CIVIL AVIATION AUTHORITY

OF SRI LANKA

Requirements for Visual Line of Sight Unmanned Aircraft Systems Rotary Wing Swarm Operations.

1st Edition -2024

Issued under the authority of the Director General of Civil Aviation and Chief Executive Officer

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Control Number: 00

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Record of Revision

Rev. No	Rev. Date	Entered by

Rev. No:	Rev Date	Entered by

List of Effective Pages

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History of Revision

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Abbreviations

ADS-B	Automatic Dependent Surveillance Broadcast
AGL	Above Ground Level
ALARP	As Low As Reasonably Practicable
BVLOS	Beyond Visual Line Of Sight
CAASL	Civil Aviation Authority of Sri Lanka
C2	Command and Control
FRZ	Flight Restriction Zone
NOTAM	Notice To Airmen
RF	Radio Frequency
RPA	Remotely Piloted Aircraft
UA	Unmanned Aircraft
UAS	Unmanned Aircraft System(s)
VLOS	Visual Line Of Sight

Glossary

Aircraft	Any machine that can derive support in the atmosphere from the reactions of the air other than the reactions of the air against the Earth's surface.
Beyond visual line of sight (BVLOS)	An operation in which the remote pilot or RPA observer does not use visual reference to the unmanned aircraft in the conduct of flight.
Command and control (C2) link	The data link between the remotely piloted aircraft and the Command Unit for the purposes of managing the flight.
Concept of operations	Describes the characteristics of the organization, system, operations, and the objectives of the user.
Command unit	The equipment or system of equipment to control unmanned aircraft remotely which supports the control or the monitoring of the unmanned aircraft during any phase of flight, with the exception of any infrastructure supporting the command and control (C2) link service.
Contingency volume	Zone between the boundary of the flight volume and the emergency buffer.
Emergency buffer	Zone outside the operational volume. If UA enters the emergency buffer, the emergency response plan must be carried out.
Flight restriction zone (FRZ)	Airspace of defined dimensions around a protected aerodrome (as defined in the Air Navigation Order, Article 94) within which the permission of the relevant ATS unit or aerodrome operator, as appropriate, is required before a small unmanned aircraft flight can take place.
Flight volume	The zone containing the planned operation, within which the UA must remain for continued safe operation.
Latency	This is defined by the time it takes for a request to travel from the transmitter (Command Unit) to the receiver (UA) and for the receiver to process that request. This is the total round-trip time from the Command Unit to the UA and back again. In reliable two-way communication systems, latency limits the maximum rate that information can be transmitted.
Lost C2 link	The loss of command and control link with the remotely piloted aircraft such that the remote pilot can no longer manage the aircraft's flight.
Operational authorization	A document issued by the CAASL that authorizes the operation of an unmanned aircraft system, subject to the conditions outlined within the authorization, having taken into account the operational risks involved.

Operational volume	The zone containing the flight volume and the contingency volume.
Recovery area	An alternative area identified for the purpose of landing the swarm in the event of an emergency.
Remote pilot	A natural person responsible for safely conducting the flight of an unmanned aircraft by operating its flight controls, either manually or, when the unmanned aircraft flies automatically, by monitoring its course and remaining able to intervene and change the course at any time.
Remotely piloted aircraft (RPA)	An unmanned aircraft which is piloted from a remote pilot station.
Remote pilot station (RPS)	See command unit.
Sterile ground area	An area on the ground or water within which only people that are involved in the operation are permitted.
Swarming	Operation of more than one UA which are controlled collectively rather than individually.
Unmanned aircraft (UA)	Any aircraft operating or designed to operate autonomously or to be piloted remotely without a pilot on board.
Unmanned aircraft system (UAS)	An unmanned aircraft and the equipment to control it remotely.
Unmanned aircraft system operator (UAS operator)	Any legal or natural person operating or intending to operate one or more UAS.
Visual line of sight (VLOS) operation	Means a type of UAS operation in which, the remote pilot is able to maintain continuous unaided visual contact with the unmanned aircraft, allowing the remote pilot to control the flight path of the unmanned aircraft in relation to other aircraft, people and obstacles for the purpose of avoiding collisions.

