PROPOSAL OF A CERTIFICATION SPECIFICATION FOR A LIGHT UNMANNED AERIAL SYSTEM (CS-LUAS)

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Abstract

Unmanned Aerial Systems (UAS) are a rising field of interest in aviation. Besides military applications where UAS have been operated for years in 4D (Dull, Dangerous, Dirty and Deep) missions, civil applications are stagnating. The development of civil Light Unmanned Aerial Systems and their integration into civil aerospace is presently a topic of interest for National Aviation Agencies and International Aviation Organizations. While large UASs will be covered by an EASA-building code, the design approval of light drones (Class I and Class II) will remain in the jurisdiction of National Aviation Authorities. To insure a homogeneous procedural method, the Joint Aviation Authorities (JAR) founded the task group Joint Authorities for Rulemaking on Unmanned Systems (JARUS) with the aim to acquire and to agree on a basic prescription.

In a preliminary investigation, a certification specification for Light Unmanned Aerial Systems (CS-LUAS) was developed in order to ensure a common and easy certification process for Unmanned Aerial Vehicles with a maximum takeoff weight of 150kg, the ground control unit and the command and control datalink. The tailoring principle was applied in order to obtain the building code. The certification specification for Very Light Aeroplanes (CS-VLA) was chosen as a baseline and every paragraph was reviewed and evaluated concerning its applicability for UASs. Besides the mentioned certification specification, the NATO Standardization Agreement STANAG 4671 was incorporated to cover aspects like the departure, landing and equipment that is necessary for a safe operation of the unmanned system.

The proposed draft of a certification specification for Light Unmanned Systems will be reviewed in the JARUS task group and will contribute to the development of a pan-European building code for light UAS.

1. INTRODUCTION

In the last century, unmanned aircraft were only used for missions with a minor value such as weather balloons or radio-controlled toys for children of all ages. This suddenly stopped when technology enabled aircraft to fly completely autonomously. Today Unmanned Aerial Vehicles are able to lift off, carry out manoeuvres or tasks and land without the need of a pilot or an operator with only the help of Global Positioning Systems (GPS) and a high performance computer.

The advantages of UAVs are obvious. Longer endurance, higher manoeuvrability and improvements in safety issues are only a few aspects that militate in favour for the use of unmanned aircraft. First, these advantages were only used by armed forces because of looser regulations and a stronger financial background. Over the years, unmanned planes and rotorcraft became more and more important in civil applications as well. Studies show that fully autonomous drones can perform Search and Rescue missions, observe crowds of people during mass rallies, carry out atmospheric research tasks and much more. But to fulfil the braced duties, these aerial vehicles must be integrated into national and international airspace.

The Convention on International Civil Aviation (also known as Chicago Convention) requires a certification of all types of aircraft that intend to fly in controlled and uncontrolled airspace [7]. Due to the fact that unmanned aviation is quite a young field in aviation, no ratified regulatory framework exists so far.. The first steps heading towards a certification specification for UASs are an EASA paper that provides basic guidelines such as the tailoring principle and the kinetic energy approach [6] and a military standardization agreement (STANAG) by NATO [8]. This agreement cannot be applied directly to civil UAS because of differences in the operation, mission requirements and claimed reliabilities. But the EASA paper claims that with the application of the tailoring principle a suitable building code for manned aircraft can be adapted for the use with unmanned aerodynes [6]. With the defined approach a certification specification for an unmanned rotorcraft system was developed. This specification is currently in a review process at EASA and will be issued as soon as the last critical aspects are clarified. The resulting building code can then be used for the type certification of unmanned rotorcraft systems (see [1]). Without a valid type certificate the unmanned aircraft is not allowed to fly in non-segregated airspace.

Another problem that has to be faced is that the whole Unmanned Aerial System consists of more than just the airplane. Certification of the operating crew is not considered in the regulatory JAR-FCL [10]. So the existing personnel licensing regulations have to be adapted for UAV operators and engineers. That leads to the embargo that that the operation of UAS in civil airspace is currently forbidden by Austrian law. The only way to operate an unmanned aircraft in Austria is when Austro Control issues an exception approval. This approval is valid for only a specific aircraft in a restricted area and comes with strict obligations that have to be followed.

