observer monitoring traffic uses the phrase: 'DESCEND!, DESCEND!, DESCEND!'. | The latency of the whole command (C2) link, i.e. the time between the moment that the remote pilot gives the command and the airplane executes the command must not exceed 5 seconds. | UAS descending to an altitude not higher than the nearest trees, buildings or infrastructure or ≤ 60 feet AGL is considered sufficient.<br>The aircraft should be able to descend from its operating altitude to the 'safe altitude' in less than a minute. | Where electronic means assist the remote pilot in detecting traffic, the information is provided with a latency and update rate for intruder data (e.g. position, speed, altitude, track) that support the decision criteria.<br>For an assumed 3 NM threshold, a 5 second update rate and a latency of 10 seconds is considered adequate (see example below). |

SDU

# SORA Methodology

SDU

# 7- SAIL

## (Specific Assurance and Integrity Levels)

The SAIL represents the **level of confidence** that the UAS **operation will stay under control**.

| SAIL Determination | | | | |
|---|---|---|---|---|
| | Residual ARC | | | |
| Final GRC | a | b | c | d |
| **≤2** | **I** | **II** | **IV** | **VI** |
| **3** | **II** | **II** | **IV** | **VI** |
| **4** | **III** | **III** | **IV** | **VI** |
| **5** | **IV** | **IV** | **IV** | **VI** |
| **6** | **V** | **V** | **V** | **VI** |
| **7** | **VI** | **VI** | **VI** | **VI** |
| **>7** | Category C (Certified) operation[10] | | | |

SDU

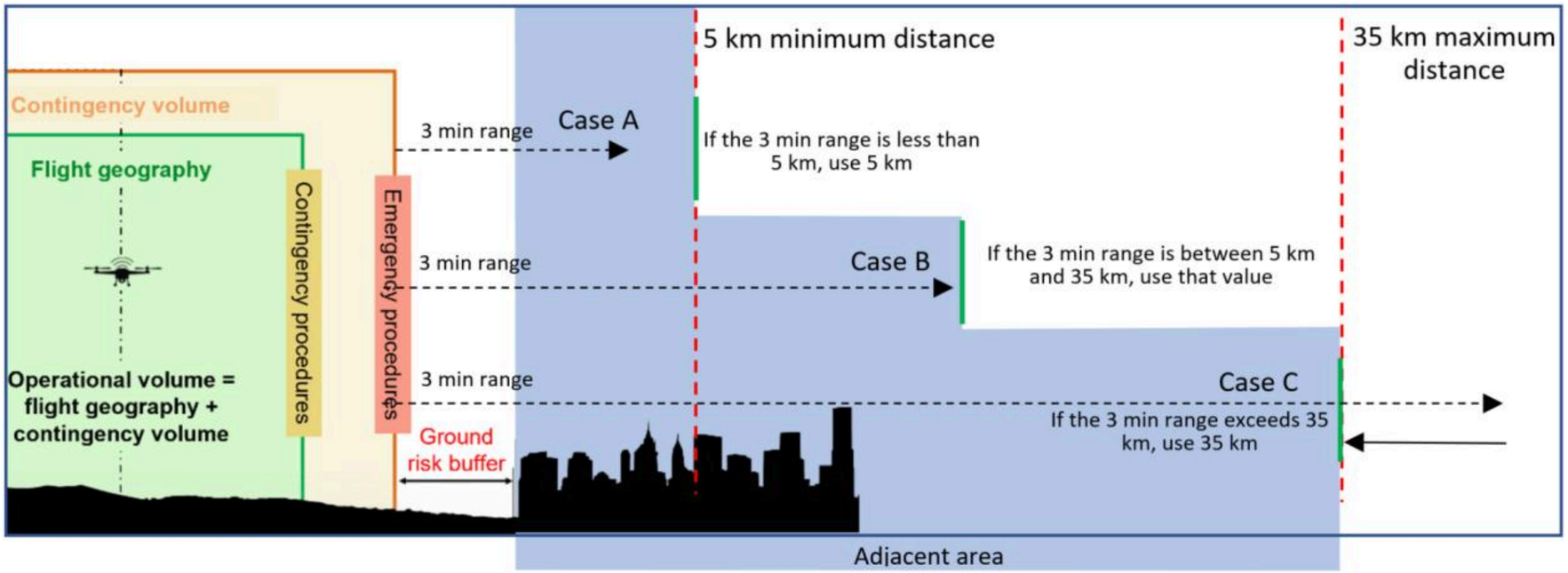
# Step 7: SAIL

| SAIL Determination | | | | |
|---|---|---|---|---|
| | Residual ARC | | | |
| Final GRC | a | b | c | d |
| **≤2** | **I** | **II** | **IV** | **VI** |
| **3** | **II** | **II** | **IV** | **VI** |
| **4** | **III** | **III** | **IV** | **VI** |
| **5** | **IV** | **IV** | **IV** | **VI** |
| **6** | **V** | **V** | **V** | **VI** |
| **7** | **VI** | **VI** | **VI** | **VI** |
| **>7** | Category C (Certified) operation[10] | | | |

SDU

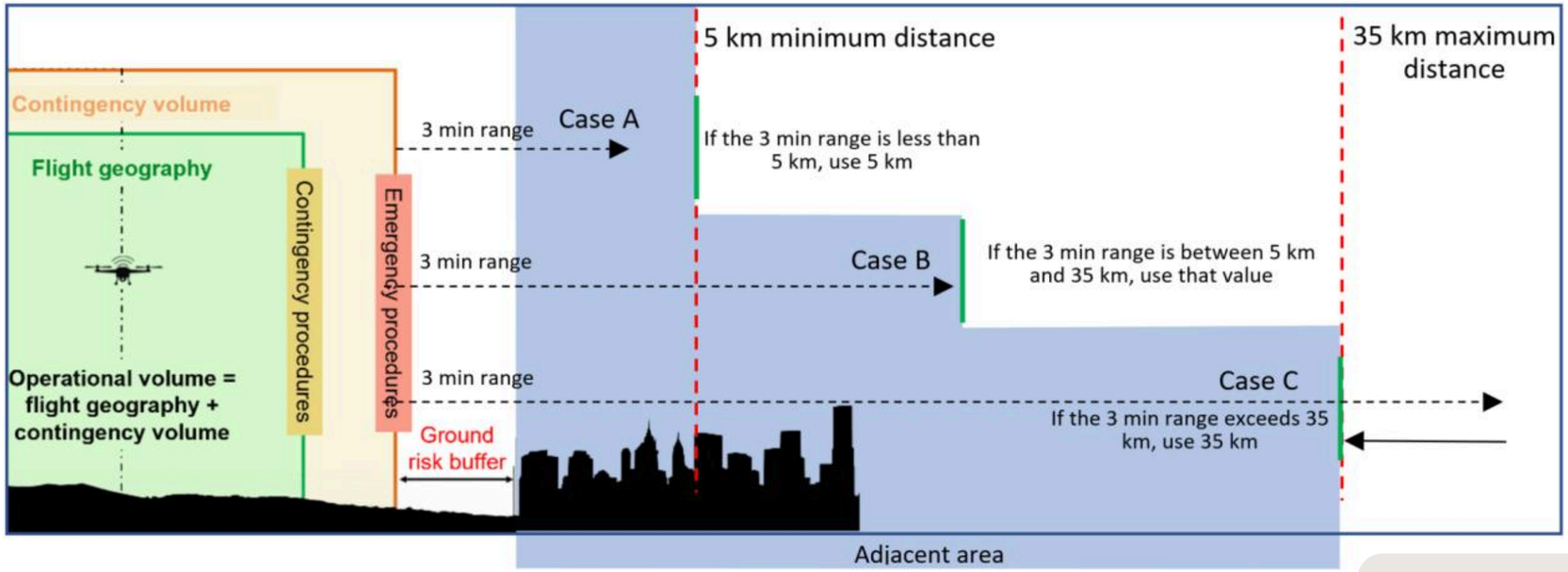
# 8- Containment Requirement

The containment requirements ensure that the **target level of safety** can be met for both ground and air risk in the **adjacent area**.



# 8- Containment Requirement

The containment requirements ensure that the **target level of safety** can be met for both ground and air risk in the **adjacent area**.