Foreword

Pursuant to the Section 80 of Civil Aviation Act No.10 of 2014 and the Implementing Standard 053 issued by DGCA, this document is issued to provide guidance to persons who are seeking authorization for Visual Line of Sight Unmanned Aircraft Systems Rotary Wing Swarm Operations.

AVM Sagara Kotakadeniya (Retd.)
Director General of Civil Aviation &
Chief Executive Office

Chapter I – Basic Requirements for all Rotary Wing VLOS Swarms.

- The following requirements must be included in the operations manual submitted to the CAASL for authorization of UA swarm operations.
- For swarming operations, the applicant must prepare and submit Operations Manual and Safety Risk Assessment. Particular attention should be paid to the Safety Risk Assessment. Identified safety risks must be specific to the proposed operation and must be mitigated to an acceptable level.

1. Operations Manual

- The operational requirements listed below **must** be included in Operations Manual.
- Any safety risks identified under any of these headings, **must** be mitigated to a tolerable and ALARP level.
- Safety Risk Assessment **must** explain why all safety risks identified in operations manual are tolerable and ALARP.

1.1.1 Remote pilot competence

- The remote pilot(s) **must** be competent to carry out UA swarm operations.
- Explain why the operator is satisfied that the remote pilot(s) is competent enough to comply with the conditions of an authorization.
- Explain how the qualifications and experience of the remote pilot(s) ensure they are competent to carry out the swarming operations.

1.1.2 Support crew competence

- The support crew **mus**t be competent to support UA swarm operations.
- Explain how the qualifications and experience of the crew ensure they are competent to support swarming operations.
- An example of a support crew member is a visual observer who keeps a lookout for other airspace users.

1.1.3 Line of sight

- The swarm operation **must** be carried out within VLOS.
- Application for approval of a BVLOS swarm operation is outside the scope of this document.

1.1.4 Dimensions of the flight volume

- The planned flight of the swarm must remain within the flight volume.
- The upper limit of the flight volume must be kept as low as possible and only be as high as necessary to accommodate the planned flight of the swarm.
- The horizontal dimensions of the flight volume must be sufficient to accommodate the planned flight of the swarm.
- The flight volume must encompass the entire swarm and its planned movement, with sufficient allowance for any operational movement around the flight path.
- State the dimensions and location of the flight volume.

1.1.5 Swarm height

- The height of the swarm must be monitored and accurately measured.
- The height of the swarm should be based on the height of the highest individual UA at any time during the flight.
- Explain how the swarm height is measured and monitored during the flight, and how accuracy is assured.

1.1.6 Airspace

- Appropriate airspace must be used for the swarm operation.
- The OSC must contain all the information listed below:
  - State the dimensions and location of the flight volume (see paragraph 2.1.4 and attachment 1, figures 1 and 2).
  - State the dimensions and location of the contingency volume and emergency buffer (see attachment 1, figures 1 and 2).
  - State the class of airspace where the swarm is to be conducted.
  - State whether any additional permission is required to operate in the proposed airspace; for example, if the operation is within a Restricted Zone.
  - Explain how any additional permission will be applied for.

1.1.7 Weather conditions

- The swarm operation must only be conducted in the appropriate weather conditions.
- State the weather limits for the operation and explain how the weather will be monitored during the operation.

1.1.8 Go/no-go criteria

- Go/no-go and abort criteria must be clearly defined for the swarm operation.

- State the go/no-go criteria for the operation.

1.1.9 Emergency abort

- The decision to abort the swarm must be made quickly and reliably enough, in response to an emergency, to prevent harm to people.
- State who will make real-time decisions to abort the flight and what qualifies them to make the decision. This person must be physically present at the site of operation while the swarm is in flight.
- Explain how the decision to abort will be made quickly and reliably to effectively intervene in an emergency to prevent harm.
- State the abort conditions which, if reached, would lead to an immediate and safe termination of the operation. Explain the abort procedures which are in place to enable this decision.
- State that the abort decision will always be free from commercial or contractual pressure.

1.1.10 Operating procedures

- Operating procedures must be clearly defined for the swarm operation.
- The operations manual must state and explain the operating procedures as necessary, including the:
  - normal operating procedures
  - lost C2 link procedures and protocols
  - contingency procedures, including:
    - UA excursion from the flight volume
  - emergency procedures, including:
    - aircraft incursion into the operational volume
    - UA excursion from the operational volume
    - uninvolved third parties crossing the crowd line and entering the sterile ground area
  - emergency response plan (ERP).

