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Guidance on Defining Flight Geography, Contingency Volume, and Ground Risk Buffer

1. Change Record

Date	Issue	Revision Description
31.01.2023	1	Initial publication.
05.04.2024	2	Change to formatting of formula

2. References

- Regulation (EU) 2019/947¹
- LBA Guidance on Defining Flight Geography, Contingency Volume und Ground Risk Buffer²

3. Purpose

Operational authorisation applications in the specific category, according to Regulation (EU) 2019/947, require the definition of an operational volume (flight geography and contingency volume), and a ground risk buffer. The purpose of this document is to provide guidance on accurately calculating, defining, and presenting these volumes and areas.

¹

https://www.easa.europa.eu/sites/default/files/dfu/Easy_Access_Rules_for_the_Basic_Regulation.pdf

² https://www.lba.de/SharedDocs/Downloads/DE/B/B5_UAS/Leitfaden_FG_CV_GRB_LUC_eng.pdf

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5. Glossary

Abbreviation	Meaning
A	Acceleration
ALOS	Attitude Line Of Sight
AMC	Acceptable Means of Compliance
baro	barometric
BVLOS	Beyond Visual Line of Sight
C_L	Lift coefficient
CD	Characteristic Dimension
CM	Contingency Maneuver
CV	Contingency Volume
C_D	Drag coefficient
DLOS	Detection Line of Sight
IR	Implementing Regulation
FG	Flight Geography
G	Gravitational acceleration = 9.81 m/s^2
GM	Guidance Material
GPS	Global Positioning System
GRB	Ground Risk Buffer
GV	Ground Visibility
H	Height
K	Cartography error
KML file	Keyhole Markup Language file extension
M	UAS mass
Pos	Position
RZ	Reaction time
S	Distance
T	time
TO/LD	Take-off/Landing location
UAS	Unmanned Aircraft System
V_0	Maximum operational speed.
$V_{\text{stall_clean}}$	Stall speed in clean configuration
VLOS	Visual Line of Sight
Z	Vertical direction
E	Glide angle
Φ	Roll angle
Θ	Pitch angle
Ψ	Yaw angle

6. Definitions

For the purposes of this guidance document, the definitions in Regulation (EU) 2019/947 apply.

The following definitions also apply:

Contingency Volume 'contingency volume' means the volume of airspace outside the flight geography where contingency procedures described in Reg (EU) 2019/947 point (6)(d) of Appendix 5 to the Annex are applied.

Extended VLOS (EVLOS) means a UAS operation whereby the remote pilot maintains uninterrupted situational awareness of the airspace in which the UAS operation is being conducted via visual airspace surveillance through one or more human Visual Observers (VOs), possibly aided by technological means. The remote pilot has direct control of the UAS at all times.

Flight Geography means the volume(s) of airspace defined spatially and temporally in which the UAS operator plans to conduct the operation under normal procedures described in Reg (EU) 2019/947 point (6)(c) of Appendix 5 to the Annex.

Ground Risk Buffer is an area over the surface of the earth, which surrounds the operational volume and that is specified in order to minimise the risk to third parties on the surface in the event of the unmanned aircraft leaving the operational volume.

Operational volume is the combination of the flight geography and the contingency volume.

Populated area should be understood as 'congested area', as defined in Regulation (EU) No 965/2012 (the 'Air Operations Regulation'): 'in relation to a city, town or settlement, any area which is substantially used for residential, commercial or recreational purposes'.

Adjacent Volume (also known as adjacent airspace) is the airspace that borders the contingency volume laterally and vertically from the outside. It lies vertically above the adjacent area on the ground. The UA would fly into this airspace if a "fly away" occurs, i.e. the UA cannot be terminated.