A second big aspect that has to be thought of is that all existing guidelines for communication links do not treat the need of high bandwidths for the Up-and Downlink of the autonomous plane. Therefore the datalink with the allocation of the required frequencies has to be a major chapter of the certification specification. The last subsystem of the UAS that has to be considered in the CS is the ground control unit. The operator of the UAV must be able to take over the control of the vehicle in order to ensure a safe operation. To fulfil this claim all cockpit instruments that are needed for a safe flight have to be displayed in the ground control unit.

For a homogenous and conjoint certification process a certification specification for Light Unmanned Aerial Vehicles has to be defined.

1.1. UAV versus Model Aircraft

Many contracting countries of EASA claim that there is currently no sufficient regulation for the certification of UAS. In Austria, national law does also not provide a jurisdiction for unmanned aircraft. Because of the lack of regulatory framework, some manufacturing companies define UAS as radio controlled aircraft for which national regulations exists.

When looking at the definition under §22 LFG [9] a radio controlled plane is rated as aeronautical equipment. Paragraph §5 of ZLLV [10] classifies R/C planes as equipment that can either be operated independent in air or on ground without being an aerodyne.

An EASA definition of a R/C airplane is that those airplanes are either a replica of an already existing plane or a plane that is designed to be flown in the visual line of sight of the pilot for non-commercial leisure or model sport use [3]. For those planes the following operating limitations exist.

Table 1: Limitations for radio controlled aircraft(data from [3])

Constrain	Value
max. altitude	150 m (above ground level)
max. weight[1]	25 kg MTOW
max. noise emission	96 dB(A)

The table shows that the weight of model planes is limited to 25 kg MTOW. To operate planes that exceed this weight a model permit is necessary. The responsible authority in Austria is the “Österreichischer Aeroclub”. To harmonize the certification for those planes the EASA intends to issue a certification guideline for R/C planes with a MTOW up to 150 kg.

[1] The weight limit of 25kg is only applicable for aircraft without a model permit.

Besides the shown limitations, model aircraft are restricted concerning the transport of animate beings and the commercial use. The last aspect is one of the major distinctions between radio controlled aircraft and UAS. Unmanned Aerial Systems are intended to be operated below the visual line of sight without the steady steering input of a pilot. Besides that, an unmanned aircraft features in contrast to a model aircraft, an up-and a downlink for communication.

Those aspects and the fact that an UAS should participate in controlled airspace show that the operation of an Unmanned Aerial System as a radio-controlled airplane is not approvable by the national aviation authorities.

1.2. Classification of UAV

UAS international has set up a draft for a categorization of UAVs depending on the Maximum Take Off Weight (MTOW), the maximum altitudes and the like [2]. This permits to slot not only all UAVs that are currently under development but also all existing unmanned planes.

The purpose of this arrangement is to implement an international and common system for the tactical categorization to simplify the certification process. The following table shows key aspects for different classes of UAV.

Table 2: Classification of UAV (data from [2])

UAS Category	Acronym	Range (km)	Flight Altitude (m)	MTOW (kg)
Nano	η	<1	100	<0,025
Micro	μ	<10	250	<5
Mini	Mini	<10	150	<30
Close Range	CR	10-30	3.000	150
Short Range	SR	30-70	3.000	200
Medium Range	MR	70-200	5.000	1.250
Medium Range Endurance	MRE	>500	8.000	1.250
Low Altitude Deep Penetration	LADP	>250	50-9.000	350
Low Altitude Long Endurance	LALE	>500	3.000	<30
Medium Altitude Long Endurance	MALE	500	14.000	1.500
High Altitude Long Endurance	HALE	>2000	20.000	12.000
Unmanned Combat Aerial Vehicle	UCAV	appr. 1500	10.000	10.000
Stratospheric	STRA	TBD[2]	>20.000 <30.000	TBD
Exo-Stratospheric	EXO	TBD	>30.000	TBD

The following figure shows the number of UAVs in development or currently in service according to the described categorization.

