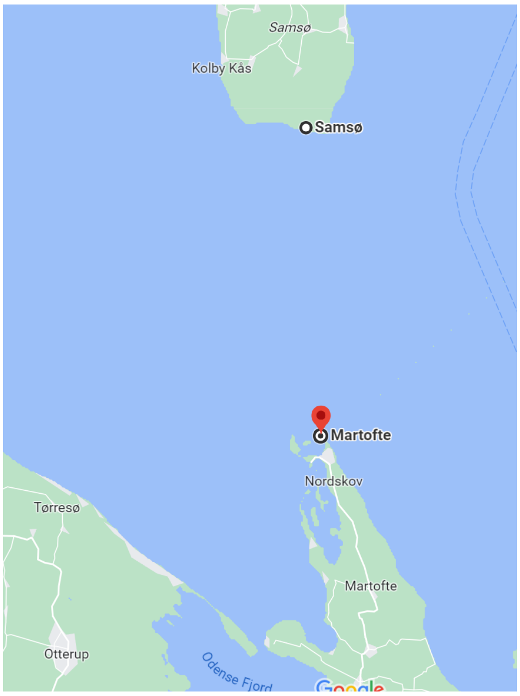
Drone EU regulation report for Avy Aera eVTOL

The drone we're looking to analyze will be the Avy Aera eVTOL:

- It will fly beyond line of sight (BVLOS)
- It will be flying from Marietoft [55.619417, 10.615725] to Samsø [55.767110, 10.603164]
- The eVTOL itself has:
    - A maximum takeoff weight of 12 Kg
    - A wingspan of 2400mm, a length of 1200mm and a height of 500mm
    - It uses 6s batteries (25,2 V), with a capacity of 30000 mAh



- **What will the Intrinsic UAS Ground Risk Class (GRC) be?**

Intrinsic UAS ground risk class				
Max UAS characteristics dimension	1 m / approx. 3 ft	3 m / approx. 10 ft	8 m / approx. 25 ft	>8 m / approx. 25 ft
Typical kinetic energy expected	< 700 J (approx. 529 ft lb)	< 34 kJ (approx. 25 000 ft lb)	< 1 084 kJ (approx. 800 000 ft lb)	> 1 084 kJ (approx. 800 000 ft lb)
Operational scenarios				
VLOS/BVLOS over a controlled ground area[3]	1	2	3	4
VLOS over a sparsely populated area	2	3	4	5
BVLOS over a sparsely populated area	3	4	5	6
VLOS over a populated area	4	5	6	8
BVLOS over a populated area	5	6	8	10
VLOS over an assembly of people	7			
BVLOS over an assembly of people	8			

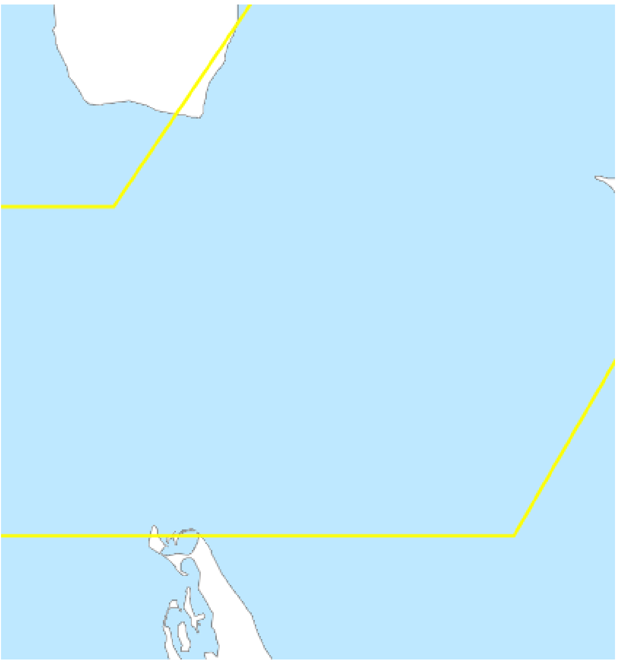
The wingspan of the drone is 2.4 meters which puts it in the second column[1]. As for the typical kinetic energy, its terminal velocity is calculated as 16.8 m/s, therefore the typical kinetic energy expected will be 1.693 kJ. On page 52-k. It is stated that for fixed wing aircrafts the Vcruise speed can be used to calculate the typical kinetic energy as 416,6 J, securing the Avy Aera to the second column.
The drone will be flying BVLOS overseas, being a sparsely populated area, the Intrinsic UAS Ground Risk Class will be 4

- **What could you do to reduce the final GRC?**
  Since the kinetic energy is below 700 J, reducing the wingspan to 1 meter would reduce the GRC from 4 to 3, however the drone might not be able to work properly in this case. Instead, the drone could utilize the parachute, reducing the effects of ground impact. The drone would have a high robustness, due to multiple partnerships with other third parties and the high integrity of an emergency parachute. Lastly an emergency response plan and UAS operator validation protocols can be implemented to further reduce the GRC, if none is implemented it will instead be increased by 1. Importantly the GRC cannot be reduced down further than the lowest value in its column according to page 53-(d), being 2. Therefore, by utilizing the different forms of mitigation, the GRC would be reduced to 2.