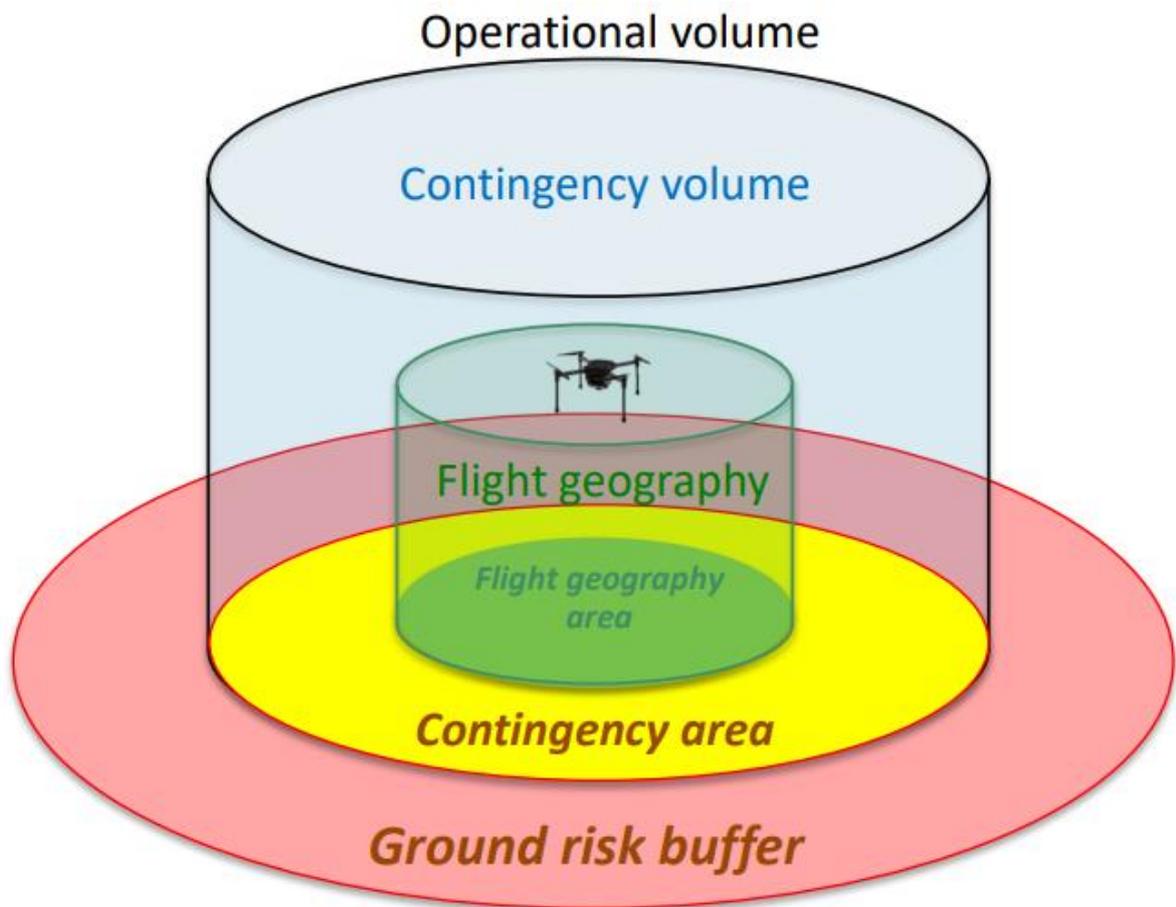


Figure 1 Flight Geography, Contingency Volume and Ground Risk Buffer

7. Example computation for contingency volume and ground risk buffer

This section provides examples for calculation of the minimum dimensions of the contingency volume and the ground risk buffer. All the following calculations are to be understood as sample calculations only. You can use these computations as an aid for your specific operations in your operations manual. If you submit deviating computations, please ensure that there is sufficient justification and documentation.

7.1. Calculation Definitions

V_0 , m/s	Maximum operational speed that is flown. Note: A speed below 3m/s for multicopter and $1.25 * V_{Stall_clean}$ for fixed-wing aircraft is not considered realistic.
CD, m	The "Maximum UAS Characteristic Dimension" or "CD" is the maximum possible length of a straight line that can be spanned from one point on the UAS geometry to another point. Propellers and rotors are part of the geometry, whereby their most unfavorable position is considered. Note: Commonly used values for: <ul style="list-style-type: none"> - Fixed-wing aircraft are wing-span or fuselage length - Multicopter is the diagonal distance from rotor tip to rotor tip, with the rotors in unfavorable position.
V_{Wind} , m/s	Maximum wind speed specified in the operations manual up to which the UAS may be operated.
FG	Flight Geography
CV	Contingency Volume
GRB	Ground Risk Buffer

7.2. Computation Flight Geography

7.2.1. Option 1

The size of the flight geography usually results from the operator's desired flight volume.

7.2.2. Option 2 (advanced)

Determination of the maximum flight geography available, when operating over a controlled ground area. For this purpose, the ground projection of flight geography, contingency volume and the ground risk buffer must be completely contained in the controlled ground area. A calculation from the outside inwards is recommended.

The outer limit of the ground risk buffer corresponds to the topology of the controlled ground area. First, the lateral extent (width) of the ground risk buffer (see Section 7.4) is subtracted from the topology of the controlled ground area. This gives the boundary between the contingency volume and the ground risk buffer. In the second step, the lateral extent (width) of the contingency volume (see Section 7.3) is then subtracted from this limit. This results in the maximum possible expansion of the flight geography as the remaining area (see the example in Section 10.3).

Notes on the realistic definition of particularly small flight geographies:

FG lateral	
Width Flight Geography: S_{FG}	$S_{FG} \geq 3CD$
FG vertical	
Height Flight Geography: H_{FG}	$H_{FG} \geq 3CD$
Note: Smaller values than $H_{FG} = 3CD$ and $S_{FG} = 3CD$ are considered unrealistic, also for automated waypoint flights.	