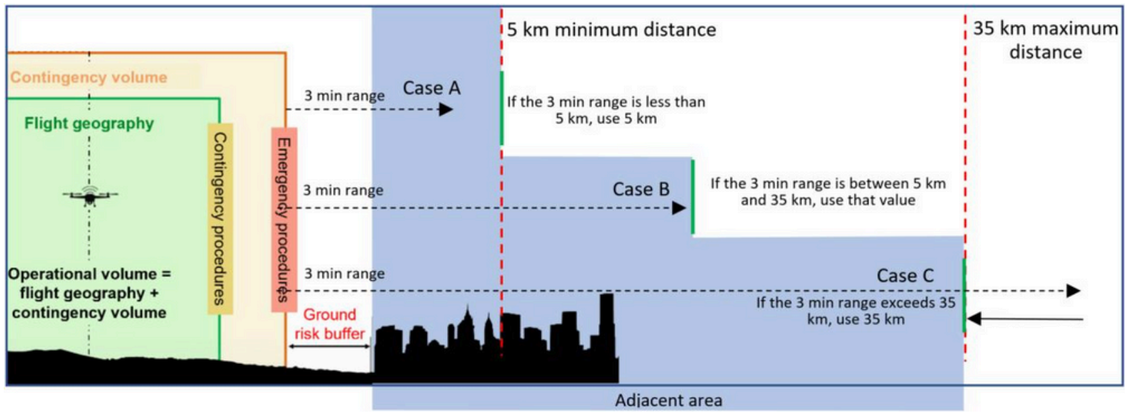

**Exercise: (5 minutes)**
How far should we set our adjacent area?

| | |
|---|---|
| Max Horizontal Speed (at sea level, no wind) | 21 m/s |

*dji.com

Join at menti.com
use code: 24377474

# 8- Containment Requirement



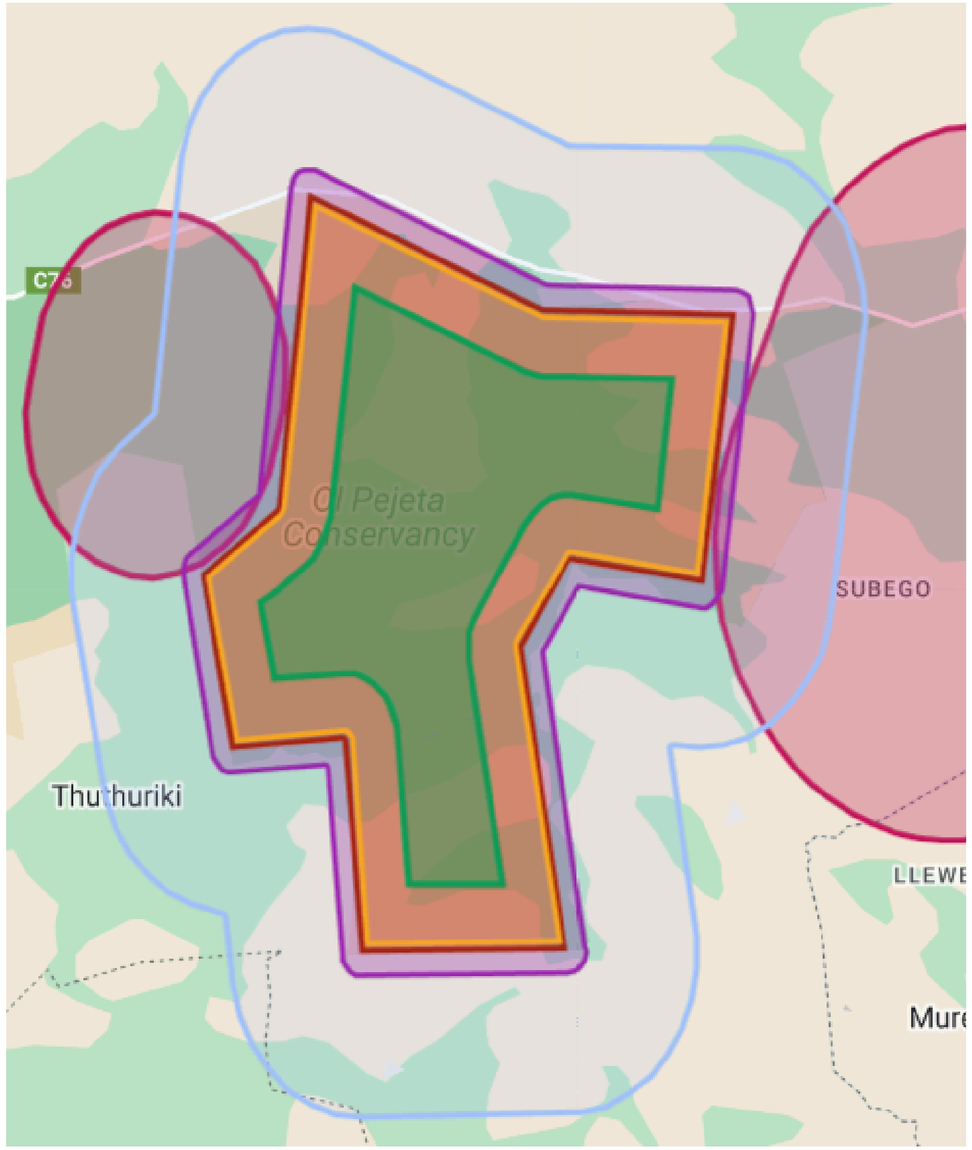

Aircraft

| | |
|---|---|
| Takeoff Weight | Mavic 3 Pro: 958 g<br>Mavic 3 Pro Cine: 963 g |
| Max Descent Speed | 6 m/s |
| Max Horizontal Speed (at sea level, no wind) | 21 m/s |

*dji.com

3 min range = 3m * 60s * 21m/s = 3,780m

3.78Km < 5Km --> **Case A: Use 5Km**



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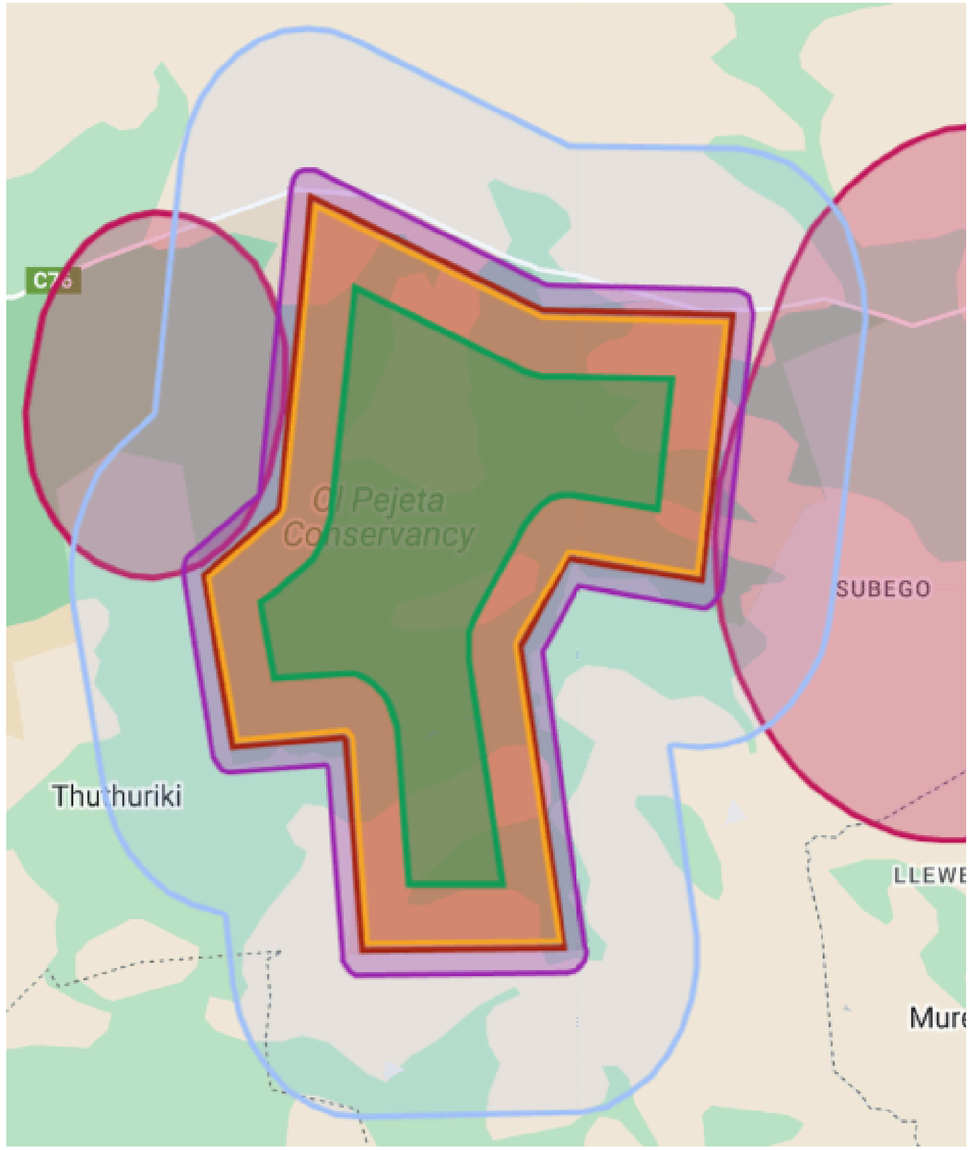
# 8- Containment Requirement

| 1 m UA (< 25 m/s)<br>Sheltering assumed applicable for the UA in the adjacent area | | | |
|---|---|---|---|
| Average Population density allowed | No Upper Limit | | < 50,000 ppl/km² |
| Outdoor Assemblies allowed within 1km of the OPS volume | > 400k | Assemblies of 40k to 400k | Assemblies < 40k |
| SAIL | | | |
| I & II | High | Medium | Low |
| III | Medium | Low | Low |
| IV - VI | Low | Low | Low |
| V-VI | Low | Low | Low |



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# 8- Containment Requirement

| Containment | LEVEL of INTEGRITY | | |
|---|---|---|---|
| | Low | Medium | High[2] |
| Criterion #1<br>(Operational Volume Containment) | (Qualitative) No **probable**[1] single failure of the UAS or any external system supporting the operation shall lead to operation outside of the operation volume.<br>OR<br>(Quantitative) The probability of the failure condition "UA leaving the operational volume" shall be less than 10-3/Flight Hour (FH). | | (Qualitative) No **remote**[3] single failure of the UAS or any external system supporting the operation shall lead to operation outside of the operational volume.<br>OR<br>(Quantitative) The probability of the failure condition "UA leaving the operational volume" shall be less than 10-4/FH. |
| *Comments* | *[1] Failures anticipated to occur one or more times during the entire operational life of an item.* | | *[2] This may be achieved by a tether that prevents the drone from exiting the operational volume.*<br>*[3] Failures unlikely to occur with each UA during its operational life but that may occur several times when considering the total operational life of a number of UA of this type.* |

