EASA Design Verification Report
Project: VC200-2
Applicant: Volocopter, Zeiloch 20, 76646, Bruchsal, Germany
EASA Task Number 60078814

Date: 16.06.2021

To whomever it may concern,

Volocopter has applied on 31 May 2021 to EASA for a design verification of the UAS model VC200-2 with scope “enhanced containment”. The design verification does not include the assessment of any operational safety objective (OSO) or mitigation means.

The requirements contained in Regulation (EU) N° 2019/947 and (EU) 2019/945 of 24 May 2019 (operation of unmanned aircraft, unmanned aircraft systems and third country operators of unmanned aircraft systems), as amended to this date, have been considered as well as AMC to regulation 2019/947 and specifications of SC Light UAS utilized as design verification basis.

EASA evaluation was based on data provided by Volocopter and on ground and flight test witnessing. Main objective of the evaluation was to assess compliance with the applicable guidance, guidelines and limitations, evaluate the associated compliance data proposed by Volocopter and agree on recommendations to the operator in terms of operational limitations and conditions to achieve the relevant enhanced containment.

Based on the evaluation conducted, EASA has no technical objection regarding the operational approval of VC200-2 as defined in Annex 1 under the following provisions :

- The EASA design verification is limited to enhanced containment step 9 of the SORA process, as per AMC to Article 11 to Regulation 2019/947, paragraph 2.5.3 (c) a) and b)
- The conditions and restrictions defined in the Design Verification Report are met
- Design verification basis: SC Light UAS adopted by EASA on 17 December 2020
    - Selected Specifications: Light-UAS 2511 (b) complemented by notes as per SC
- Applicable limitations and conditions:
    1. Operation in VLOS only
    2. Geographical Volume, Contingency Volume and Ground Buffer: Annex 1
    3. FTS ground segment installation, position and operation constraints: Annex 1
    4. CU position and operation constraints: Annex 1
    5. Environmental limitations: Annex 1
    6. Maximum Cumulative Flight Hours: -3
        - Volocopter shall record and make available to the competent authority the flight time performed by the aircraft up to the request of any operational authorization for which this DVR constitutes evidence of design compliance required by the competent authority
    7. The evaluation was based on operational areas located outside the center of large cities

This letter does not constitute operational approval. The operator remains responsible for demonstrating compliance with any requirement as established by the competent authority in the frame of an operational authorization. Operational aspects described in Annex 1 need to be addressed

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as part of the operational procedures included the risk assessment provided to the competent authority.

Annexes:

- Annex 1: ENG-VC2-256-006, Rev. A00, dated 16.06.2021, UAS Configuration and Operational Limitations Linked with Design

Sincerely,

Volker Arnsmeier
Section Manager
EASA - Certification Directorate

cc.: Antonio Marchetto, EASA Certification Directorate

Engineering Documentation

Document ID:

ENG-VC2-256-006

UAS Configuration and Operational Limitations Linked with Design

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Revision History

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A00	All	New Document	2021-06-16

References

[1] „ENG-VC2-042-031, Fligh Test Results, 2X Flight Termination System“.

[2] „ENG-VC2-256-001, VC200-2 Flight Termination System Summary Report“.

[3] „ENG-VC2-010-021, VC200-2 SORA for Paris Air Forum unmanned flight“.

[4] „ECM-2021-193, VC200-2 Crash Area Assumptions“.

[5] „ENG-VC2-010-022, Concept of Operations for VC200-2 Unmanned Flight during Paris Air Forum 2021“.