7.3. Computation Contingency Volume

Notes on the realistic dimensioning of the contingency volume:

CV lateral	
GPS inaccuracy: S_{GPS}	$S_{GPS} = 3m$
Position holding error: S_{POS}	$S_{POS} = 3m$
Map error: S_K	$S_K = 1m$
Reaction distance: S_{RZ}	<p>Manual initiation of measures Response time: $t=1s$, with V_0 results in</p> $S_{RZ} = V_0 \cdot 1s$ <p>Note: S_{RZ} can also be smaller in fully automatic systems (e.g. geofence).</p>
Contingency maneuvers: S_{CM}	<p>Multicopter, stopping Based on $S = \frac{1}{2}at^2 + V_0t$ follows with a thrust to weight ratio of at least 2</p> $\text{Thrust to weight} \geq 2mg$ <p>and a maximum pitch angle of less than 45 degrees</p> $\Theta_{max} \leq 45^\circ$ <p>The minimum distance for stopping to hovering mode is:</p> $S_{CM} = \frac{1}{2} \frac{V_0^2}{g \tan(\Theta)}$ <p>Fixed-wing aircraft, 180° turn: Assumption: roll angle $\Phi_{max} \leq 30^\circ$.</p> <p>The radius for the turn is:</p> $S_{CM} = \frac{V_0^2}{g \tan(\Phi)}$
Alternative contingency maneuver parachute: S_{CM}	<p>Flight terminated with parachute opening directly when leaving the FG</p> <p>t = Time to open the parachute</p> $S_{CM} = V_0t$
Lateral extension contingency volume: S_{CV}	$S_{CV} = S_{GPS} + S_{POS} + S_K + S_{RZ} + S_{CM}$

Examples	
Example multirotors: $V_0 = 10\text{m/s}$, $\Theta = 45^\circ$, $[\tan(45) = 1]$	$S_{CV} = 3\text{m} + 3\text{m} + 1\text{m} + 10\text{m} + \frac{1}{2} * \frac{(\frac{10\text{m}}{\text{s}})^2}{9.81\text{m/s}^2 * 1} = 22.1\text{m}$
Example fixed-wing aircraft: $V_0 = 30\text{m/s}$, $\Phi = 30^\circ$	$S_{CV} = 3\text{m} + 3\text{m} + 1\text{m} + 30\text{m} + \frac{(30\text{m/s})^2}{9.81\text{m/s}^2 \tan(30^\circ)} = 195.9\text{m}$

CV vertical	
Altitude measurement error: H_{baro}	$H_{\text{baro}} = 1\text{m}$ for barometric altitude measurement, or $H_{\text{baro}} = 4\text{m}$ for GPS based altitude measurement
Response height: H_{RZ}	<p><u>Manual initiation of measures</u></p> <p>Response time: $t=1\text{s}$, with 45° pitch angle results</p> $H_{\text{RZ}} = V_0 \cdot 0.7 \cdot 1\text{s}$ <p><i>Note: H_{RZ} can also be smaller in fully automatic systems (e.g. geofence).</i></p>
Contingency maneuvers: H_{CM}	<p><u>For multirotor</u></p> <p>The forward kinetic energy is completely converted into potential energy.</p> <p>This results in the height</p> $H_{\text{CM}} = \frac{1}{2} \frac{V_0^2}{g}$ <p><u>For fixed-wing aircraft</u></p> <p>Exit the FG upwards with a 45° pitch angle, then fly on a constant circular path with V_0 and radius r until level flight is achieved. With</p> $r = \frac{V_0^2}{g}$ <p>results in the contingency maneuver height being approximately</p> $H_{\text{CM}} = \frac{V_0^2}{g} \cdot 0.3$
Alternate contingency maneuver parachute: H_{CM}	<p>Flight terminated with parachute opening directly when leaving the FG</p> <p>Exit FG with 45° pitch angle</p> <p>t = Time to open the parachute</p> $H_{\text{CM}} = V_0 \cdot t \cdot 0.7$
Contingency volume: H_{CV}	$H_{\text{CV}} = H_{\text{FG}} + H_{\text{baro}} + H_{\text{RZ}} + H_{\text{CM}}$

Examples	
Height of Flight Geography: H_{FG}	$H_{\text{FG}} = 100\text{m}$
Example multirotor: $V_0 = 10\text{m/s}$	$H_{\text{CV}} = 100\text{m} + 1\text{m} + 7\text{m} + \frac{1}{2} \frac{(10\text{m/s})^2}{9.81\text{m/s}^2} = 113.1\text{m}$

Example fixed-wing aircraft:
 $V_0 = 30\text{m/s}$

$$H_{CV} = 100m + 1m + 21m + \frac{(30\text{m/s})^2}{9.81\text{m/s}^2} \cdot 0.3$$
$$= 149.52m$$

7.4. Computation Ground Risk Buffer

GRB Lateral	
Simplified approach: 1:1 rule: S_{GRB}	$S_{GRB} = H_{CV} + \frac{1}{2}CD$
Ballistic Approach: S_{GRB} Note: Only permitted for rotorcraft and multi-rotors.	$S_{GRB} = V_0 \sqrt{\frac{2H_{CV}}{g}} + \frac{1}{2}CD$
Termination with parachute: S_{GRB} Note: Values below $V_{Wind} = 3m/s$ are not considered realistic for this computation.	t = time to open the parachute From the rate of descent with the parachute open (V_Z) and the maximum permissible wind speed for operation (V_{Wind}) results $S_{GRB} = V_0 t + V_{Wind} * \frac{H_{CV}}{V_Z}$
Termination with fixed-wing aircraft: S_{GRB}	Power is switched off With the glide ratio ($E = \frac{1}{\epsilon} = \frac{C_L}{C_D}$) Power is switched off and the rudder position is permanently selected in a way that no gliding is possible: The simplified approach can be chosen (1:1 rule).