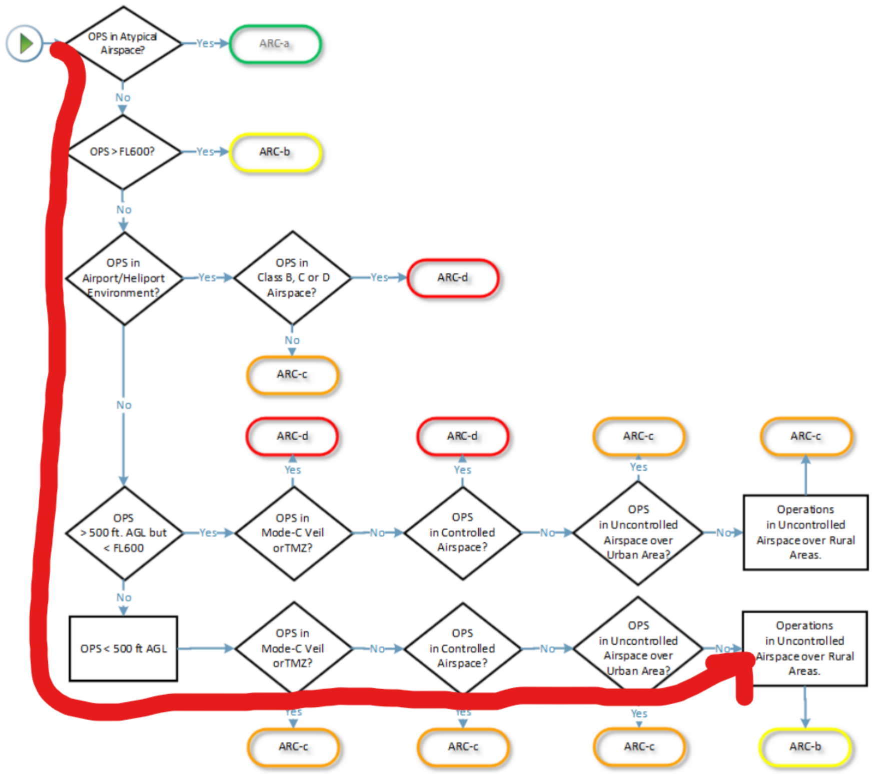
		Robustness		
Mitigation Sequence	Mitigations for ground risk	Low/None	Medium	High
1	M1 — Strategic mitigations for ground risk[1]	0: None -1: Low	-2	-4
2	M2 — Effects of ground impact are reduced[2]	0	-1	-2
3	M3 — An emergency response plan (ERP) is in place, the UAS operator is validated and effective	1	0	-1

[1] Avy_-_Specsheet_Jan_2021.pdf - Dimensions, Wingspan

- **What is the initial Air Risk Class (ARC)?**



Based on the zoning of the areas, it is designated as a non active drone zone, meaning that for the most part drone flight is permitted, but the area can be regularly active, thus making drone flights illegal. This is all based on the NOTAM for the area. We will be flying at below 500 ft.



Based on this, the ARC class will end at the ARC-b, operations in uncontrolled airspace over rural areas.

Residual ARC	TMPRs	TMPR level of robustness
ARC-d	High	High
ARC-c	Medium	Medium
ARC-b	Low	Low
ARC-a	No requirement	No requirement

Since we are operating as BVLOS, this table will need to be fulfilled, luckily we are in the ARC-b category.
For the TMPRs the drone will be flying below 120m as recommended and if needed the drone would quickly dive to altitudes where manned aircrafts would never operate, furthermore we have Redundant comms link independent of range for increased robustness, which should at least qualify for low.

- **With your final GRC and initial ARC, what is the SAIL?**
  With a GRC of 2 and initial ARC of class b, the SAIL is determined to be II.

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 operation			

3.2 Operational Safety Objectives (OSOs)

The OSOs change based on the SAIL. Some are excluded at low levels and common for all is that they increase in robustness requirements when the level goes up.

- Which OSOs are optional in a SAIL II scenario?