SDU

# 9- OSOs
## (Operational Safety Objectives)

**Tip:**
There are only **17** OSOs in total!

| OSO ID | Operational Safety Objective | SAIL | | | | | | Dependencies (Crit. references as per Annex E) | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | I | II | III | IV | V | VI | Operator | Training org | Designer |
| OSO#01 | Ensure the Operator is competent and/or proven | NR | L | M | H | H | H | x | | |
| OSO#02 | UAS manufactured by competent and/or proven entity | NR | NR | L | M | H | H | | | x |
| OSO#03 | UAS maintained by competent and/or proven entity | L | L | M | M | H | H | Crit. 1<br>Crit. 2 | | Crit. 1 |
| OSO#04 | UAS components essential to safe operations are designed to an Airworthiness Design Standard (ADS) | NR | NR | NR | L | M | H | | | x |
| OSO#05 | UAS is designed considering system safety and reliability | NR | NR[(c)] | L | M | H | H | | | x |
| OSO#06 | C3 link characteristics are appropriate for the operation | NR | L | L | M | H | H | x | | x |
| OSO#07 | Conformity check of the UAS configuration | L | L | M | M | H | H | Crit. 1<br>Crit. 2 | | Crit. 1 |
| OSO#08 | Operational procedures are defined, validated and adhered to | L | M | H | H | H | H | x | | Crit. 1 |
| OSO#09 | Remote crew trained and current | L | L | M | M | H | H | x | x | |
| OSO#13 | External services supporting UAS operations are adequate to the operation | L | L | M | H | H | H | x | | |
| OSO#16 | Multi crew coordination | L | L | M | M | H | H | Crit. 1<br>Crit. 3 | Crit. 2 | |
| OSO#17 | Remote crew is fit to operate | L | L | M | M | H | H | x | | |
| OSO#18 | Automatic protection of the flight envelope from human errors | NR | NR | L | M | H | H | | | x |
| OSO#19 | Safe recovery from human error | NR | NR | L | M | M | H | | | x |
| OSO#20 | A Human Factors evaluation has been performed and the HMI found appropriate for the mission | NR | L | L | M | M | H | x | | x |
| OSO#23 | Environmental conditions for safe operations defined, measurable and adhered to | L | L | M | M | H | H | x | | x |
| OSO#24 | UAS designed and qualified for adverse environmental conditions | NR | NR | M | H | H | H | | | x |

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# 9- OSOs
## (Operational Safety Objectives)

| TECHNICAL ISSUE WITH THE UAS | | LEVEL of INTEGRITY | | |
|---|---|---|---|---|
| | | **Low (SAIL II)** | **Medium (SAIL III)** | **High (SAIL IV to VI)** |
| **OSO #01**<br>**Ensure the Operator is competent and/or proven** | Criterion | The applicant is knowledgeable of the UAS[1] being used and as a minimum has the following relevant operational procedures[2]:<br>• checklists,<br>• maintenance,<br>• training,<br>• responsibilities, and associated duties. | Same as Low. In addition, the applicant has an organization appropriate[3] for the intended operation, with at least the following in place:<br>• a method to continuously evaluate whether the operator is operating according to the terms of the operational authorization and check whether the mitigations proposed as part of the operational authorization are still appropriate;<br>• occurrence analysis procedures and reporting to the designer in case of design-related in-service events. | The applicant has a safety management system in place in line with ICAO Annex 19 principles. |
| | *Comments* | *[1] Including monitoring of any related airworthiness directives or recommendations issued by National Aviation Authorities and designer recommendations (Service Bulletin, Service Information Letter, etc.)*<br>*[2] Operational procedures (checklists, maintenance, training, etc.) can be justified in the context of other applicable OSO.* | *[3] For the purpose of this assessment appropriate should be interpreted as commensurate/proportionate with the size of the organization and the complexity of the operation.* | *N/A* |

| TECHNICAL ISSUE WITH THE UAS | | LEVEL of ASSURANCE | | |
|---|---|---|---|---|
| | | **Low (SAIL II)** | **Medium (SAIL III)** | **High (SAIL IV to VI)** |
| **OSO #01**<br>**Ensure the Operator is competent and/or proven** | Criterion | The elements delineated in the level of integrity are available. | Prior to the first operation, a competent third party performs an audit of the organization. | The applicant holds an Organizational Operating Certificate or is/has a recognized flight test organization.<br>In addition, a competent third party recurrently verifies the Operator's competence. |
| | *Comments* | *N/A* | *Audits should be adapted to the size and scope of the organization and focus on items that can be connected to the applicable OSOs and their robustness depending on the SAIL of the operation. Audits can take the form of desk reviews, if deemed appropriate.* | |

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# 10- Comprehensive Safety Portfolio (CSP)

01 Detailed operational description (Step #1)

02 Safety claims

03 Derived requirements

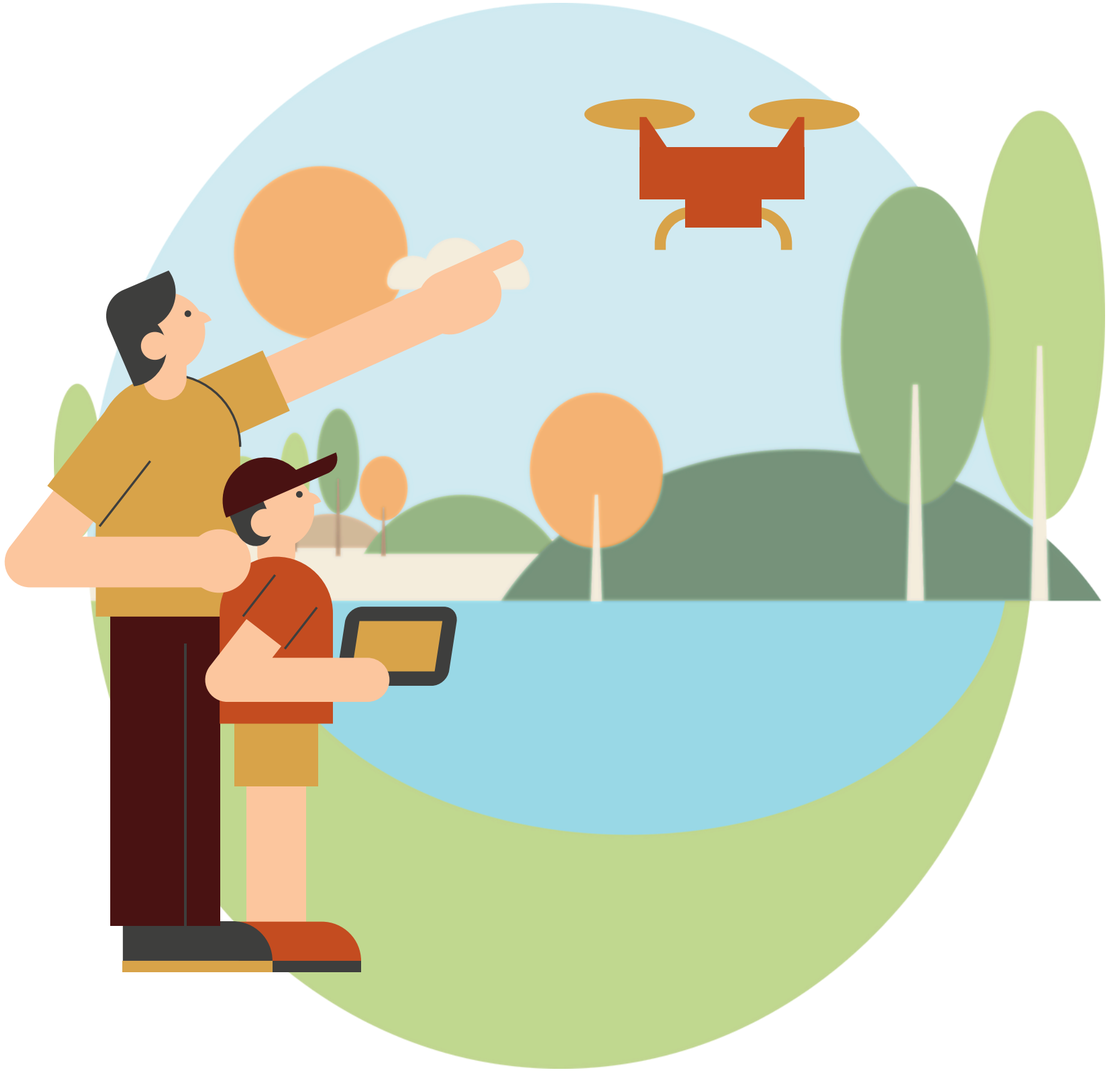
04 Compliance evidence

05 Justified safety case

06 Compliance matrix

# Any questions?

# Now you are ready to fly safely!



SDU

# well ... almost

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**But first,**
let's take a
break...