Abbreviations and Definitions

a. List of Abbreviations

Abbrev.	*Meaning*
COTS	Commercial Off the Shelf
FTS	Flight Termination System
FTR	Flight Termination Receiver, onboard
FTU	Flight Termination Unit, on ground
N/a	Not applicable

Abbrev.	*Meaning*
SOC	State of Charge
SORA	Specific Operational Risk Assessment
UAS	Unmanned Aircraft System

b. Definitions

N/a

1. Introduction

The purpose of this document is to provide summary information regarding Volocopter VC200-2 UAS design, design of Flight Termination System (FTS), required operational limitations for safe operation of aircraft and system and performance data used for the assessment of critical scenarios. The data provided to support design verification of the FTS system by EASA within task number 60078814 to obtain flight approval for the aircraft.

2. Applicable UAS Configuration and Performance Limitations

2.1 UAS Configuration

2.1.1 UAS General Design

Volocopter VC200-2 "2X" aircraft in remote-controlled configuration is a purely electric aircraft that uses distributed electric propulsion technology to enable vertical take-off and landing (VTOL), hover as well as cruise capabilities and allows it to carry heavy loads along a remote piloted flight path. Flights are carried out under conditions of VLOS/Day. Aircraft can be converted in man and remote-controlled configurations.

The primary structure of aircraft is manufactured from composite materials. The distributed electric propulsion system of the VC200-2 is comprised of 18 evenly distributed, independently controlled electric motors which by design provide a high level of redundancy with respect to and contributing to a high system reliability.

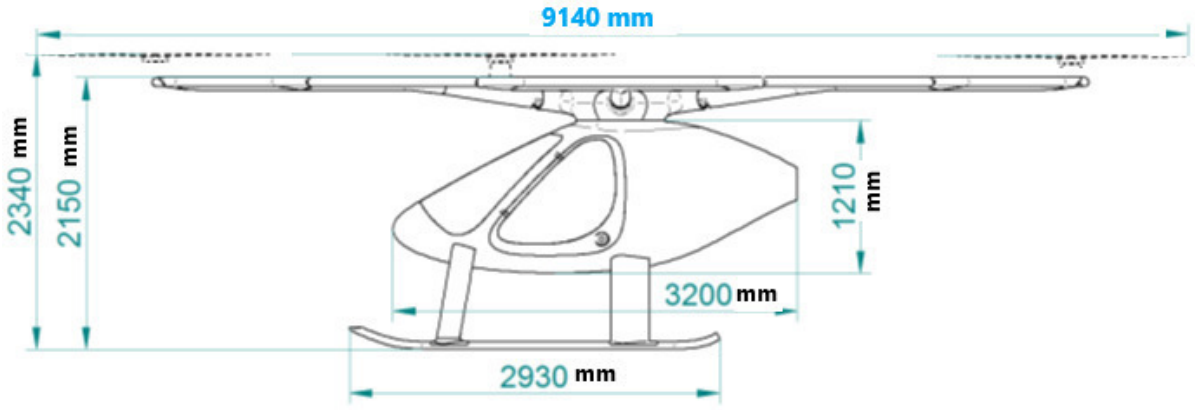

Fig. 1: Volocopter VC200-2, side view

The following table shows an overview of the technical data:

Item	Value
number of electrical motors and propellers	18
diameter of the rotor rim (excl. propellers)	7.34 m
diameter of a single propeller	1.80 m
overall aircraft height	2.34 m
max maneuvering load	+2,5/-1 g
aircraft width / length	9.14 m

The aircraft is equipped with airborne equipment which provides all necessary information to the remote pilot to perform the intended flight. This includes specifically means of measuring and displaying magnetic heading, time in hours, minutes and seconds, pressure altitude and ground speed indication.

The aircraft has been designed in accordance with requirements of LTF-ULC in status as of 2018-11-05 and has obtained a Permit to Fly (PtF) from the German Authority DULV as an ultralight aircraft.

2.1.2 FTS Design

The Flight Termination System (FTS) comprises of ground based and onboard COTS components.