Following OSOs are optional when flying in a SAIL 2 scenario

OSO#02	UAS manufactured by competent and/or proven entity	O	O
OSO#04	UAS developed to authority recognised design standards[1]	O	O
OSO#05	UAS is designed considering system safety and reliability	O	O
OSO#18	Automatic protection of the flight envelope from human error	O	O
OSO#19	Safe recovery from human error	O	O
OSO#24	UAS is designed and qualified for adverse environmental conditions	O	O

- According to the OSOs, is a procedure manual for maintenance required for a SAIL III?

Based on OSO#8 and OSO#11, a procedure manual for maintenance is highly required for a SAIL III.

- What are the OSO#02 integrity requirements for a SAIL IV and how is it assured?

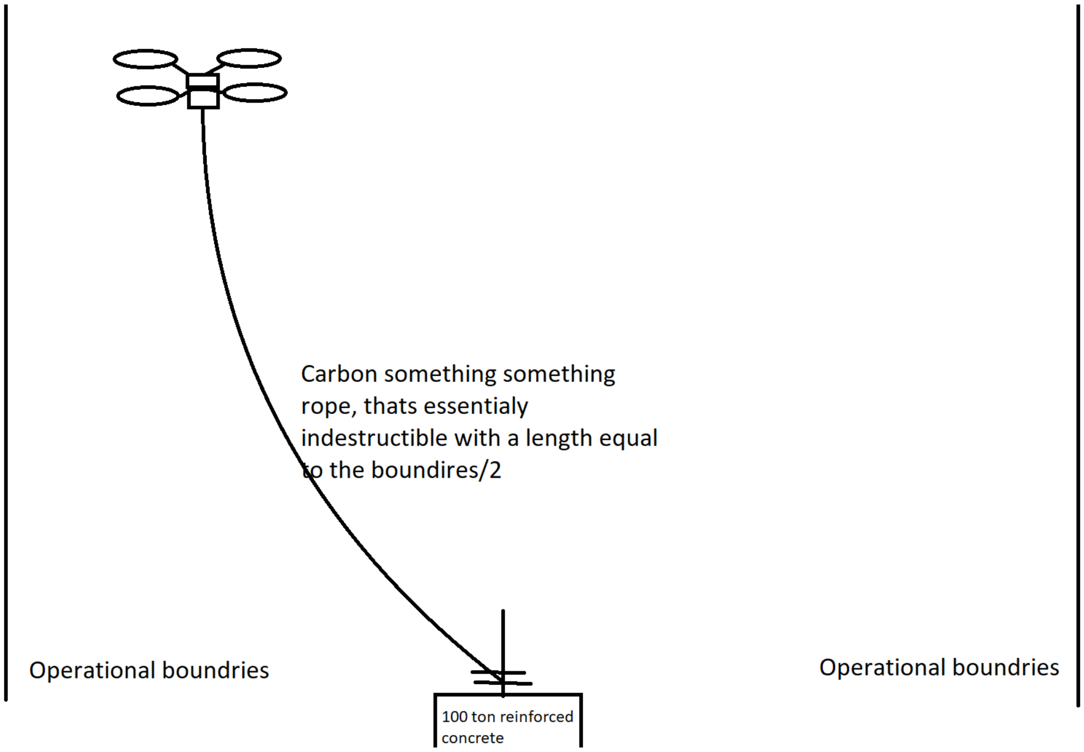
That the UAS is manufactured by a competent/proven entity. For a SAIL IV medium required. It can be assured by looking at certifications for both UAS and producer.

3.3 Step #9

Step #9 in the SORA states that *"no probable failure of the UAS or of any external system supporting the operation should lead to operation outside the operational volume"*. A failure could for instance be a motor breaking or a navigation malfunction.

- Come up with a drone design fulfilling this requirement. Explain the design and provide a sketch.