Examples	
Simplified approach: Multirotor: $V_0 = 10m/s$, $CD = 1.5m$, $H_{CV} = 113.1m$	$S_{GRB} = 113.1m + \frac{1}{2} \cdot 1.5m = 113.85m$
Ballistic Approach: Multirotor: $V_0 = 10m/s$, $CD = 1.5m$, $H_{CV} = 113.1m$	$S_{GRB} = 10 \text{ m/s} \sqrt{\frac{2 \cdot 113.1m}{9.81 \text{ m/s}^2}} + \frac{1}{2} \cdot 1.5m = 48.77m$
Fixed-wing aircraft only power is switched off: $V_0 = 30m/s$, $CD=3m$, $H_{CV} = 149.52m$	$\epsilon = \frac{1}{20}$ $S_{GRB} = 149.52m \cdot 20 = 2990.4m$
Fixed-wing aircraft power is switched off and rudder position selected so that no gliding is possible: $V_0 = 30m/s$, $CD = 3m$, $H_{CV} = 149.52m$	$S_{GRB} = 149.52m + \frac{1}{2} \cdot 3m = 151.02m$
GRB vertical	- not applicable -

8. Computation adjacent volumes

The adjacent volume begins at the outer limit of the contingency volume. Its width results from a two-minute flight of the UA at its operating speed V_o :

Adjacent volume horizontal	
Width of the adjacent volume: S_{AV}	$S_{AV} = 120 \text{ s} \cdot V_o$
Example	
$V_o = 10 \text{ m/s}$	$S_{AV} = 120 \text{ s} \cdot 10 \text{ m/s} = 1200 \text{ m}$

The height of the adjacent volume is at least 500 feet (150 m) above the operational volume.

Adjacent volume Vertical	
Height of the <i>adjacent volume</i> : H_{AV}	$H_{AV} = H_{CV} + 150\text{m}$
Example	
$H_{CV} = 100\text{m}$	$H_{AV} = 100 + 150\text{m} = 250\text{m}$

Note: If the operating volume does not reach the floor, any airspace below the operating volume is also considered an adjacent volume.

9. Computation VLOS/BVLOS Maximum Distance

When determining the operating range for Visual Line of Sight (VLOS) operations, care must be taken to ensure that the remote pilot can actually operate the UAS within visual range. To check whether the described UAS operation is in VLOS or Beyond Visual Line of Sight (BVLOS), the following calculations may be used.

Definitions	
VLOS Limit	The maximum possible VLOS distance between remote pilot and UAS results from the smaller value of ALOS and DLOS. Anything beyond that is considered BVLOS. See section 8 for EVLOS operations.
ALOS: Attitude Line of Sight	<p>The maximum distance up to which a remote pilot can detect the position and orientation of the UAS. Up to this limit, the remote pilot is able to control the flight path of the UAS, and is able to determine the attitude and position of the UAS.</p> <p>N.B. This distance was determined in practical tests by Luftfahrt-Bundesamt. Alternative values may be utilised with sufficient justification and evidence.</p>
DLOS: Detection Line of Sight	<p>The distance up to which other aircraft can be visually detected, and sufficient time is available for an avoidance maneuver.</p> <p>The ground view is crucial for this.</p>
GV: Ground Visibility	<p>Depends on the operational area and the meteorological condition and must be determined at the respective time of operation. The procedure for precisely determining ground visibility should be described in the operations manual. The use of landmarks or the use of a transmissometer are possible.</p> <p>The maximum ground visibility to be assumed is 5km, analogous to the visibility according to the VFR rules in airspace Golf.</p>
ALOS - limit	<p><u>For rotorcraft and multirotors</u></p> $ALOS_{max} = 327 \cdot CD + 20 \text{ in meters}$ <p><u>For fixed-wing aircraft:</u></p> $ALOS_{MAX} = 490 \cdot CD + 30 \text{ in meters}$
DLOS - limit	$DLOS_{MAX} = 0.3 \cdot GV$ <p>GV depends on the actual ground visibility at site and time of operation. However, it always applies:</p> $GV_{MAX} = 5\text{km}$

Note: If the largest possible distance between the pilot location and the outer side of the contingency volume (boundary between contingency volume and ground risk buffer) is greater than the VLOS boundary, no VLOS operation can take place. Operations must then take place in BVLOS.

10. Extended VLOS

For all EVLOS operations please engage with the IAA to discuss proposals.

Reg (EU) 2019/947 AMC1 Article 11

- 2.3.(g) “EVLOS operations are to be considered to be BVLOS for the intrinsic GRC determination”.
- 2.4.4.1.(c) “In general, all VLOS requirements are applicable to EVLOS. EVLOS may have additional requirements over and above those of VLOS. The EVLOS verification and communication latency between the remote pilot and the observers should be less than 15 seconds.”

11. Development of *.kml Files

The outer coordinates of Flight Geography, Contingency Volume and Ground Risk Buffer should be provided to the IAA. For Flight Geography and Contingency Volume these are the external coordinates projected onto the ground.

The topology of flight geography, contingency volume and ground risk buffer should clearly emerge from the coordinates. The outer coordinate points are sequentially connected with straight lines.

11.1. Introduction

For easy processing, we require to define the above areas digitally with cartography software and save them as a *. kml file.