Onboard FTS components are:

- FTS Receiver Unit – TFTR-3945,
- FTS Antenna Signal Combiner Unit – TPU2-UHF-W2,
- FTS Onboard Antenna 1&2 – Airborne Blade Antenna UHF Type TB0405,

The components of FTU are:

- FTS Ground Transmitter Unit – FTS FTU Flight Termination System Field Test Unit,

Fig. 2. – FTU General Appearance

- FTS Ground transmitter antenna - TOC-500/RK70,

The antenna can be mounted on different mast. The tripod is the default option to allow for a convenient transportation.

The FTS receiver antennas are installed on the bottom side of aircraft fuselage, as shown on Figure below.

Fig. 3. – allocation of FTS onboard antennas on aircraft

The receiver and antenna signal combiner are installed on the special equipment board in aircraft cockpit.

Detailed information regarding FTS system components and their tested installation configuration is provided within [1], [2] and Manufacturer manuals.

2.1.3 UAS Command Unit, Command and Control Datalink

JETI DS-14 hand-held transmitters are used as primary and backup controls of the aircraft. The general view of transmitter DS-14 is shown on figure below:

Fig. 4 – Transmitter DS-14 General View

The specifications of the JETI DS-14 are shown in the following table:

Weight [g]	1300
Dimensions [mm]	194x233x40
Output Power - 2.4GHz [mW]	100
Number of channels	14
Resolution	4096 steps
Telemetry	Yes
Operational temperature [°C]	-10 ... 60
Operating time [h]	11
Compatible protocols	DUPLEX 2.4GHz EX, EX Bus

As C2Link onboard equipment, the receiver DUPLEX R14 EX is used as primary and Jeti Duplex RSAT 2 as backup for each control link.

Fig. 5 – Receiver Duplex R14 EX

Fig. 6 – Receiver Jeti Duplex RSAT 2

Weight [g]	30
Dimensions [mm]	62 x 38 x 16
Number of channels	14
Telemetry	Yes
Operational temperature [°C]	-10 ... 85
Compatible protocols	DUPLEX 2.4GHz EX, EX Bus
Antenna Length [mm]	2 x 400
Supply Voltage [V]	3,2 - 8,4
Average Current [mA]	40
Satellite receiver support	Yes
Output Power [dBm]	15
Receiver Sensitivity [dBm]	-106

Fig. 7 Duplex R14 EX parameters

Weight [g]	6
Dimensions [mm]	38 x 20 x 7
Number of channels	16
Telemetry	Yes
Operational temperature [°C]	-10 ... 85
Compatible protocols	DUPLEX 2.4GHz EX, EX Bus
Antenna Length [mm]	2 x 200
Supply Voltage [V]	3,2 - 8,4
Average Current [mA]	30
Satellite receiver support	No
Output Power [dBm]	15
Receiver Sensitivity [dBm]	-106

Fig. 8 –Jeti Duplex RSAT 2 parameters

For the first C2Link - the primary Duplex R14 receiver is located inside cockpit in forward area and connected with a backup receiver Duplex RSAT 2 located on the front right landing gear skid outside the aircraft.
For the second C2Link - the primary Duplex R14 receiver is located behind the pilot seat and connected with a backup receiver Duplex RSAT 2 on the rear of landing skid outside the aircraft.

2.2 UAS Performance Limitations

The following UAS performance limitations are applicable and assumed to support intended safe operation of UAS:

Item	Value
max. take-off weight (MTOW) (remote controlled configuration)	467 kg
Operational flight speed*	8 m/s
Electrical energy (70% SOC)	14 kWh

*maximum ground speed allowed during operation

Flight time and flight range highly depends on temperature of air as it affects operating temperature of motors and motor controllers. The following values are specified as limitations depending on OAT:

Temperature range	Limitation
-5°C to +30°C	Maximum flight time 17 minutes
+31°C to +35°C	Maximum flight time 10 minutes
+36°C to +40°C	Maximum flight time 5 minutes (3 km)

These values are based on performed flight testing in different environmental conditions and provided within Aircraft Flight manual as operating limitations.