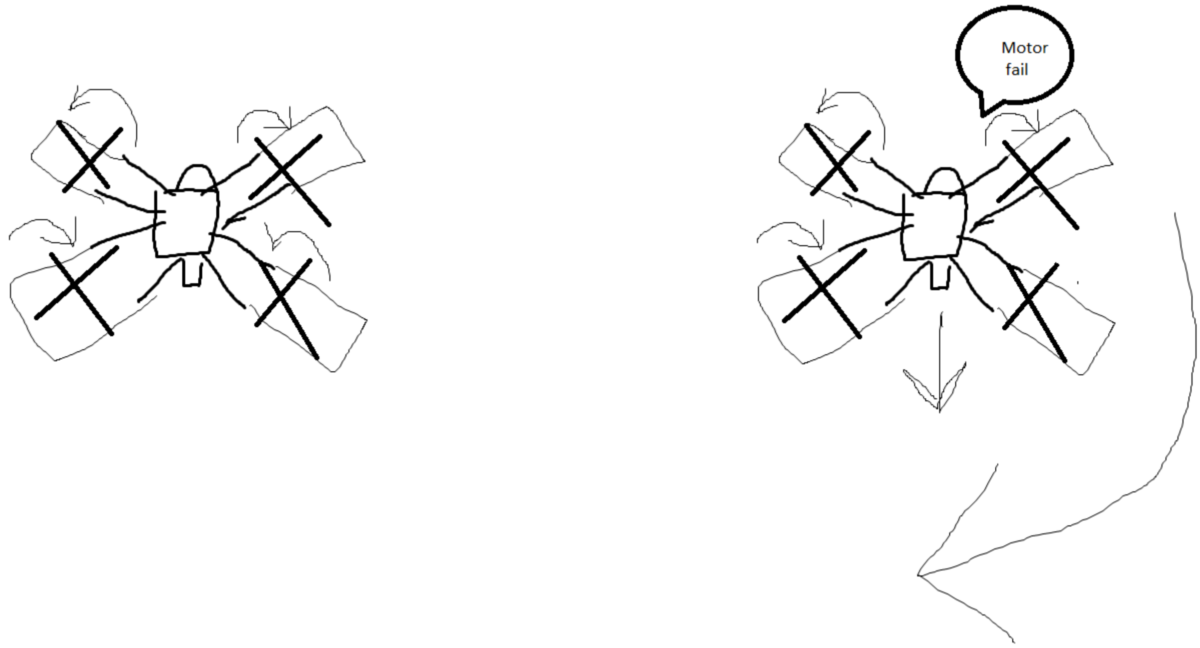
Proposal 1: tethered drone 10/10



(This is a joke, more proposals below)

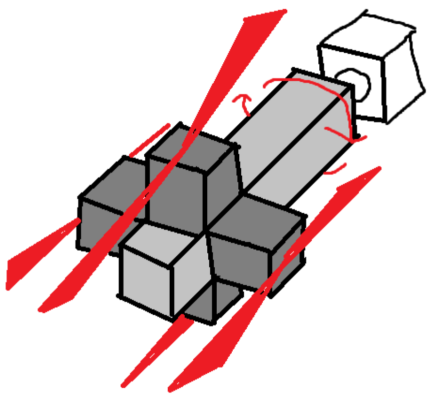
Proposal 2:
Extra GPS with geo fence, making sure the drone always keeps within the allowed area. another set of propellers on the bottom of the drone, which allow the drone to make a 180° and let the other propellers take over in case the original ones stop working.

Proposal 3:
Controlling the descent if a motor fails. It is unavoidable that it will begin spinning but with correct maneuvers it is possible to keep airborne. This way a safe landing might be possible. This should be possible on drones with 4+ propellers. On drones with many propellers it might be ideal to turn off other motors to add stability but it all comes down to physics.

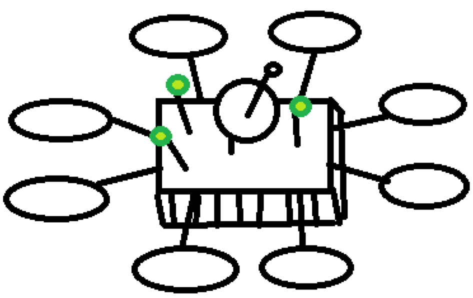


Proposal 4:
Question didn't ask that it needed to be realistic.
Octocopter drone:

- Each arm has a servo, attached to that servo is 2 pairs of motors propellers, making it so that if a rotor fails another can take it's place instantly, if too many fail each arm is able to have either propeller pitch direction, making it so that 28 motor/esc combos has to fail before the drone loses control
- The drone has 3 flight controllers, each is attached to a raspberry PI. The Pi compares the outputs of the flight controllers making sure they are all in agreement of the position, speed and desired motor outputs. If 1 of the flight controllers "fails" they will be disconnected and the control authority is transferred to another flight controller and the drone will make an emergency landing.
- The drone is able to deploy a parachute for immediate safe decent.
- The drone has 2 main batteries and 4 backups.
- Each wire is redundant 2 times, being controlled by a set of high frequency FPGA circuits.
- In case all else fails, 4 small explosives are placed in the drones corners, allowing for a controlled explosion forcing it in any direction.
- Position and communication redundancy:
    - Each flight controller has it's own GPS module, again this information is relayed through the PI
    - An array of 5G towers connect to a pair of 5G pads on the drone (idk what they are called, but the thing the fixed wing drone had from the demonstration.) (both for position and communication)
    - A series of starlink satellites provide communicational and position to the drone with 100% optime, so it will need a parabola.
    - A phone is attached to the drone playing Pokemon GO, if the positions are ever the same the drone knows that it has lost it's position and will deploy it's parachute.



Arm



Full drone