1.1.11 Illumination of take-off, landing and nominated recovery areas

- The take-off, landing and nominated recovery areas must be sufficiently illuminated.
- Use of recovery areas is recommended.
- Explain how the take-off, landing and any nominated recovery areas are sufficiently illuminated to ensure safe operation of UA when using the areas.

1.1.12 Insurance

- The insurance policy **must** provide adequate cover for swarming operations.
- Include copies of the relevant insurance documents.

1.1.13 Projection or dropping of articles

- The safety risks associated with the projection or dropping of articles must be tolerable and ALARP.
- Permission from the CAASL must be obtained for any dropping of articles from a UA.
- Explain what articles will be projected or dropped.
- Explain how articles will be projected or dropped.
- Explain how the safety risk is tolerable and ALARP in Safety Risk Assessment.

1.1.14 Overflight of uninvolved third parties

- The swarm **must** not overfly uninvolved third parties.
- Explain how the overflight of uninvolved people will be avoided.
- Explain how the safety risk is tolerable and ALARP in Safety Risk Assessment.

1.1.15 Swarms for public display – sterile ground area

- A sterile ground area must be in place for the operation.
- Uninvolved third parties must not be present in the sterile ground area.
- The sterile ground area is the entire ground or water area covered by the flight volume, the contingency volume and the emergency buffer. (See attachment 1, figures 1 and 2.)
- State the dimensions and location of the sterile ground area.

1.1.16 Swarm for public display – crowd line position

- A crowd line must be established outside of the sterile ground area for the operation.
- A crowd line is applicable to any number of uninvolved people.
- Based on the sterile ground area description in paragraph 2.1.15, the crowd line must be outside the emergency buffer.
- The crowd line must never be less than 50m from the operational volume.
- State the position of the crowd line. (See attachment 1, figures 1 and 2.)

1.1.17 Swarm for public display – crowd line marking and monitoring

- Uninvolved third parties must not be permitted to cross the crowd line when the swarm is in flight.
- Explain how the crowd line will be marked and how its observation will be enforced.
- Explain how you will respond if uninvolved third parties cross the crowd line.

1.2Technical Specifications Manual

- The technical requirements listed below must be included in Technical Specifications Manual.
- Any safety risks identified under any of these headings, must be mitigated to a tolerable and ALARP level.
- Safety Risk Assessment must explain why all safety risks identified are tolerable and ALARP.

1.2.1 UA Type

- The swarm **must** only be comprised of rotary wing UA.
- State the type of UA to be used in the swarm.

1.2.2 Number of UA in the swarm

- The number of UA in the swarm must be no more than necessary to complete the operation.
- The number of UA in the swarm is important; as the number increases, so does the swarm's potential to harm people. It also increases the potential for RF interference, C2 spectrum issues and loss of control or fly-away events.
- While the number of UA within the swarm will not necessarily increase the amount of energy transferred to a person if the swarm were to crash, it would affect the likelihood of a person being struck.
- State the number of UA to be used in the swarm.

1.2.3 UA Speed

- The highest speed of an individual UA must be no greater than necessary to complete the operation.
- State the highest speed of the individual UA in the swarm.

1.2.4 UA Mass

- The mass of an individual UA **must** be no greater than necessary to complete the operation.
- State the mass, including payload, of the individual UA in the swarm.

1.2.5 UA Kinetic Energy

- The kinetic energy of an individual UA **must** be no greater than necessary to complete the operation.
- Kinetic energy is increased with higher UA speed. Kinetic energy is also increased with greater UA mass.
- State the kinetic energy of the individual UA in the swarm at their highest speed.

1.2.6 UA Size

- The size of the UA **must** be no larger than necessary to complete the operation.
- State the size of the individual UA in the swarm.

1.2.7 Swarm Coordination Protocol

- The swarm must be effectively controlled.
- State how the UA in the swarm establish and maintain communication with each other through an RF channel. For example, is it a 'lead' and 'follower' configuration, a mesh system, or a pre-defined waypoint configuration.
- Describe how individual UA in the swarm avoid one another and obstacles.