[2] TBD: To Be Defined

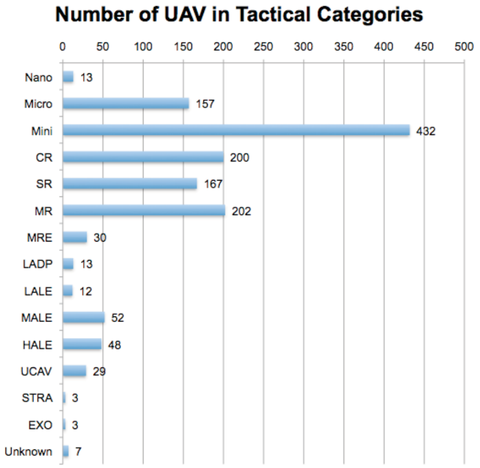

Figure 1: Number of UAV in tactical Categories (data from [2])

2. CERTIFICATION SPECIFICATION

In the next chapter the methodical background and the resulted certification specification for light Unmanned Aerial Systems are presented. First the kinetic energy method and the Tailoring Principle are highlighted followed by an explanation of the building code CS-LUAS.

2.1. Kinetic Energy Method

Typically the methodology of kinetic energy is used for determining the applicable airworthiness codes. The kinetic energy for two scenarios, the unpremeditated descent scenario and the loss of control scenario are calculated and with the help of two figures, the suitable building code can be identified.

The first state that has to be computed is the unpremeditated descent scenario (UDS). This describes the kinetic energy that results in the inability of the aircraft to maintain a safe altitude above the ground. This state is dominated by the reliability of the propulsion system and is calculated with the maximum takeoff mass and the stalling speed in landing configuration to the power of two multiplied with a safety factor of f=1,3 according to the type of aircraft.

(1) $$v_{UDS} = f \cdot v_s$$

(2) $$E_{kin\_UDS} = \frac{m_{MTOW} \cdot v_{UDS}^2}{(10^9 J/GJ)}$$

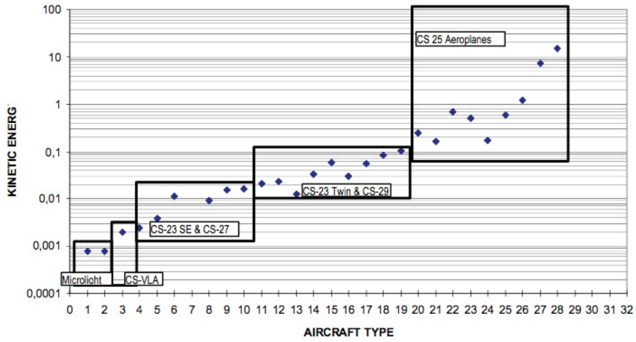

Figure 2: Assignment of applicable certification specifications according to the kinetic energy (UDS scenario) [6]

Figure 2 shows the graphical interpretation of the kinetic energy method. The gained values in the figure are only applicable for the regarding aircraft type. For the CS-LUAS the aircraft type is a very light aircraft with a single piston engine (type 3 in the graphical illustration).

The second state that has to be considered is the loss of control scenario (LOC). This state describes the kinetic energy that occurs in case of a failure that may lead to an impact on ground at a high velocity. The mass is again the MTOW multiplied with the maximum operating speed to the power of two combined with a safety factor of g=1,4.

(3) $$v_{LOC} = g \cdot v_{mo}$$

(4) $$E_{kin\_LOC} = \frac{m_{MTOW} \cdot v_{LOC}^2}{(10^9 J/GJ)}$$

The calculated values can be interpreted with the following figure. Again the code for the aircraft type is 3 for very light aircraft.