This file should be submitted with the application for an operational authorisation. The coordinate data generated by this process in the *. kml file becomes part of the operational authorisation. The *. kml file can also be opened directly with a text editor or spreadsheet program, which allows the coordinates to be displayed and exported to a geofence system.

There are several free software tools that can be used to create *. kml files. These include, (among others):

- Google Earth browser mode
- Google Earth Pro Desktop
- QGIS
- GPS Prune.

Depending on the software, it is possible to also define a height for the generated areas. This allows a 3D volume to be created for flight geography and contingency volume. This is not necessary if the flight geography and contingency volume have a constant height. The height of flight geography and contingency volume must then be clearly stated in the operations manual.

The following items should be in the *.kml file - the nomenclature is shown here in bold.

- **Flight Geography** - as a polygon in green
- **Contingency volume** - as a polygon in yellow
- **Ground Risk Buffer** - as a polygon in red
- **Pilot** - pilot position as location marker
- **TO/LD** - UAS take-off and landing position as location marker

It must be strictly ensured that the previously calculated minimum sizes of the contingency volume and ground risk buffer are correctly compiled in the *. kml. If the contingency volume and ground risk buffer are drawn manually in software as a polygon, exact positioning is often difficult.

Note: Compliance with the calculated contingency volume and ground risk buffer is checked using automatic software tools. **Falling short of the calculated sizes will not be accepted.**

11.2. Example 1 *.kml in Google Earth

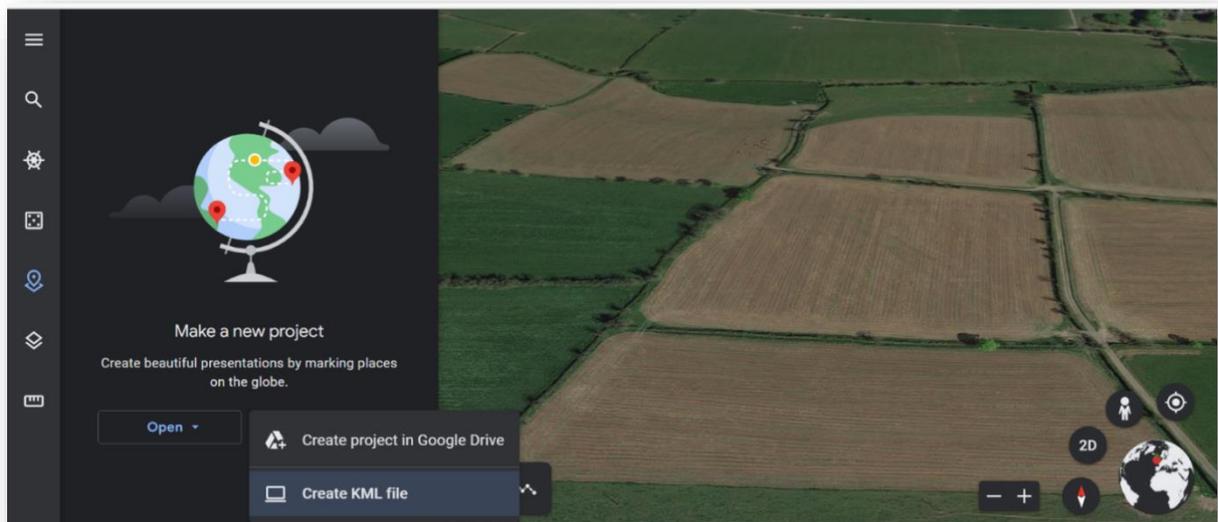
The following example explains how to use the browser version of Google Earth to create a compliant *.kml file. In this example, an operator should fly over an agricultural field. The size of the flight geography results from the size of the field.

The browser version of Google Earth is available at <https://www.google.com/earth>

The example of a multicopter in Section 6 is used.

- $V_0 = 10\text{m/s}$
- $CD = 1.5\text{m}$
- $H_{FG} = 100\text{m}$
- $H_{CV} = 113.1\text{m}$
- $S_{CV} = 22.1\text{m}$
- $S_{GRB} = 48.77\text{m}$

Step 1. A new KML file is created via the Projects tab.