1.2.8 Intra-swarm collision avoidance and movement

- All UA in the swarm must remain separated from each other during the operation.
- Explain the collision avoidance and movement co-ordination technologies between UA.

1.2.9 Whole system single points of failure

- All single points of failure **must** be identified and mitigated.
- State all single points of failure and explain how these points are mitigated in Safety Risk Assessment.

1.2.10 Known failure modes

- All known failure modes **must** be identified and mitigated.

- State all known failure modes and explain how these are mitigated in Safety Risk Assessment.

1.2.11 ADS-B dual frequency receiver

- The remote pilot should use technical means to supplement visual lookout.
- The remote pilot should be aware of other ADS-B equipped aircraft close to the operation.
- An ADS-B dual frequency receiver operating on 978MHz and 1090MHz should be used and must be in the same place as the swarm.
- ADS-B receivers may be airborne, or ground based and must be in the immediate vicinity of the swarm.
- One ADS-B receiver may be used for the entire swarm.
- If an ADS-B receiver is used, describe how it will be used to monitor ADS-B equipped aircraft nearby.
- Describe the use of any third-party web-based application to supplement visual lookout and explain its limitations in terms of reliability and coverage.
- If an ADS-B receiver is not used, explain why.

1.2.12 C2 link

- An effective C2 link must be maintained between the command unit and the swarm.
- State how a C2 link between the command unit and the swarm is assured.
- Describe how the C2 link works and the risks of it being lost during the operation.
- Describe all technical mitigations designed to prevent the loss of the C2 link. For example, any redundancy provided within the system through the use of independent C2 links.

1.2.13 C2 link frequency

- Any interference on the C2 link frequency must not present an intolerable risk of the loss of the C2 link.
- State which C2 frequency or frequencies will be used.
- Explain how potential RF interference is assessed prior to and during the operation. A calibrated spectrum analyzer or equivalent signal monitoring system should be used before and during flight.
- Explain how the operator ensures that they are aware of any notified RF interference for the date and time of the intended flight of the swarm.

1.2.14 C2 link signal latency

- The C2 link signal latency must be tolerable to maintain control of the swarm.
- Describe the proof that the signal latency timing within the C2 link falls within the tolerable limit.

1.2.15 GNSS

- The planned flight of the swarm must remain within the flight volume.
- GNSS must not be lost to the extent that the safe and effective control of the swarm cannot be maintained.
- It is not a requirement to use GNSS. However, if GNSS is used the following information must be included:
  - Describe the GNSS equipment used.
  - Explain how GNSS is used in the operation and the navigational precision required.
  - State the minimum number of satellites required for the operation.
  - Explain how the number of satellites is monitored before and during the operation.
  - Explain any use of dilution of precision indicators.

1.2.16 'Geo-caging' function

- The planned flight of the swarm must remain within the flight volume.
- A technical function which 'automatically' retains the swarm within a pre-defined airspace volume (sometimes referred to as a 'geo-caging' capability) may be used.
- However, if such a capability is being relied upon as a safety mitigation, the following information must be provided:
  - Describe the equipment being used to provide this capability.
  - Explain how the capability is used in the operation.
  - Explain how the navigational data being used accurately represents the flight volume.
  - Explain how reliable it is.

1.2.17 Visual conspicuity

- The swarm must be visually conspicuous.
- If operating at night, conspicuity lighting must be fitted to each UA.
- Display lighting may be used for visual conspicuity.
- If the swarm is for the purpose of public display, it is accepted that some or all UA may have their conspicuity lights off or flashing for periods of time. These periods should be minimized, and operators must demonstrate how they will mitigate the

safety risk to other air users during periods when some or all UA are not displaying conspicuity lighting.

- Describe how periods of flight by UA that are part of a public display and are not displaying conspicuity lighting are minimized.
- State the maximum distance that each individual UA can be expected to be seen using unaided eyesight (corrective spectacles may be used).

1.2.18 Flight termination function

- A flight termination function must be available to stop the swarm's flight in an emergency to prevent harm to people.
- Explain the flight termination function and how it ensures safe termination of the flight if required.
- Explain how the flight termination function ensures the swarm will not leave the emergency buffer.
- Return to Home function is not an appropriate flight termination function for swarms.