The following UAS performance values are considered within analysis of aircraft operation critical scenarios:

Item	Value
V_C, cruise speed	65.6 km/h (35.4kts)
V_{BE}, speed for best endurance	44 km/h (23.7 kts)
$V_{NE,}$ never-exceed speed	100 km/h (54kts)
Horizontal speed at maximum rate of climb	56.5 (30.5 kts)
Maximum rate of climb	2.5 m/s
Rate of climb at V_{BE}	2.0 m/s

The detailed information and assessment of critical operational scenarios and related information on termination speeds, impact areas and potential flyaway ranges is provided within documents [3], [4].

3. CONOPS Syllabus

Following the performed analysis, the finally defined values of the Operational Volume and Risk Buffers are:

Flight Geography: 75 meters (width) x 150 meters (length) x 30 meters (height)

Operational Volume – 135 meters (width) x 210 meters (length) x 60 meters (height).

Ground Risk Buffer – not less than 95 meter per side around ground perimeter of Contingency Volume

Optional Air risk Buffer – additional 30 meters above Contingency Volume, lead to the 90 meters of height.

The plan view of the Operational Volume and minimum required Ground Risk Buffers are shown on Figure 9.

The vertical cross-section view of the Operational Volume and minimum required Ground Risk Buffers are shown on Figure 9.

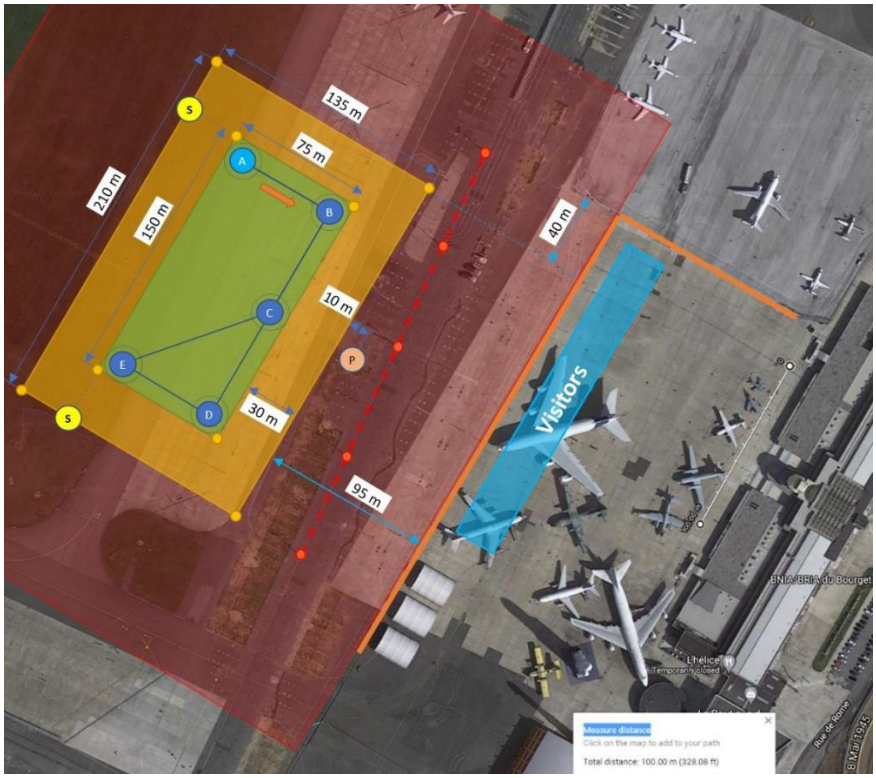

Fig. 9 – Operational Volume and Risk Buffers, Plan View.