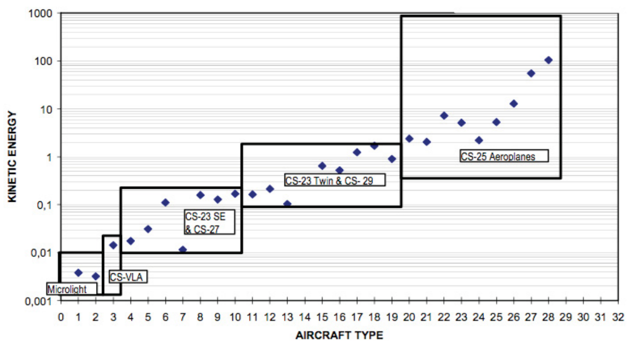

Figure 3: Assignment of applicable certification specifications according to the kinetic energy (LOC scenario) [6]

For the LUAS certification specification the described kinetic energy calculation works vice versa. With the maximum allowed kinetic energy for this class the according speed limitations can be calculated. Figure 2 and Figure 3 show the maximum allowed kinetic energy per aircraft type. These values can be used to calculate the maximum speeds for the certification specification LUAS. The adapted formulae that are described in this chapter result in the maximum allowed operating v_{mo} and stalling speed v_s.

(5) $$v_s = \frac{1}{f}\sqrt{\frac{E_{kin\_UDS} \cdot 10^9}{m_{MTOW}}}$$

(6) $$v_{mo} = \frac{1}{g}\sqrt{\frac{E_{kin\_LOC} \cdot 10^9}{m_{MTOW}}}$$

With the maximum energies referring to Figure 2 and Figure 3 and the described safety factors the speeds can be calculated.
For the calculations the maximum takeoff weight is fixed to 150kg, the maximum allowed weight for aircraft certified with the CS-LUAS.

Table 3: Kinetic energy according to [6]

Scenario	max. kinetic energy
USD	0,003GJ
LOC	0,02GJ

These values provide the following results:

- v_s=108,8kt
- v_{mo}=260kt

The computed values show that the maximum stalling speed is limited to approximately 105kt and the maximum operating speed is limited to 260kt in order to comply with the requirements given by the EASA.

2.2. Tailoring Principle

The certification of a new aircraft demands a certification guideline, the certification specification. There are two approaches to define a new certification. The first approach is to start the certification specification without any baseline off the scratch. The other mean is to tailor an already existing certification specification for an aircraft type similar to that type that is intended to be certified. If this is the case, every paragraph of the existing certification specification has to be reviewed and it's applicability has to be evaluated.

In order to ensure a consistent tailoring procedure, the following code issued by the EASA should be used.

Table 4: Tailoring code according to [6]

Code	Description
F	This aspect of the certification specification is fully applicable
N/A	The explained paragraph in the CS is not applicable for UAS due to their characteristics (e.g.: no onboard pilot, no passenger compartment, …)
N/A-C	Not applicable to UAS because of the assumed configuration
I	This aspect is intended to be used for the new CS. Minor changes in the wording etc. have to be done
P	The paragraph is only partially applied. This means that some aspect must be applied but others are not applicable for the unmanned aerial system.
A	This aspect is not applicable but alternative criteria have to be issued.

After the tailoring, some paragraphs might have to be added to the resulting certification specification in order to ensure the safe operation of the equipment that exists in the UAS.

During the certification process of an UAS, critical review items (CRIs) can be raised by the National Aviation Authority to provide an equivalent level of safety compared to manned aviation. In particular this is the case where the code A (alternative) was proposed which results special conditions in the certification specification.

2.3. CS-LUAS

In the following paragraph the draft of the CS-LUAS is presented. In order to get a better overview this section is split into three parts, namely the vehicle itself, the command and control datalink and the ground control unit.

2.3.1. Unmanned Aerial Vehicle

The requirements for the vehicle (A – General, B – Flight, C – Structure, D – Design and Construction, E – Powerplant, F – Equipment and G – Operating Limitations and Information) were tailored from the certification specification for Very Light Aeroplanes. Due to the similarities like the speeds, weight and operational characteristics the bulk of requirements remained unchanged. This resulted in a building code with unchanged factors of safety, flight loads, stability and performance characteristics.

Because of weight, operational and noise abating reasons, a lot of today's operating UAVs are equipped with an electrical engine. Therefore requirements like the maximum engine torque were added to this draft for this type of engine. In order to keep the certification specification as ubiquitous as possible, requirements for turbine engines were added as well. The two standards for electrical and jet engines were tailored from a draft of the certification specification for Light Unmanned Rotorcraft System (CS-LURS).