1.3 Safety Risk Assessment

- All safety risks associated with the operation must be tolerable and ALARP.
- It is important to ensure that mitigations that you rely on to reduce safety risk are described in Operations Manual and Technical Specifications Manual.
- In the Safety Risk Assessment, you must explain why all safety risks identified in operations manual and technical specifications manual are tolerable and ALARP.

1.4 Demonstration flight

- A demonstration flight, observed by CAASL staff, must be conducted.
- During the application process the applicant must conduct a demonstration flight which will be observed by CAASL staff. The demonstration flight is only required as part of the application process.
- The flight must comply with the following requirements:
  - The flight must be carried out in a sterile ground area.
  - The flight must demonstrate the proposed operation and emergency procedures.
  - Relevant equipment capabilities, particularly those which are being relied upon as safety mitigations, must be demonstrated.

Appendices

Appendix 1- VLOS Swarm for Public Display Diagrams

Note: The diagrams are not to scale

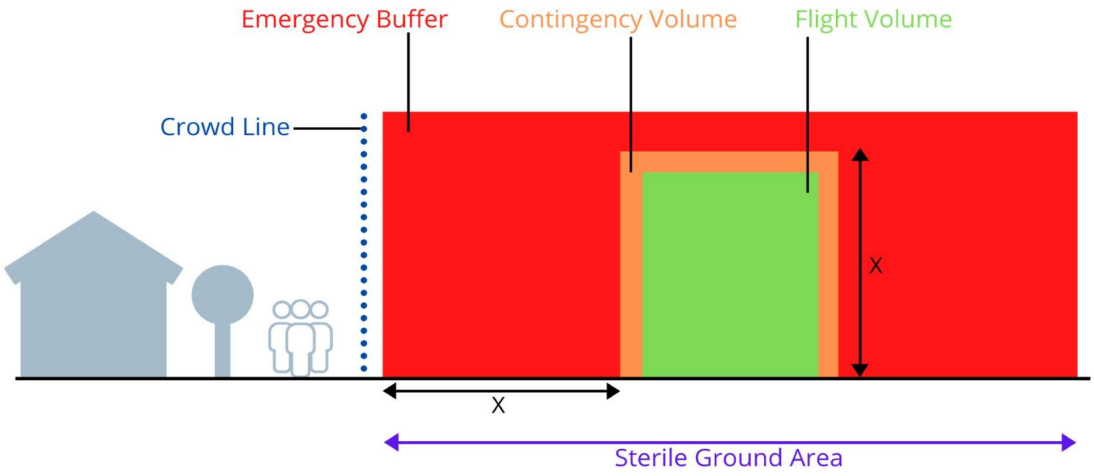

Figure 1. Side elevation view

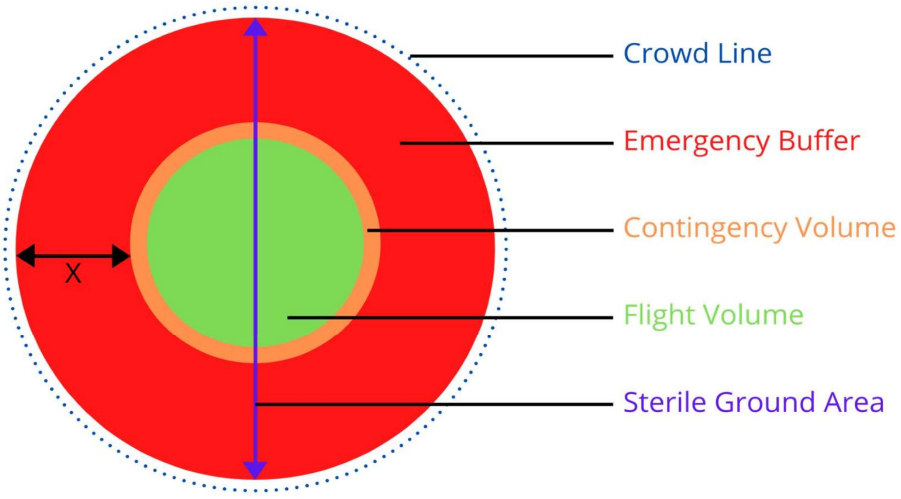

Figure 2. Plan view