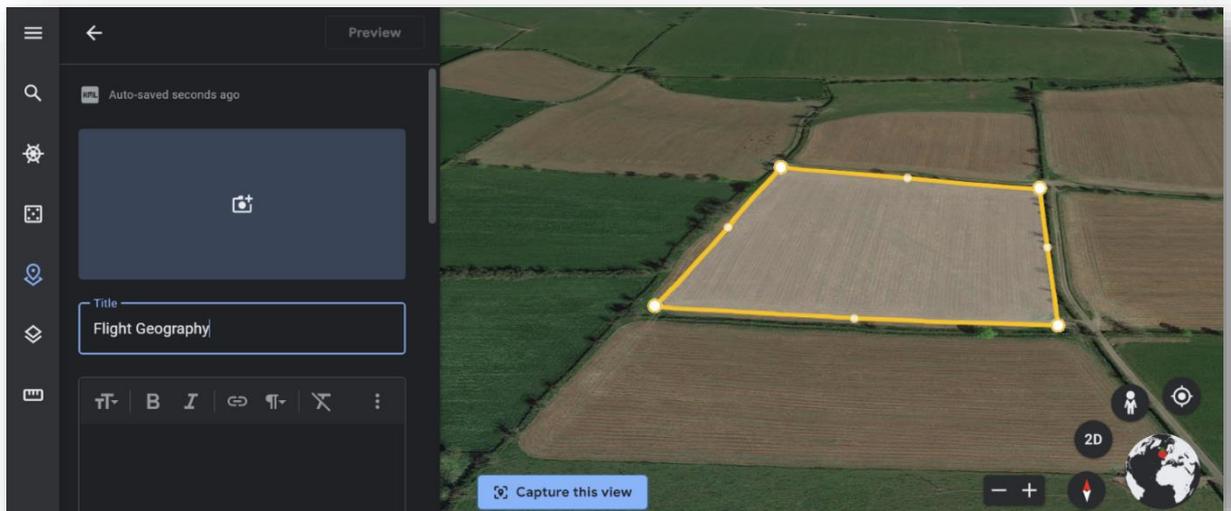
Step 2. A line or shape is drawn with the button 



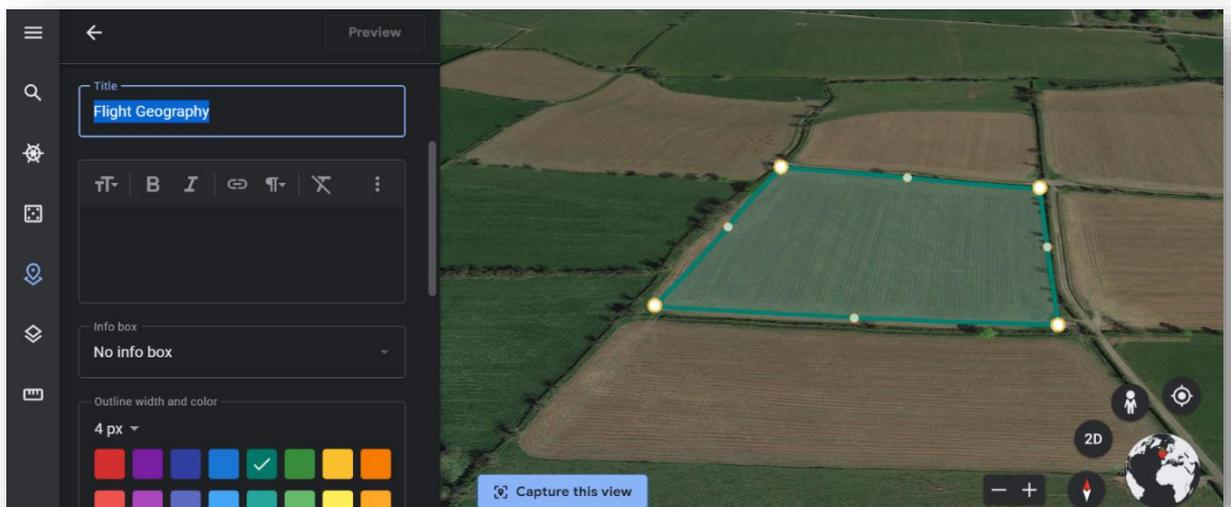
Step 3. Lines are drawn as the outer contour of the Flight Geography. Click to create a corner point. The coordinates of these corner points (here in the picture small circles) are saved later in the *.kml file. The contour is closed by clicking on the starting point.



Step 4. After closing the form, you can give it a name. The nomenclature should be clear and correspond to that previously outlined.



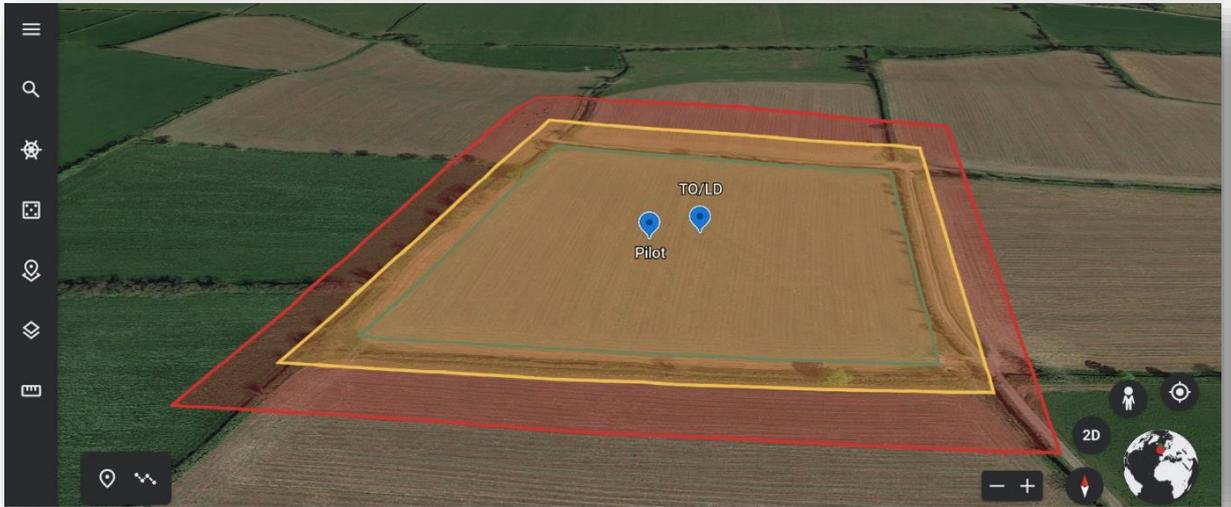
Step 5. Using Edit Element, the generated Flight Geography can be coloured according to the specifications previously outlined.