# Operational Procedures

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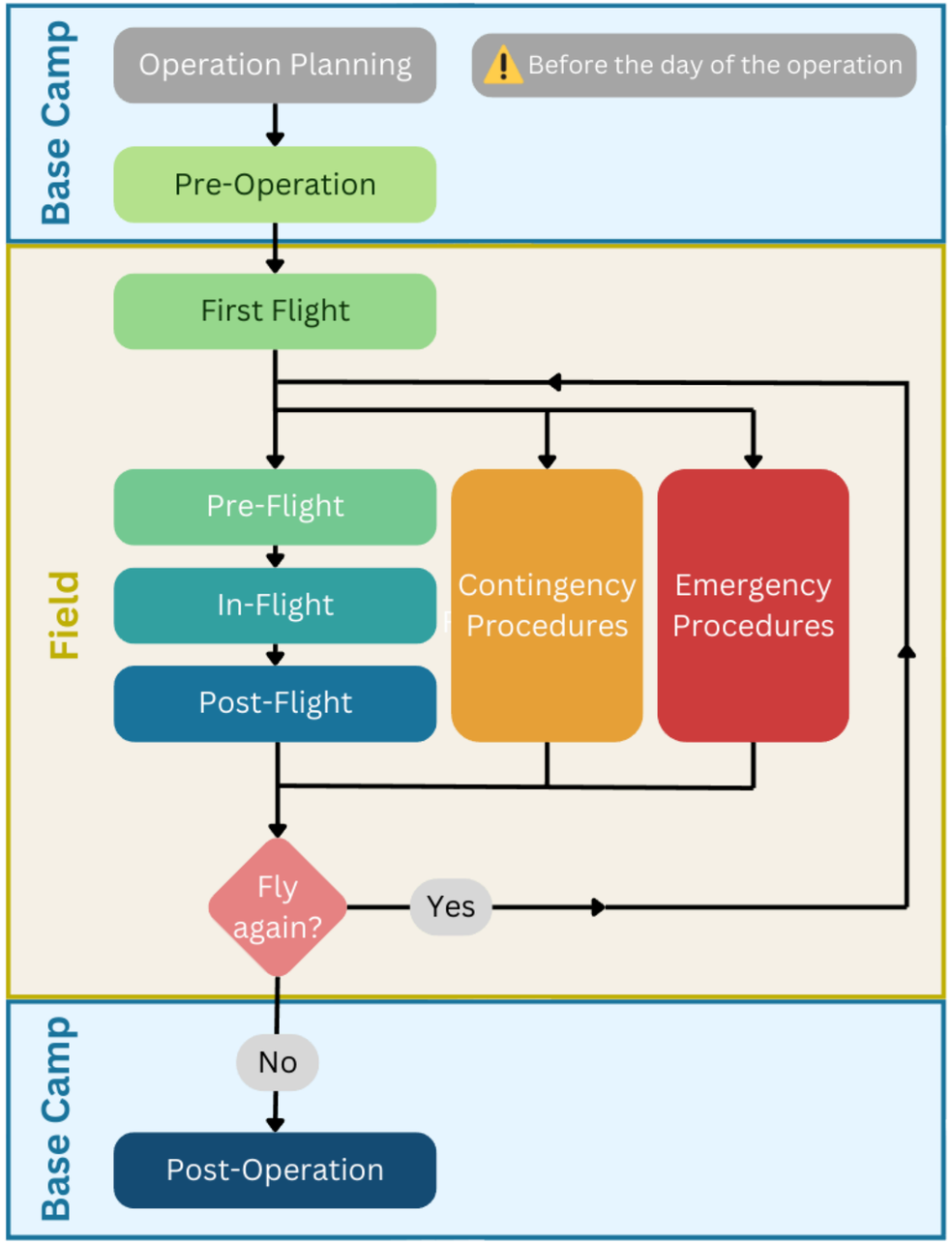
# Procedures Workflow

**Activity: (15 minutes)**
Can you design your own operational procedures to operate in Kenya?



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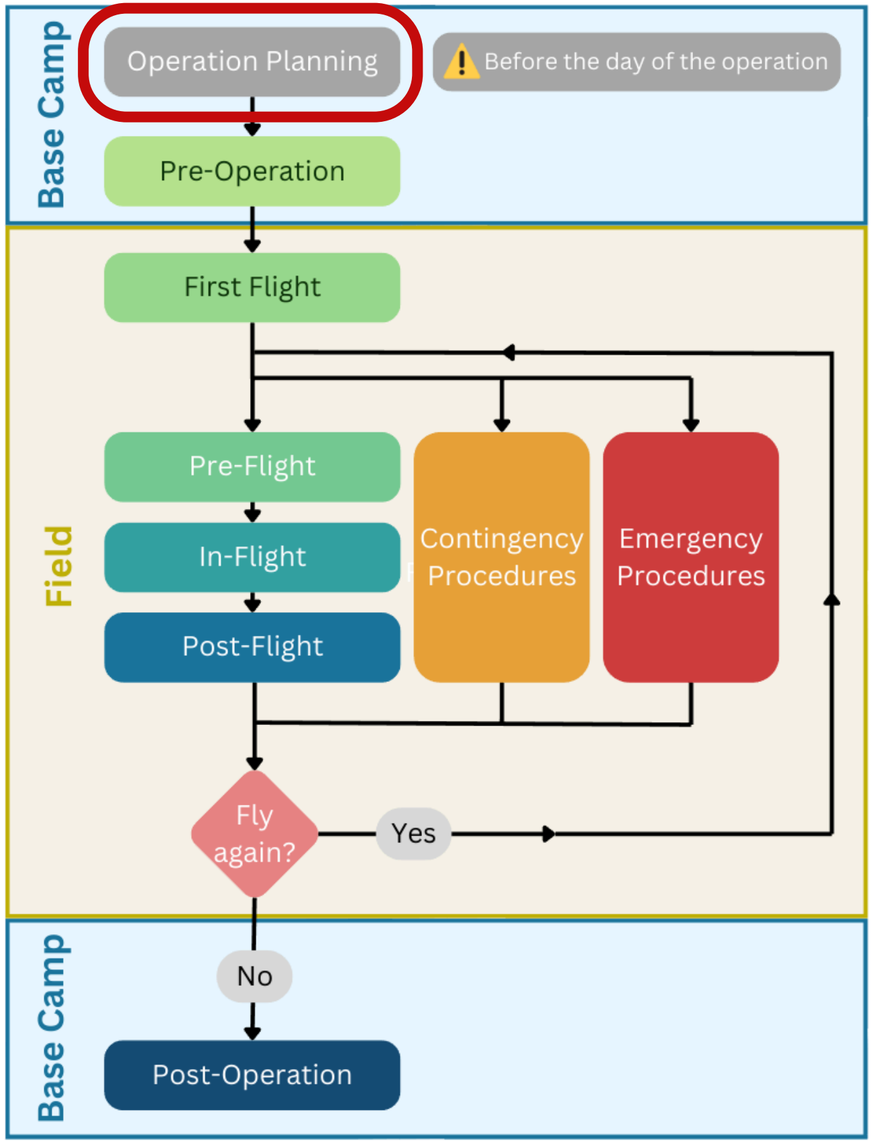
# Operation planning

- **Operational environment**
  - No-fly zones
  - Weather
- **Crew**
  - Pilot with valid license
  - Book assistant
- **Regulations**
  - Check operational limits
- **Equipment**
  - Inspect
  - Pack



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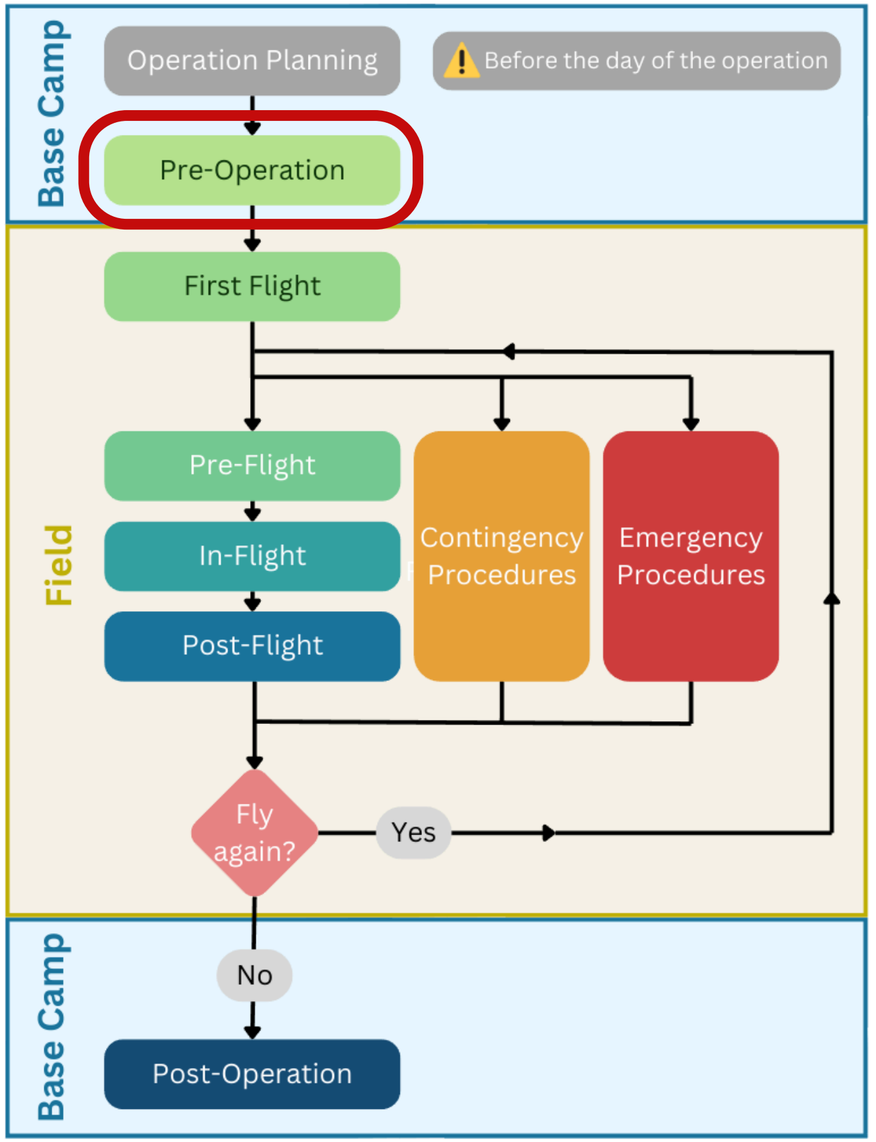
# Pre-Operation

