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Operation Manual Drone Swarms

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The Operation Manual shall contain a description of the following:

1. **Organisation overview:**
    - Responsibilities and duties of the UAS operator. Describe the responsibilities and duties of personnel, describe all positions and people involved.
    - Safety: Describe how safety is integrated in the organization. What Safety Management System (SMS) is in place?
    - Maintenance: The maintenance instructions and procedures should be described. A maintenance log system should be available and a list of maintenance staff authorised to carry out maintenance is established and kept up to date. A record of all relevant qualifications and trainings completed by the staff shall be established and kept up to date. A management of the control software versions should be available.

2. **Standard Operating Procedures (SOP)**:

    Checklists (Pre-mission, Pre- and, Post-Flight) including the assessment of meteorological conditions and SOPs (to set up the drones). Drones and the Ground Control Station are inspected according to the manufacturer inspections. The crew is trained to perform inspections. Procedure to ensure coordination between the crew members and robust effective communication channels are available and cover assignment of tasks to the crew and the establishment of step-by-step communications. A policy is defined for the crew to declare themselves fit to operate.

    Procedure to assess the area of Operation: The operational volume and the buffers should be assessed by means of a Pre-mission checklist. The Pre-mission checklist should at least address:

    - Evaluation of the people in the operational Volume and the ground risk buffer. Only people directly involved with the operation of the UAS are allowed to be present. Those people should be fully aware of the risks involved with the UAS operation and have accepted these risks. They should furthermore be informed and able to follow relevant effective emergency procedures and contingency plans.

- Evaluation of the class of airspace and other aircraft operations. Coordination with local airports/heliports (5km radius) available if necessary. Includes assessment of: https://map.geo.admin.ch/?topic=aviation&bgLayer=ch.swisstopo.pixelkarte-grau&layers=ch.bazl.einschraenkungen-drohnen&X=189554.62&Y=664804.11&zoom=1&catalogNodes=1379&layers_opacity=0.6&lang=de

- The assessment of the surrounding environment and airspace, including, for example, the proximity of restricted zones and potential activities by other airspace users; Includes the assessment of the Daily Airspace Bulletin (DABS): https://www.skybriefing.com/

- Evaluation of Obstacles (High Voltage Lines, Buildings and so on): The operational volume and the ground risk buffer should not contain areas with obstacles unless under the control of the applicant. The flight should be planned accordingly.

- Evaluation of roads and railways: The Operational volume and the ground risk buffer should not contain areas with roads and railways unless closed or under control of the applicant.

- When UA VOs are used, the assessment of the compliance between visibility and planned range, the potential terrain obstruction, and the potential gaps between the zones covered by each of the UA VOs.

3. Normal procedures:

- The Normal Operation Strategy should contain all the safety measures, such as technical or procedural measures, crew training etc., that are put in place to ensure that the UAS can fulfil the operation within the approved limitations, and so that the operation remains in control.

- The intent of this chapter is to get a clear understanding of how the operation takes place within the approved technical, environmental, procedural limitations. Procedures to evaluate environmental conditions before and during the mission are available and include assessment of meteorological conditions with a simple recording system.

4. Abnormal operation and emergency operation:

- Contingency procedures: Procedures when a UA breaches the flight geography and/or the lost link strategy in case of loss of Command and Control.

- Emergency procedures: This procedure comes into force when exiting the contingency volume.

- Procedures to cope with uninvolved persons entering the controlled ground area, if applicable.

- De-confliction scheme (i.e. the criteria that will be applied for the decision to avoid incoming traffic). In cases where the detection is performed by UA VOs, the phraseology to be used.

5. Training:

- Brief description of the processes and procedures that the operator uses to develop and maintain the necessary competence for all staff involved in operations.

- Description of the processes and procedures that the operator uses to recruit and qualify all staff involved in operations. In particular, it should be described which are the licensing and rating requirements for remote operators (if any) or, if license is not required, how their qualification is carried out.

- Describe which processes and procedures the operator uses to ensure that the remote operators (if any) or other operational staff acquire and maintain the required currency to execute the various types of duties. A record of all relevant qualifications and trainings completed by the staff shall be established and kept up to date.

- Describe the Crew Training to avoid misunderstanding when communicating and to provide support and Monitoring.

- The training contains as minimum following elements:
  a) UAS regulation
  b) UAS Airspace Operating Principles
  c) Airmanship and aviation safety
  d) Human performance limitations
  e) Meteorology (Assessment of Meteorological conditions)
  f) Navigation/Charts
  g) Drone Swarm knowledge
  h) Standard Operating Procedures (SOP) and Procedures for Normal and Abnormal Operations (incl. Multi Crew coordination)

6. Emergency Response Plan (Optional but highly Recommended)

7. Unmanned Aircrafts (UA):

- Describe in detail the physical characteristics of the Aircraft (mass, center-of-mass, dimensions, etc.). Include photos diagrams and schematics, whenever deemed necessary to support the description of the UA.