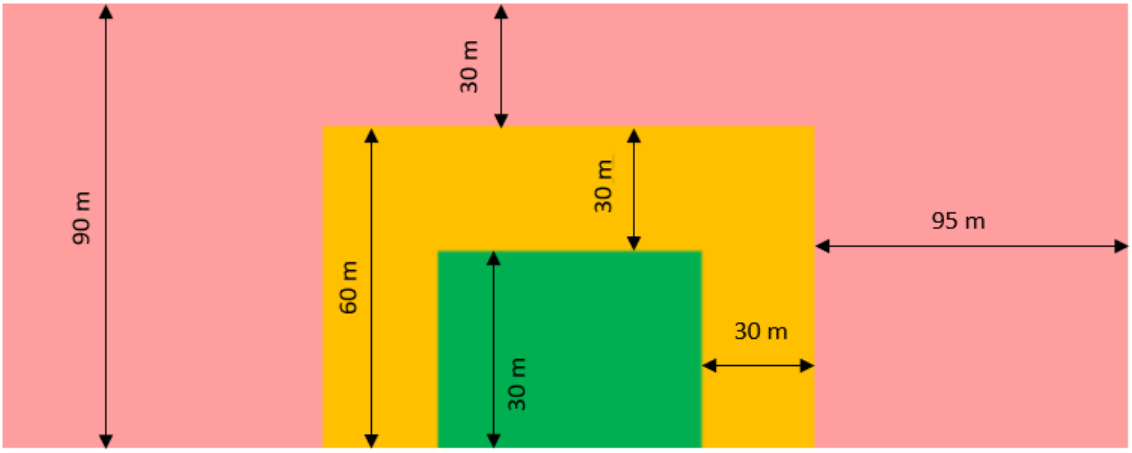

Fig. 10 – Operational Volume and Risk Buffers, Section (Vertical) View.

Operational Volume and required Ground Risk Buffer are based on UAS operation height in operational volume, operational speed, latency of equipment, latency of human reaction and assumption of crash areas for worth case scenarios with further termination of aircraft by FTS. Detailed calculations are provided within [3], [4].

4. Command Unit and Flight Termination System Operation

The Flight Termination System (FTS) comprises a Flight Termination Unit (FTU) (part of system operated on the ground) and an airborne Flight Termination Receiver (FTR). The FTU need to be located next to the Pilot (Position “P”, Figure 11.) The overall setup respects the following considerations and learning regarding the FTU antenna placement, distance to be covered in general and radio line of sight (signal obstruction risk):

- The FTU to be located at position “P”, i.e. inside the “red” ground risk buffer area next to pilot “P” (about 5 m away from pilot);

- The FTU antenna to be mounted on tripod not less than 2 m height, distanced at 10 m away from its power supply (e.g. from van used as power supply source) and FTU;
- During the performance of each aircraft flights, the radio line of sight between FTU antenna and aircraft must not be obstructed;
- The Command Units must not move during operation. The ground crew, including Remote Pilot and other personnel can be located in vicinity of FTS Operator (at point “P”), but are instructed to not obstruct the FTS Operator’s view towards spotters and the aircraft, nor the radio line of sight between FTU antenna and aircraft at any point in time.
- FTU with antenna need to be located at least 60 m away from any big metal objects such as metal light poles, metal fences or any other metal structure with potential effect on FTS operation.
- The ground on which the antenna and FTU to be placed, is evenly flat and solid similar to the airfield used for ground and flight tests in Lahr Airport.
- The aircraft flight is performed by direct commands of the Remote Pilot. The Command Units are portable handheld devices operated by the Remote Pilot and Backup Pilot, with geometry such that radio line of sight exists at all times between Command Unit(s) and aircraft. The aircraft health monitor (Laptop) is located next to the FTU on a desk.
- The maximum expected distance from position “P”, where the FTS transmitter antenna is located, to the furthest extent of the Operational Volume is around 150 m in horizontal plane, such that an additional distance buffer of min. 50 m exists, compared to the tests performed at Lahr Airport. The maximum allowable operational distance between FTU transmitter and aircraft (slant) must not exceed 200 meters, and AGL must be less than 90 meters . These values were confirmed by flight test and test results are described in [1].