- **Inform 3rd parties**
  - ATC
  - Ol Pejeta radio room
- **Review Weather**
- **Assign Roles**
- **Packing checklist**



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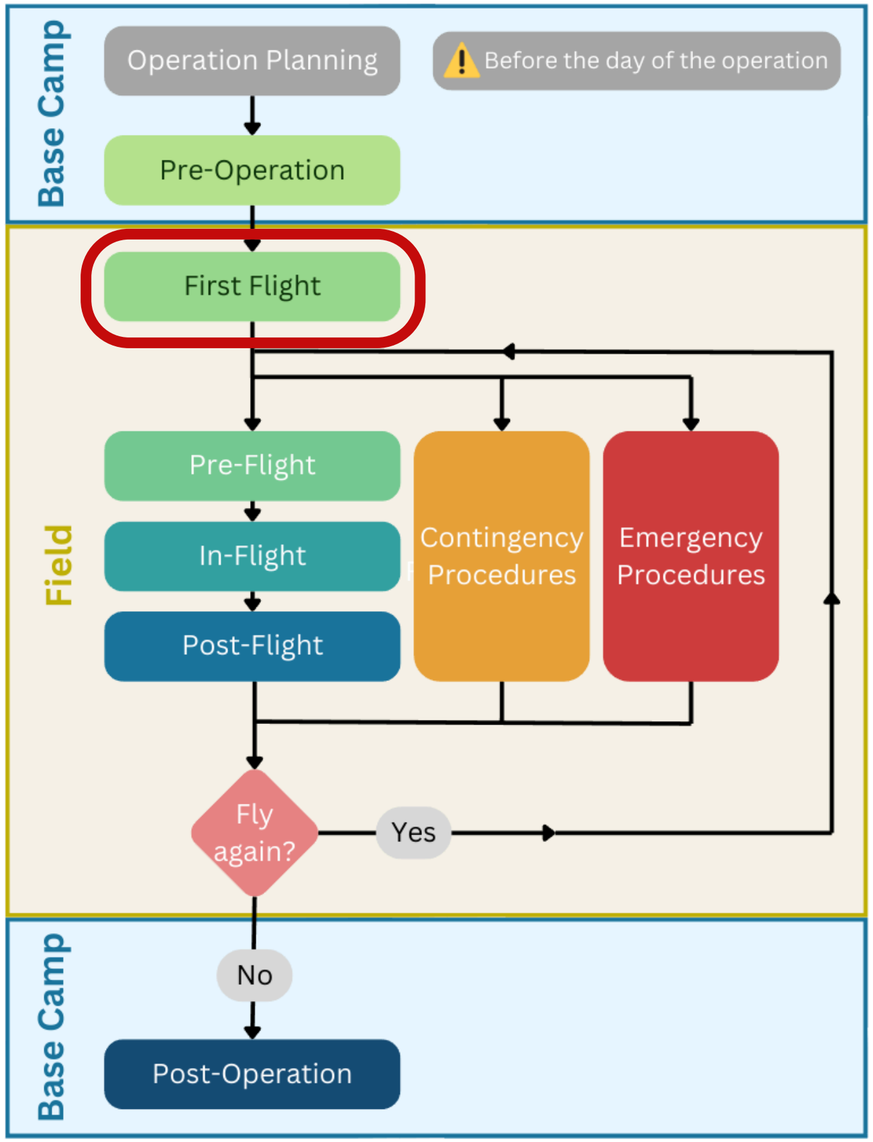
# First Flight

- **Operational Environment**
  - No-Fly zones
  - Topography (ground obstacles)
  - Identify north direction
- **Equipment**
  - UAS inspection
  - Failsafes
- **Safety briefing**
  - Role allocation (pilot, assistant, ground obs., air obs.)
  - Assign evacuation seat
  - Review contingency and emergency procedures
  - IMSAFE (Illness, Medication, Stress, Alcohol, Fatigue, Emotion)



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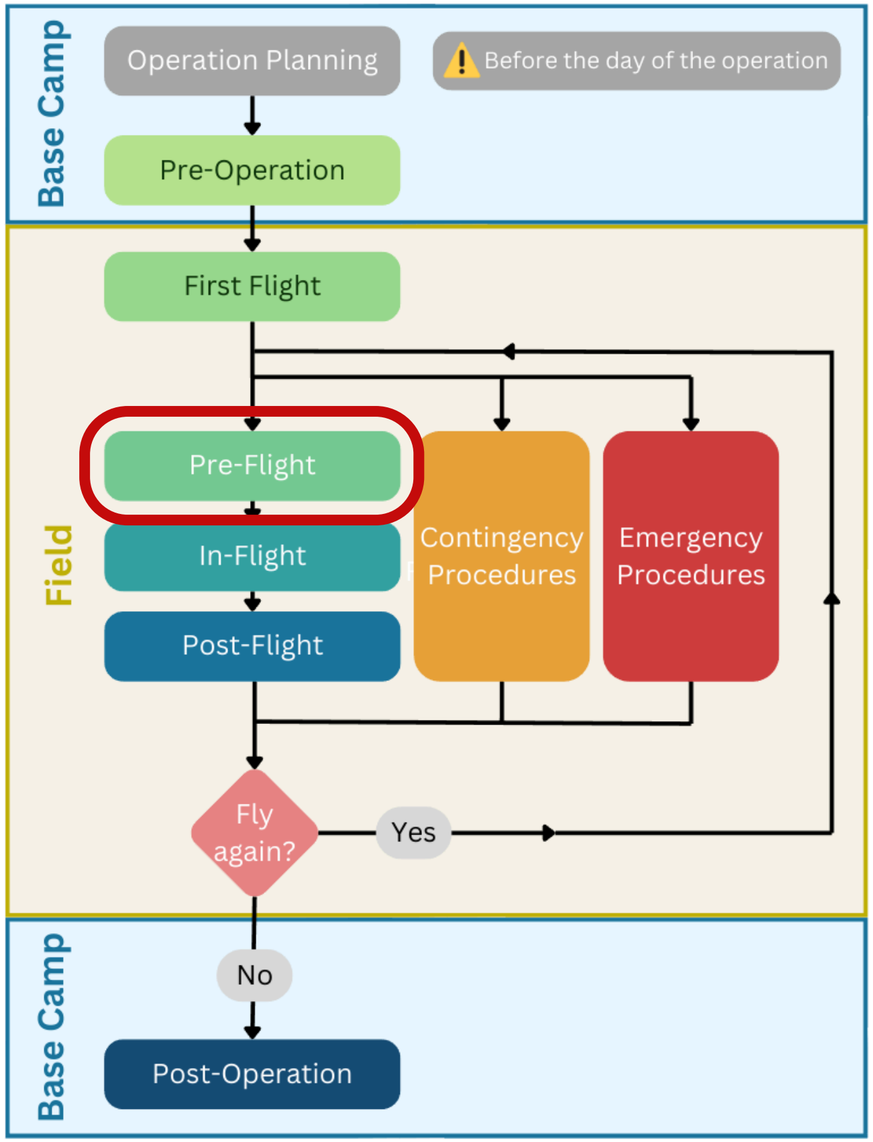
# Pre-Flight

- **Equipment**
  - New battery & SD card
  - Check status (GPS fix, RSSI)
- **Check surroundings (weather)**
- **Confirm plan & advise ground team**