Step 6. The process is repeated for the contingency volume and the ground risk buffer. It is important to ensure that the previously calculated distances are met. This is where the distance measurement tool from Google Earth (ruler icon) can help.



Step 7. The pilot's position is to be added as a placemark (*New Item*). The same process is repeated with the UAS take-off and  landing position.



Step 8. The finished representation can be exported as a *.kml file and sent to the IAA as part of the application.

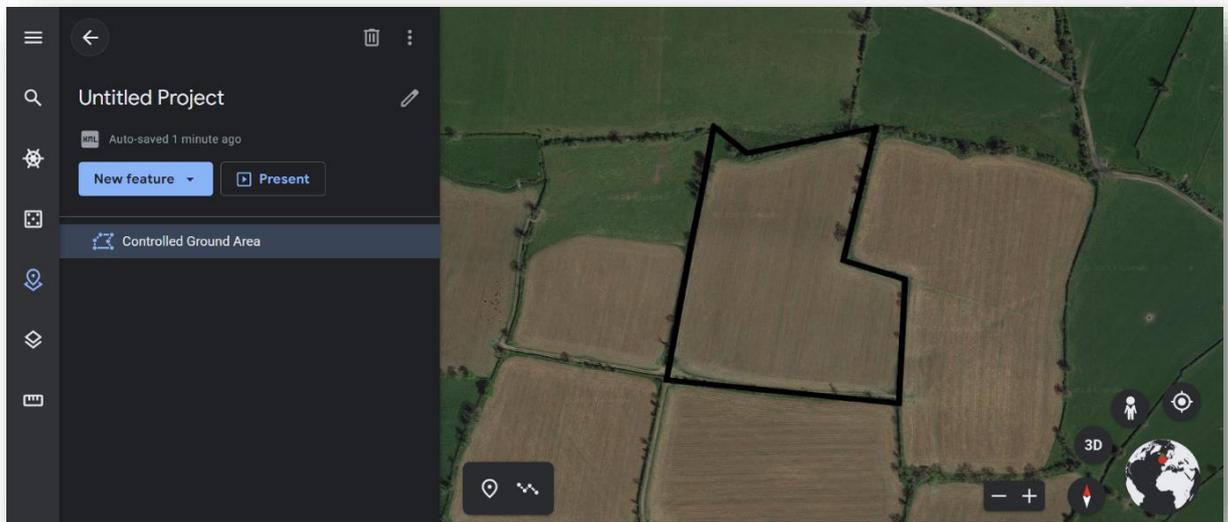
11.3. Example 2 *.kml in Google Earth

In this example, a UAS operation is to be implemented over a controlled ground area. For this purpose, Flight Geography, Contingency Volume and Ground Risk Buffer must be completely contained in the controlled ground area. We therefore recommend to use the procedure shown in Section 7.2.

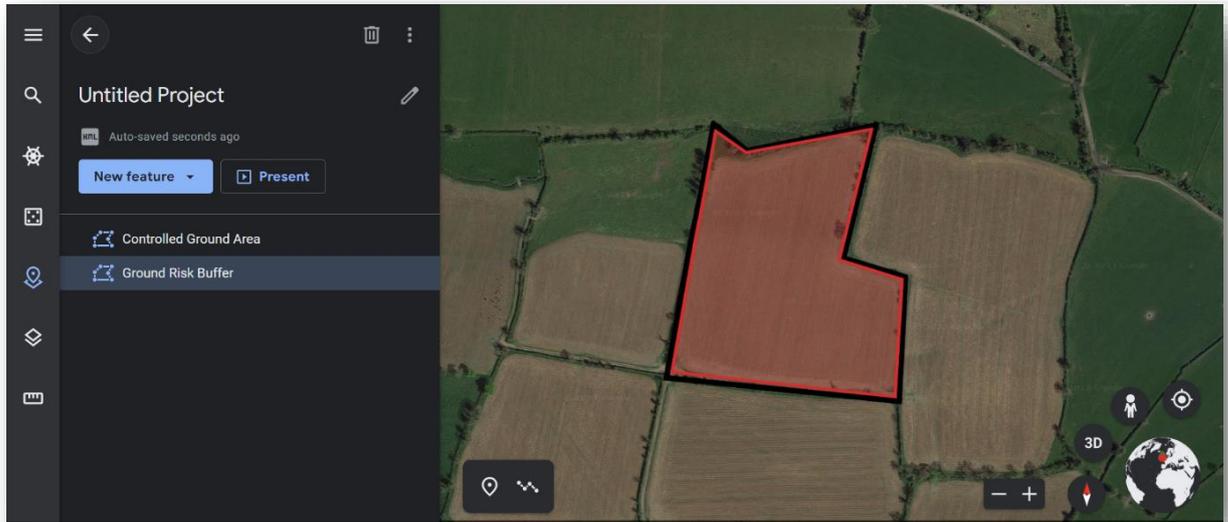
Again, the example of a multicopter in Section 6 is used.