- Describe the performance of the aircraft within the proposed flight envelope. Specifically, address at least the following items:
  a) Maximum altitude
  b) Maximum endurance
  c) Maximum range
  d) Maximum rate of climb
  e) Maximum rate of descent
  f) Maximum bank angle
  g) Nominal cruise speed
  h) Max cruise speed
  i) Never exceed airspeed

- Describe the motors, ESCs and propellers and their ability to provide reliable and sufficient power to take off, climb, and maintain flight at expected mission altitudes.
  a) Provide a high-level description of the electrical distribution architecture. Include items such as regulators, switches, buses, and converters, as necessary.
  b) What type of motor is used?
  c) How many motors are installed?
  d) What is the max continuous power output of the motor [Watt]?
  e) What is the max peak power output of the motor [Watt]?
  f) What current range does the motor have [Amps]?
  g) Does the propulsion system have a separate electrical source? If not, how is the power managed with respect to the other systems of the UA?
  h) Describe the electrical system and how it distributes adequate power to meet the requirements of the receiving systems. Provide a system level diagram showing electrical power distribution throughout the aircraft.

i) How is power generated on-board the aircraft (for example generator, alternator, batteries)?
j) If a limited life power source such as batteries is used, what is the useful life of the power source during normal and emergency conditions? How was this determined?
k) How is information on battery status and remaining battery capacity provided to the operator (if one is in the loop) or watchdog system?
l) If available, describe the source(s) of backup power in the event of loss of the primary power source.
  - What systems are powered during backup power operation?
  - Is there any automatic or manual load shedding?
  - How much operational time does the backup power source provide? Include the assumptions used to make this determination.
m) How is the propulsion system performance monitored?
n) What status indicators and alerts (such as warning, caution and advisory) messages are provided to the operator?
o) Describe the most critical propulsion-related failure modes/conditions and their impact on system operation.
p) How does the Unmanned Aircraft respond, and what safeguards are in place to mitigate the risk of propulsion system loss for each of the following?
  - Low battery
  - Failed signal input from the control station
  - Motor controller failure
q) Does the motor have in-flight reset capabilities? If so, describe the manual and/or automatic features of this capability

- Describe the LED equipment on-board the aircraft

8. UAS Control Segment

Provide an overall system architecture diagram of the avionics architecture. Include the location of all air data sensors, antennas, radios, and navigation equipment. Describe any redundant system, if available.

- Navigation:
  a) How does the UAS determine its location?
  b) How does it navigate to its intended destination?
  c) Describe the procedures to test the altimeter navigation system (position, altitude)?
  d) How does the system identify and respond to a loss of the primary means of navigation?
  e) Is there a backup means of navigation?
  f) How does the system respond to a loss of the secondary means of navigation, if available?

- Autopilot:
  a) How was the autopilot system developed? Which industry or regulatory standards were used in the development process?
  b) Is the autopilot a commercial off-the-shelf (COTS) product? If so, name the type/manufacturer and provide the criteria that was used in selecting the COTS autopilot?
  c) Describe the procedures used to install the autopilot. How is correct installation verified? Reference any documents or procedures provided by the manufacturer and/or developed by your organization.
  d) Does the autopilot employ input limit parameters to keep the aircraft within defined limits (structural, performance, flight envelope, etc.)? If so, what are these limits? How were these limits defined and validated?

- Control Station (CS[1]):
  a) Describe or diagram the CS configuration. Include screen captures of the control station displays.
  b) How accurately can the operator determine the attitude, altitude (or height) and position of the UA?
  c) What critical commands are safeguarded from inadvertent activation and how is that achieved /for example, is there a two-step process to command “kill-engine”)? What kind of inadvertent input could the operator enter to cause an undesirable outcome (for example, accidentally hitting the “kill engine” command in flight)?
  d) Are any programs running concurrently on the ground control computer? If so, what precautionary measures are used to ensure that flight-critical processing will not be adversely affected?
  e) What are the provisions taken against a CS display or interface lock-up?
  f) What alerts (such as warning, caution, and advisory) does the system provide to the operator (for example low fuel or battery, failure of critical systems, operation out of control)?
  g) Describe the means of power to the CS, and redundancies if any.
  h) What are the procedures in place in case of CS loss of primary and secondary power (if any)?
  i) If a “Handover” is envisaged between two or more control stations, describe the process to ensure that only one control station has control over the UA.

- Command and control link segment:

  Provide a detailed control system architecture diagram that includes informational or data flows and subsystem performance. Include values for data rates and latencies, if known.

  Describe the control link(s) connecting the UA the CS and any other ground systems or infrastructures, if applicable. Specifically address the following items:
  a) What spectrum will be used for the control link? What is the maximum power spectrum?
  b) Is there a radio signal strength and/or health indicator or similar display to the operator? How is the signal strength and health value determined, and what are the threshold values that represent a critically degraded signal?
  c) What design characteristics or procedures are in place to prevent or mitigate the loss of the datalink due to the following?
     - RF or other interference
     - Flight beyond communications range
     - Antenna masking (during turns and/or at high attitude angles)
     - Loss of UA functionality
     - Atmospheric attenuation including precipitation

- C2 Link Degradation and/or loss:

  a) What are the procedures in case of C2 link degradation?
  b) How is the status of the C2 Link displayed to the operator?
  c) What are the conditions to trigger the C2 link loss procedure?
  d) What are the measures in case of loss of the C2 link (lost link)?

- Safety features

  Describe the emergency recovery capability to prevent third party risk (incoming air traffic or people entering the ground control area). This typically consists of:
  a) A flight termination system (FTS), procedure or function that aims to immediately end the flight, or,
  b) An Automatic Recovery System (ARS) that is implemented through UAS crew command or by the on-board systems. This may include automatic preprogramed course of action to reach a predefined and unpopulated forced landing area.

[1]The UAS information and control interfaces should clearly and succinctly present and do not confuse, cause unreasonable fatigue, or contribute to remote crew error that could adversely affect the safety of the operation. Remote Control Display, UA Interface as well as alerting/warning system design take into account the capabilities and limitations of human information processing to prevent human error.