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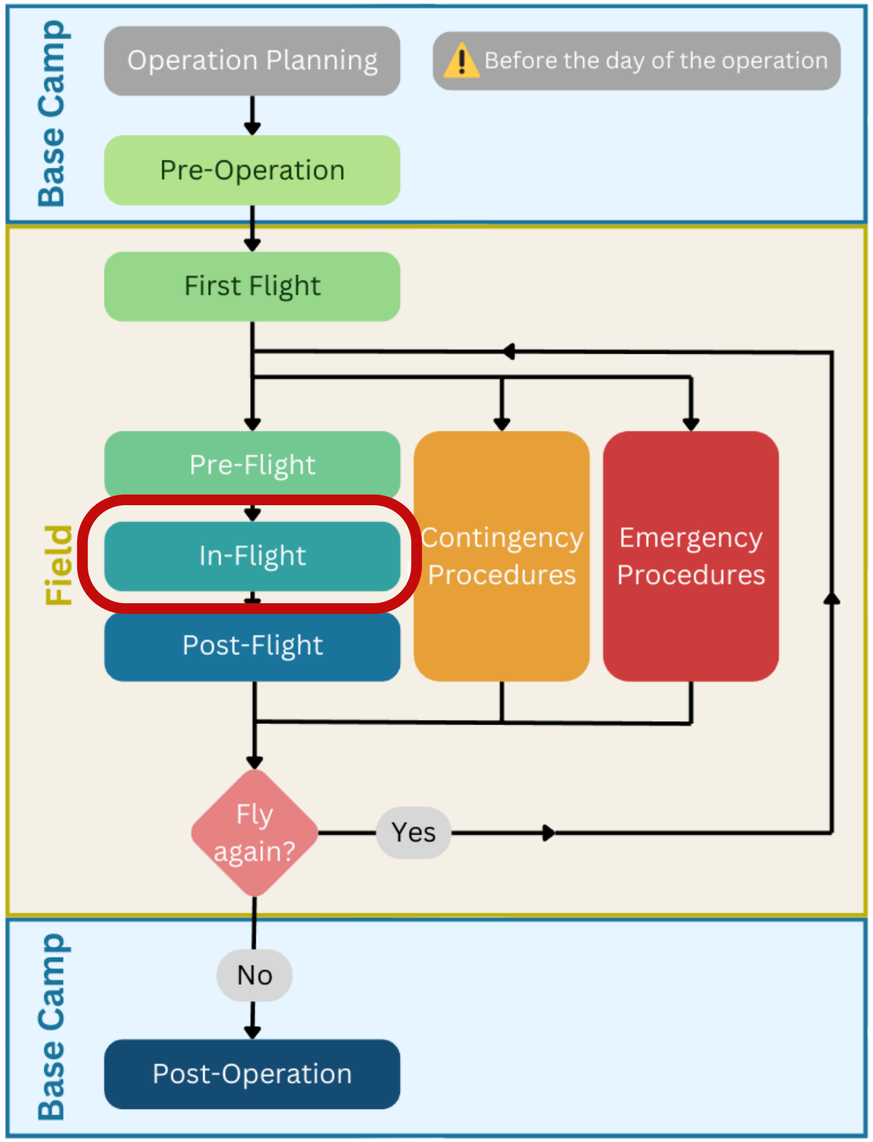
# In-Flight

- **UAS performance**
- **UAS status**
  - Battery, GPS, RSSI, Altitude, Speed, Position
- **Check weather**
- **Check surroundings (airspace, ground)**



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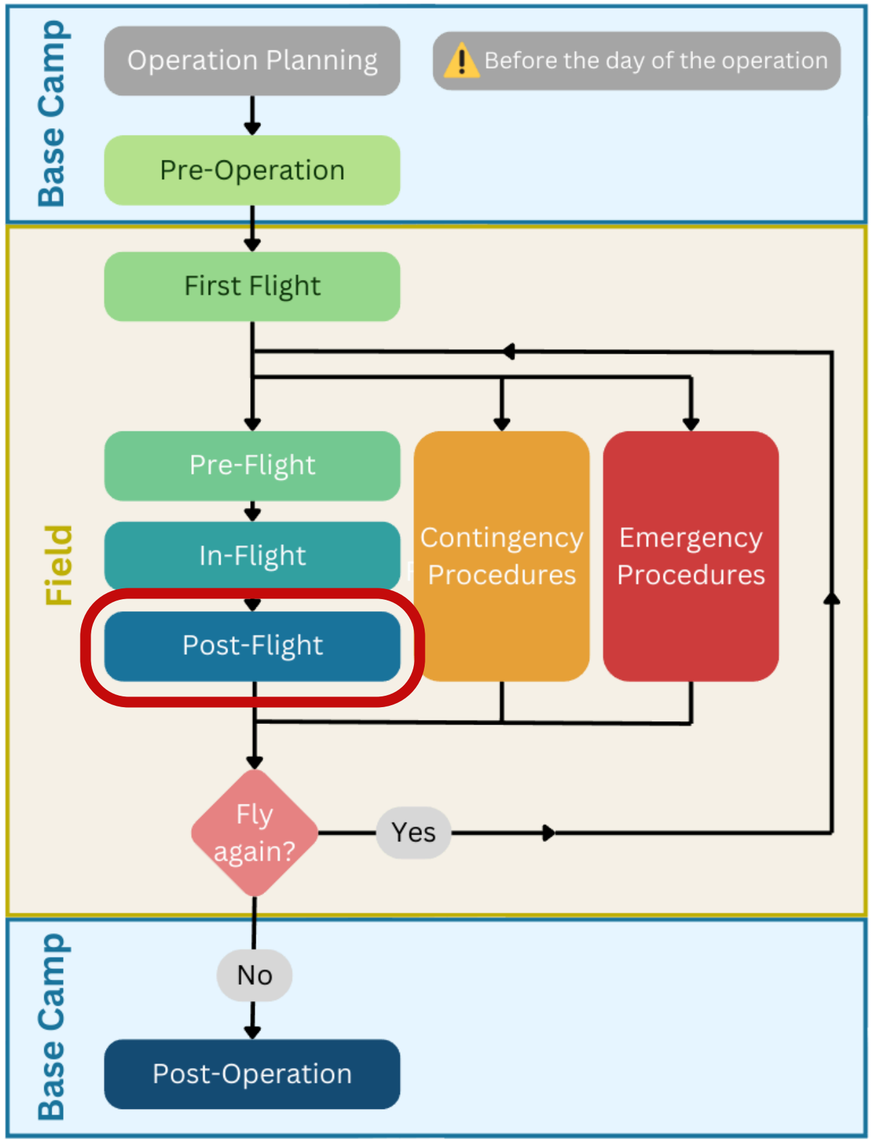
# Post-Flight

- Stop recording
- Remove batteries
- Visual UAS inspection



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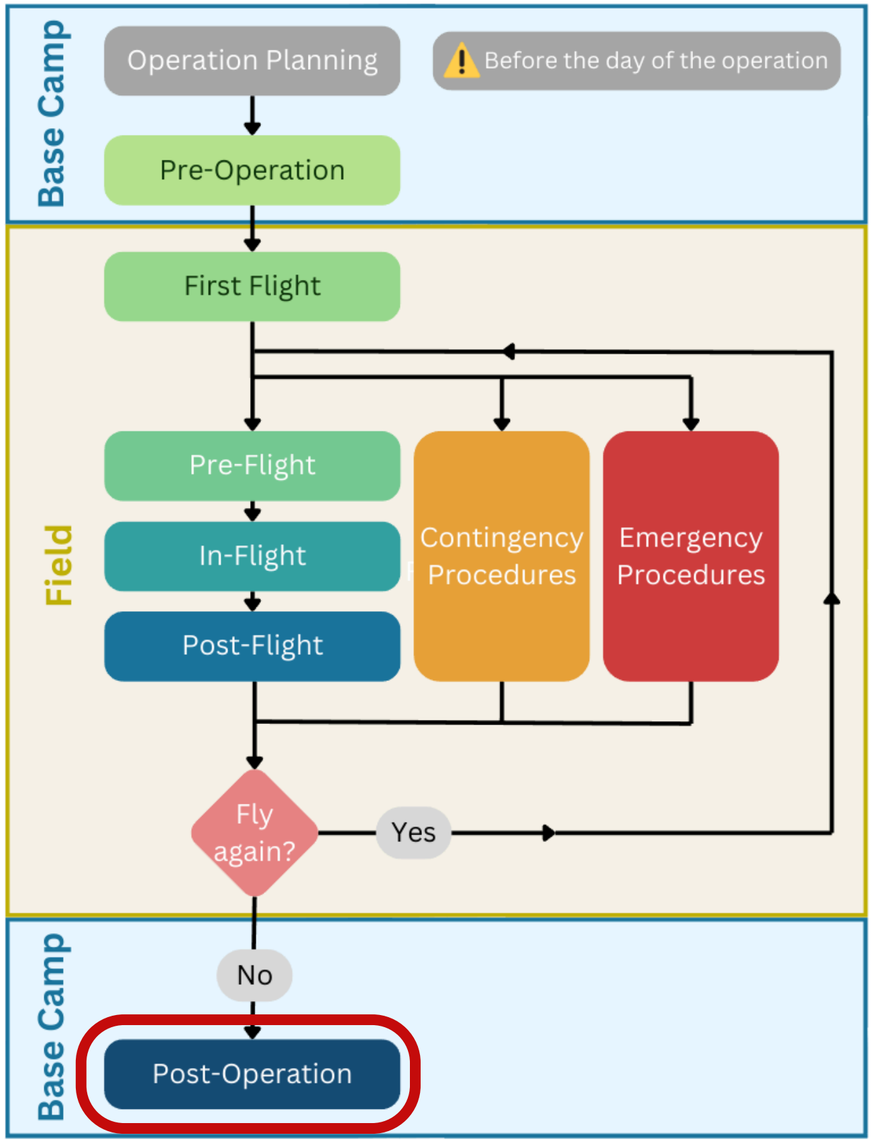
# Post-Operation

- **Inform 3rd parties**
  - ATC
  - Ol Pejeta
- **Backup Data**
- **Recharge batteries**
- **Fill flight logs**



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# Contingency Procedures

**C01 - Low battery/high drain**

- Sufficient battery to RTH?
  - **YES:** RTH
  - **NO:** Slow landing
- Drone close to home?
  - **YES:** Manual landing
  - **NO:** RTH