Step 1. The controlled ground area is drawn (here as a black line)

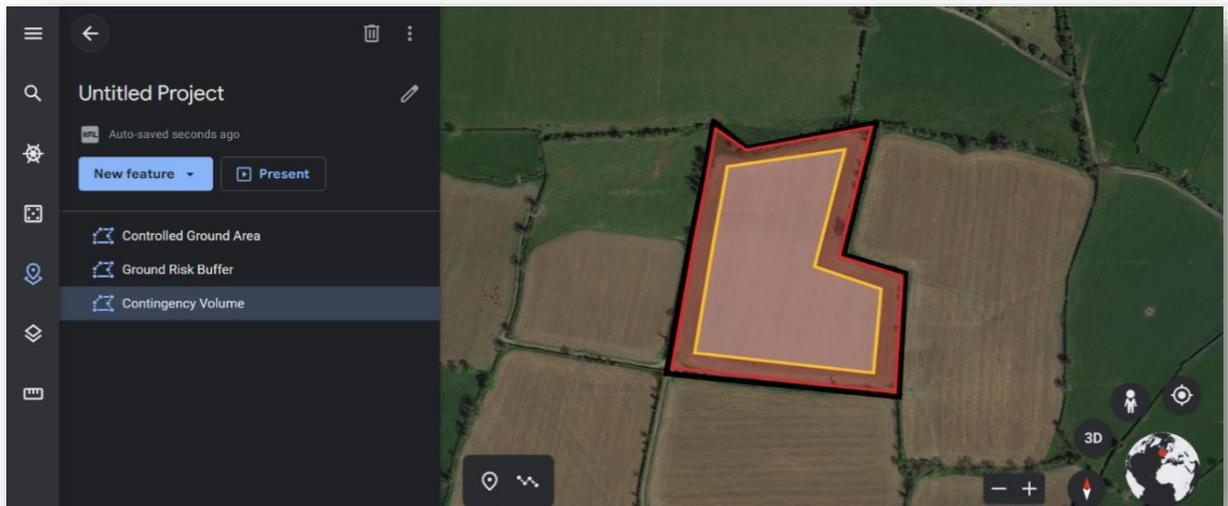
Note: According to Article 2 – 21 IR (EU) 2019/947, a “controlled ground area” means the ground area where the UAS is operated and within which **the UAS Operator** can ensure that only involved persons are present. Persons involved is specified under: GM1 Article 2(18) Definitions - IR (EU) 2019/ 947.



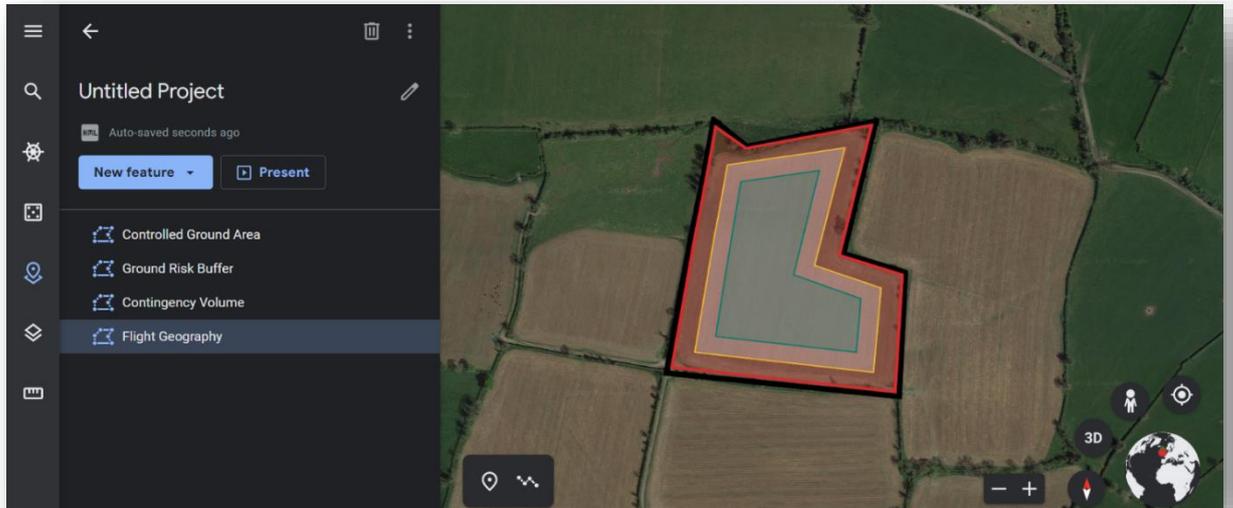
Step 2. The outer contour of the Ground Risk Buffer corresponds to the controlled ground area.



Step 3. The contingency volume is drawn using the calculated ground risk buffer.



Step 4. The flight geography results from the area still available after deducting the width of the contingency volume.



Step 5. The location of the pilot and the take-off and landing point of the UAS are marked. The *.kml file can be exported.