2.3.2. Command and Control Datalink

The command and control datalink is used for the interaction between the ground control unit and the aerial vehicle. During a normal flight, the UAV transmits data like the flight path angles, the Euler angles and the position and speed to the ground control unit, where the data is displayed to the operator who must be able to take over the control of the aircraft at any time. When the UAV is operated in the radio line of sight the transmission can be accomplished via antenna signals. Depending on the range, the mission and the visibility this can be sufficient. If the UAV is operated beyond the radio line of sight, a satellite is needed in order to relay the signals.

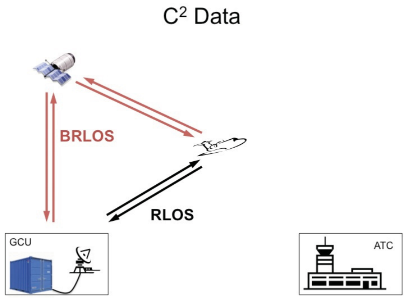

Figure 4: Data transmission via command and control datalink

An important aspect that has to be considered when planning to integrate unmanned systems into the non-segregated airspace is the communication between the vehicle and an air traffic controller. Due to the described advantages of unmanned aircraft, the vehicle can be thousands of miles away from the ground control unit. So the operator is not able to receive the instructions given to the UAV because of the limited range of the communication signal. In that case the UAV must serve as a relay station for voice signals.

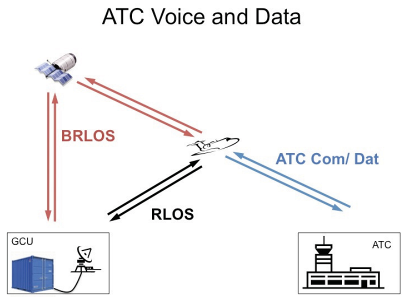

Figure 5: Data transmission via command and control datalink with ATC communication

Another aspects that has to be considered in the CS-LUAS is the loss of the datalink. Besides a certain reliability against a total loss of the command and control datalink, the UAV must be equipped with a back up system that controls the vehicle in case of a lack of steering data from the operator.

The time delay in the command and control datalink (namely latency) shall be specified in the flight manual of the system and must not irritate the operator. This means that the delay must not confuse the operator or lead him to the wrong decisions. For a light UAS the maximum latency is specified in chapter I of the CS-LUAS (see [4]).

2.3.3. Ground Control Unit

The ground control unit is the workplace of the operator of the UAS. Therefore not only technical but also ergonomical aspects have to be considered when defining standards. On the one hand all existing regulations concerning the design and the arrangement of the instruments have to be taken into account but on the other hand new aspects like the handover of the UAV between two workplaces in the GCU, the GCU infrastructure and the power supply have to be considered.

Furthermore the following requirements for the minimum crew were defined for a safe and economical operation of the UAS. In order to comply with the defined requirements the crew must consist of so many members that the following tasks can be performed without any stress or excessive workload of every crew member:

- Operation and monitoring of all essential UAV System elements
- Navigation
- Flight path control
- Communication
- Compliance with airspace, air traffic and air traffic control requirements
- Command decisions including crew resource managements

3. CONCLUSION

The rising number of UAS and the plan to integrate type certified unmanned aircraft into the non-segregated airspace clearly require a general building code to ensure a safe and economical operation The kinetic energy method and the tailoring principle seem to be the best approach to gain requirements regarding the structure, powerplant, flight characteristics, and the design and construction. The two new chapters, namely the ground control unit and the datalink, make demands concerning different disciplines in aviation like ergonomics and human-machine-interaction. Therefore the gained requirements for these chapters have to be reviewed and discussed by experts of the concerning fields.

Another critical aspect for the operation of UAS in non-segregated airspace is the frequency allocation of the datalink. After the estimation of the required bandwidth of the command and control link a suitable band in the aviation frequency spectrum has to be found and allocated.

When all these actions are carried out and the draft of the building code was reviewed, a type certification and the associated integration of unmanned aircraft into non-segregated airspace can be accomplished.

4. REFERENCES

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