**C02 - High-wind carries UAS**

- Exited the flight geometry?
  - **YES:** Follow Emergency **E03**
- Able to RTH?
  - **YES:** RTH
  - **NO:** Slow landing

**C03 - Aircraft approaching**

- Lower drone to a safe altitude (below 30m AGL)

**C04 - Wildlife approaching**

- RTH
- Get in the car
- Control drone, move away

**C05 - UAV warnings or errors**

- Able to RTH?
  - **YES:** RTH
  - **NO:** Slow landing

**C06 - C2 link warnings or errors**

- Orient antenna towards UAS
- RTH
- Consider driving towards UAS

**C07 - Poor Weather (Rain, Wind, Visibility)**

- RTH

**C08 - Crew feeling unwell**

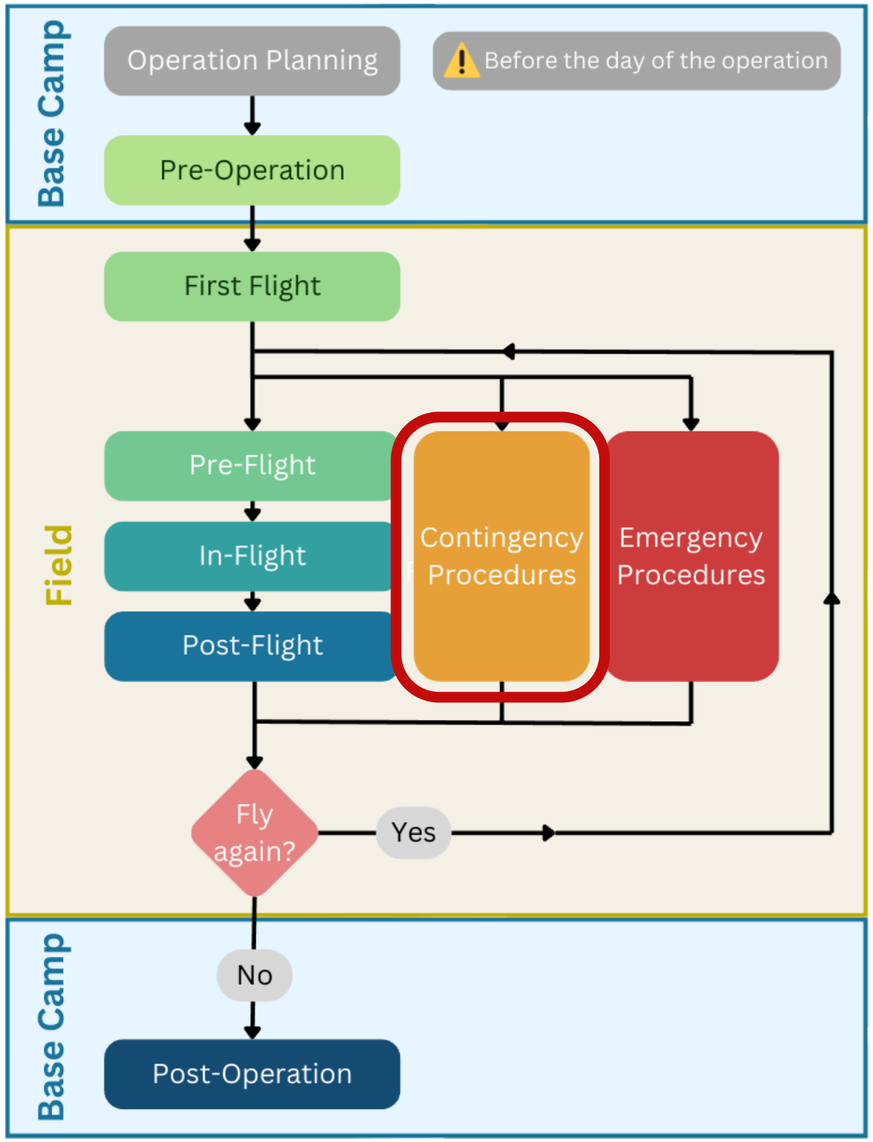
- RTH

**C09 - 3rd party approaching**

- Assistant communicates, and avoids distracting the RPIC.

**C10 - Flight geography breached**

- UAV under control?
  - **YES:** RTH
  - **NO:** Follow Emergency **E04**



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# Emergency Procedures

### E01 - Aircraft dangerously close

- AP shouts “Kill Kill Kill”
- Activate kill switch

### E02 - Threatening Wildlife

- Get in the car ASAP!
- Manually RTH

### E03 - Operational Vol. Breached

- Activate kill switch
- Communicate with ATC (+254-XXX XXX XXX):
  - Location, bearing, time
  - Remaining flight time, drone size / type, speed

### E04 - Loss of control/ fly-away

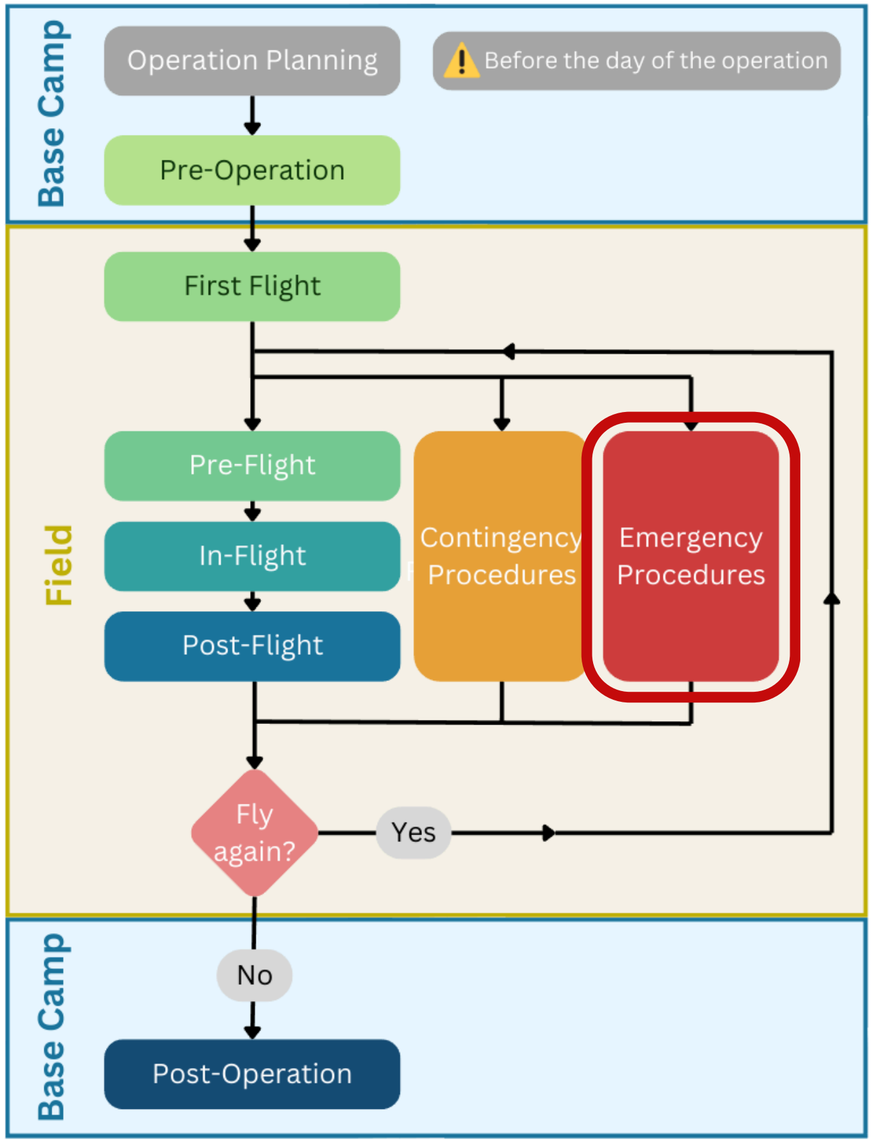
- Try switching flight modes
- Try to regain control, or activate kill switch
- Communicate with ATC (+254-XXX XXX XXX):
  - Location, bearing, time
  - Remaining flight time, drone size / type, speed