The FTU is operated by in independent person in its role as “FTS Operator” as per ConOps [5]. Trained spotters (positions “S”, Figure 11) will signal a breach of the contingency area to the FTS Operator.

FTS Operator performs independent (from Remote pilot) decision for arming of FTS (as soon as aircraft enter Contingency Volume) and activation of FTS (as soon as aircraft leaves Operational Volume).

The spotters issue the kill command to the FTS operator when the aircraft reaches the Ground Risk Buffer. The spotters inform FTS Operator regarding movement towards the limit of the Operational Volume visually and by radio, as specified in Conops [5]. There are unique visual and radio spotter’s signals for the cases of Contingency Volume enter and case of Ground Buffer enter, as specified in [5].

In addition, the Remote Pilot may call a “kill, kill, kill” command to FTS Operator before it leaves Contingency Volume and enter Ground Risk Buffer as well. This way, flight termination command is independently assured from the pilot’s role to safe the aircraft in case of difficulties, as it is described in Conops [5].

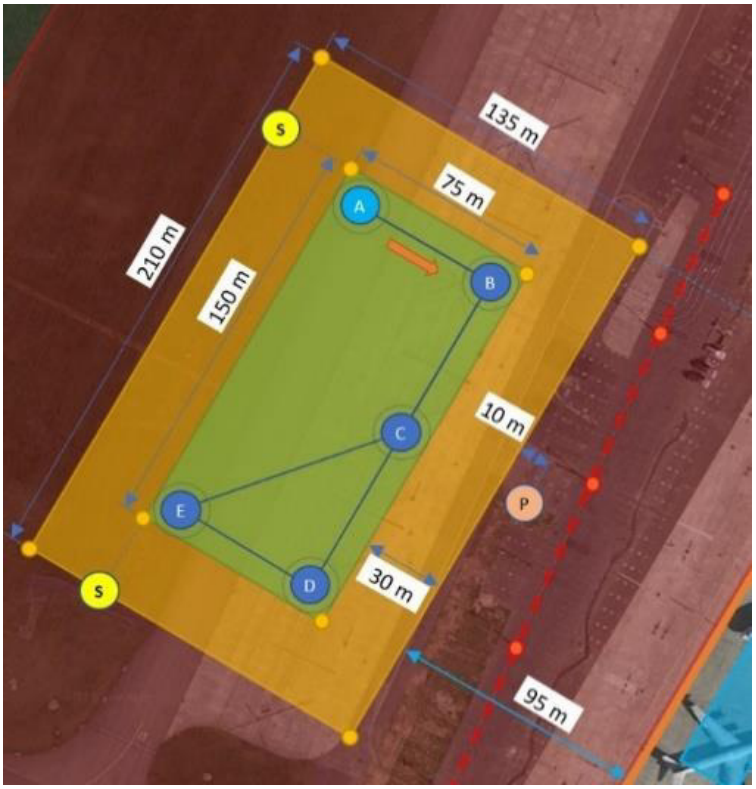

Fig. 11.- Operational Area (green and amber) and ground risk buffer (red). Pilot and FTS Operator are located at positon "P".

Detailed information on the performed ground and flight testing for substantiation of operational limitations as specified above are provided within [1].

5. Environmental Limitations

Operation of the VC200-2 is only permitted for:

- Daylight conditions,
- No rain, no lightning conditions,
- OAT temperatures: -5°C +40 °C,
- Maximum wind below 10 kts, gusting 15 kts,
- barometric pressure above 972mbar (1,05 kg/m³).

The onboard FTS components can be operated in temperature range: -40°C to +85°C. The FTS FTU component can be operated in temperature range: -40°C to +85°C, with humidity up to 95%. The C2 Link Command Unit can be operated in temperature range: -10°C to +60°C.