### E05 - Bush fire

- Call radio room: +254-XXX XXX XXX

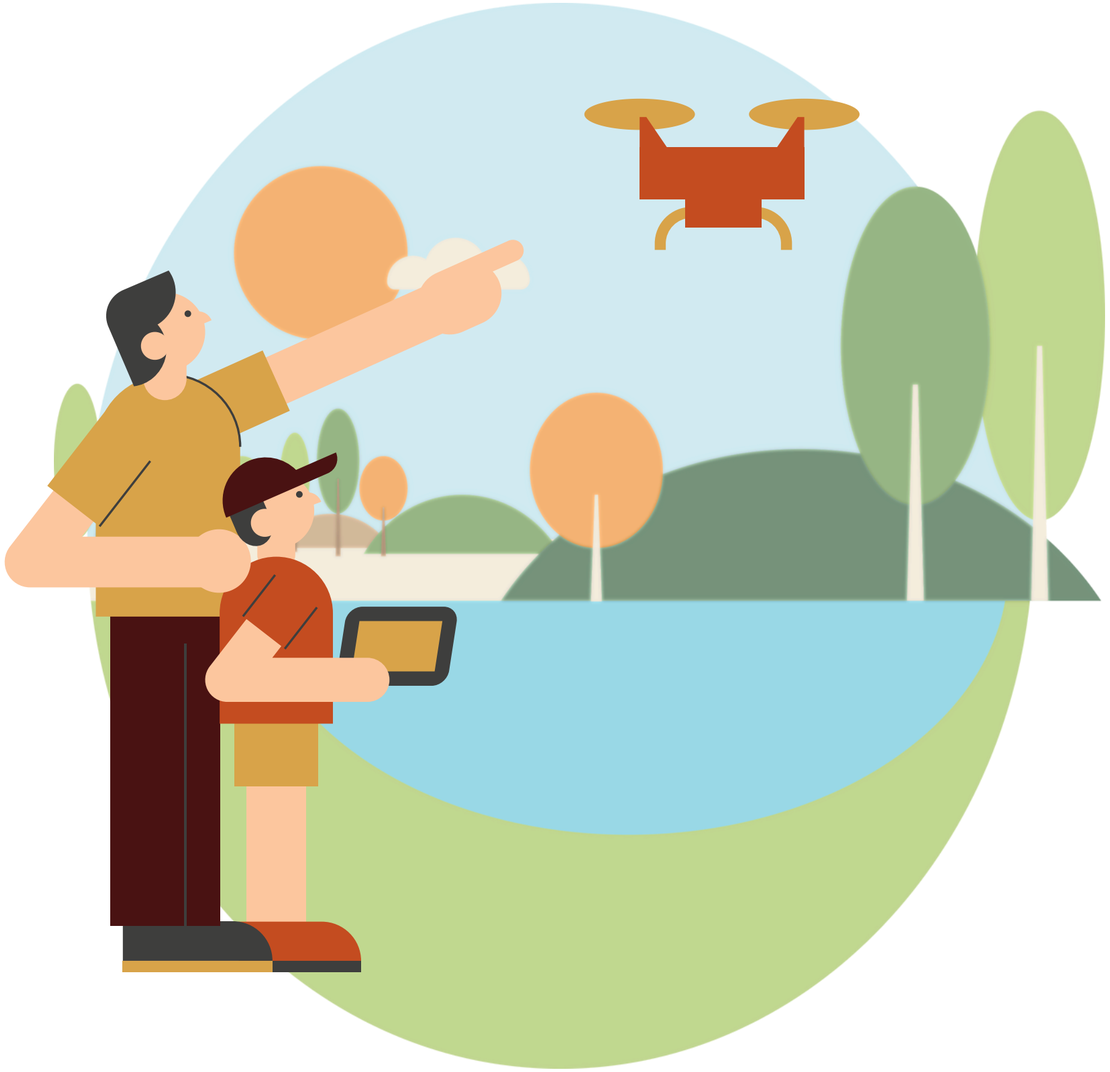
### E06 - Crew unfit for flight

- RTH
- Provide first aid
- Call radio room: +254-XXX XXX XXX



# That's it!

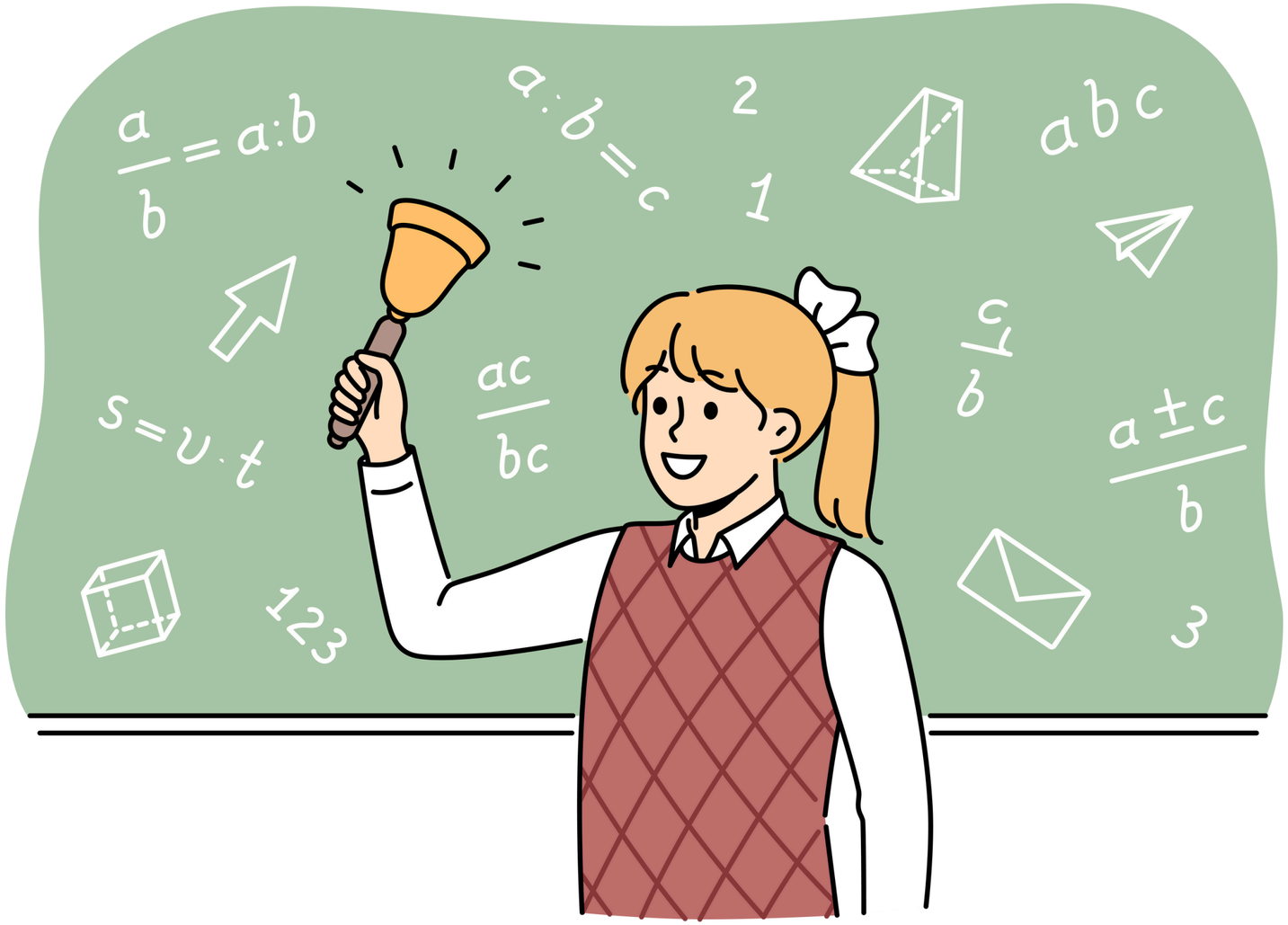
Now you are **officially** ready to fly safely!



# Any Questions?

SDU

# Time for some practice!



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# Before we start, please download the following:

Google earth Pro: https://www.google.com/earth/about/versions/#earth-pro

SORA documents: http://jarus-rpas.org/publications/

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# Exercise:

## Mission:

Ditlevsdal Bison Farm want to fly an EbeeX drone **BVLOS** to monitor their bisons.

Help them complete their **SORA** assessment by filling **this document** which goes through the 10 steps of SORA.

Try to **minimise the final SAIL score** to make the operation easier to perform.

**Tip:** *try to maximise the operational geography, not necessarily the whole farm.*


Ditlevsdal Bison Farm

Ebee X Specs

SORA Assessment

SDU

# EbeeX Tech Specs

RESULTS | **HARDWARE** | SOFTWARE | OPERATION

| | |
|---|---|
| Wingspan | 116 cm / 45.7 in |
| Weight (incl. camera & battery) | 1.3 kg - 1.6 kg / 2.2 - 3.6 lbs, depending on camera and battery |
| Electric motor | Low-noise, brushless |
| Radio link range [3] | 3 km nominal (up to 8 km) / 1.9 mi (up to 5 mi) |
| Detachable wings | Yes |
| Cameras (supplied) | None |
| Cameras (optional) | S.O.D.A. 3D, Aeria X, S.O.D.A., Corridor, Duet T, Duet M, Parrot Sequoia+ |
| GNSS grade | Survey |

RESULTS | HARDWARE | SOFTWARE | **OPERATION**

| | |
|---|---|
| Cruise speed | 11-30 m/s (40-110 km/h or 25-68 mph) |
| Wind resistance | Up to 12.8 m/s (46 km/h or 28.6 mph) |
| Maximum flight time | Up to 90 minutes, depending on camera and battery |
| Endurance extension available (fly more than 60 minutes) | Yes |
| Nominal coverage at 120 m (400 ft) | 220 ha / ~550 ac, with S.O.D.A. / no endurance extension |
| Maximum coverage at 120 m (single flight) | 500 ha / ~1,250 ac, with S.O.D.A. 3D / with endurance extension |
| Max. flight range | Standard: 37 km / ~23 mi. Endurance: 55 km / ~34 mi |
| Post-processed kinematic (PPK) | Yes |
| Real-Time Kinematic / Virtual Base Station | Yes |
| Real-Time Kinematic / Base Station Unknown point | Yes |
| Real-Time Kinematic / Base Station Known point | Yes |
| Ground control points (GCPs) | Not required |
| Oblique imagery | Yes, with S.O.D.A. 3D |
| Hand launch | Yes |
| Landing | Automatic linear landing (5 m / 16.4 ft accuracy in 20° angle cone) |

SDU

# Stay safe, and feel free to reach out!

LinkedIn


## Guy Maalouf

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**Safe UAS BVLOS Operations**
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