A NEW APPROACH OF CERTIFICATION OF THE AIRWORTHINESS OF THE UAV AUTOMATIC FLIGHT CONTROL SYSTEMS

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Abstract
Certification of the airworthiness of the UAV (Unmanned Aerial Vehicle) and UAS (Unmanned Aerial System) systems meets many difficulties due to lack of legal norms defined for these types of aircraft and aircraft systems. At the international level there are some steps made in this field, however these regulations are not ratified yet in Hungary. The main goal of the author is to present the existing international and the domestic legal system dealing with the topic of this article, and to make the proposal for the elements of the UAV and UAS systems’ airworthiness certification procedure first in Hungary, and, partly, at the international level, too.

Keywords: UAV, UAS, airworthiness, certification methodology

1. Introduction – Historical Backgrounds
The UAVs and theirs military application concerned many experts, scientists and the Military since the early years of the 110-year powered flight history. The design of the first UAV is said to be connected to Prof. Archibald Low, air minister of England. During IWW (I World War) in 1916 he planned to apply against German-made Zeppelin-airships air torpedo called Aerial Target (A.T.) (Figure no. 1.)
From Figure no. 1 it is easy to see that the A.T. UAV airframe is very close to that of the manned aircraft. The main difference is the missing cockpit. The A.T. was the new adaptation of the existing aircraft to a brand-new application in fatal mission extremely increasing effectiveness of the air defense system.

The next example of the UAV being applied in military missions of the IWW was the flying torpedo aircraft called *Kettering Bug* dated from 1918 (Figure no. 2.)


Worth mentioning that both of aircraft shown above remained as a concept of the new application of the manned aircraft. Due to lack of technologies needed to design and manufacture UAVs the concepts remained as *paper aircraft* being never built.

The modern, up-to-date UAVs and theirs applications cover a large scale spectrum, i.e. they can be applied from simplest reconnaissance missions till combat applications (Figure no. 3).

From the early years of the design of the UAV and UAS it was evident that design and production of the UAV and UAS go ahead of the regulations. The regulatory work those early years of the flight history was not started. The first famous organization established 1915 was the NACA (National Advisory Committee for Aeronautics), responsible for harmonization of the activity of the industry and academic research branch to improve aviation production. In 1958 NACA had transferred to NASA (National Aeronautics and Space Administration) and its early branches still work in the frame of NASA.

In public and civil aviation there is a famous organization of ICAO (International Civil Aviation Organization) founded in 1944 with the purpose of improving flight safety and its effectiveness of the flights executed in the member-countries airspace via accepted international regulations and standards. It is easy to understand that in the field of the manned flight there is a huge set of experiences of many aspects of the aviation, such as aircraft design and maintenance.

When discussing the problem of the type – and airworthiness certification of the UAV, or UAS there are many arising questions: how UAVs are designed, how they are manufactured, how they are flown and operated, how the personnel is trained, how the training organization is founded and run. This set of questions started above is not limited to those items included. The UAV and UAS systems history started in 80’s is a relatively short one. However there were many UAV applications since 80’s, these actions were mainly military ones in segregated airspace not threatening other aircraft in the airspace. The trend of the UAV development today shows that military segment is decreasing whilst the other public segments, i.e. police; firefighter, or the civil segment is extremely increasing. There is a large demand on the market to use UAV or UAS capabilities in the agriculture, in several branches of the industry, i.e. monitoring large-length pipelines, electrical systems etc. As time goes ahead as demands are renewed or new demands appear.

2. Motivation and Problem Formulation

The purpose of the author is to highlight how the Hungarian law handles the UAV, or UAS technologies, what is the current status, and, what to do in the future to fill gaps, create missing regulations making possible to design and manufacture UAV or UAS as a valuable product, or valuable service offered on the global market.

In Hungary, the basic law about air transportation was created and accepted in 1995, as Act No XCVII [1]. The public aviation branch, namely the Military created an Order of the Minister of Defense No 21/1998. (XII. 21.) about nomenclature, production, repair, type – and airworthiness of the piloted aircraft in 1998 [2]. However, the order regulated relationships of the piloted aircraft the methodology outlined inside is very modern and in parity with existing international regulations.

If to analyze both the international and the Hungarian regulations, standards and norms easy to understand that is a very complex, and very strict set of regulations. The modern era today is a turned inside out one: it means that the UAV and UAS design run ahead, and produces new applications, applies newest technologies and newest tools for prototyping and design are not regulated yet. It means that in many segments of the UAV and UAS design regulations follow the every-day life of the designers, and productions of the UAV.

The situation is that there are many designers designing UAVs and UASs in the poor regulatory system facing type – and airworthiness certification problems due to regulations created after. The author published a paper dealing with these dilemma and challenges. In this article the author dealt with this question
provocatively, i.e. this situation can be a friend or a foe for the designers [3].

If to deal with regulations there might be two sides of participants. First is the team of followers agreeing with necessity of the regulations and obeying them. The second one is the team of vanguards opposing the new regulations thinking that regulations generate only bottlenecks for them.

3. Related Literature and Preliminary Studies

When dealing with UAV, and its on-board systems type- and airworthiness certification worth to stop at piloted aircraft regulations of the same interests. Many countries went ahead with regulations, and had shown example and models how to handle the legal situation. In this chapter author will highlight some examples how other experts think about the topic of this article.

3.1. The UAS Airworthiness Criteria of the U.S. DoT FAA (United States, Department of Transportation, Federal Aviation Administration)

One of the first questions to be answered here is how to classify the UAV?! To what of the existing class of the aircraft to include it?! In general, what is UAV, and how to define it?! In 1981 the FAA published his advisory circular defining model aircraft, which was a trigger in regulatory works on UAV and UAS systems definition. This circular stated that the model aircraft is used for entertainment purposes. This circular with regulations inside is for voluntary compliance to reduce level of risk of hazardous model aircraft flights to other aircraft, and to persons and property on the surface [4].

The US DoT FAA categorized UAVs and UASs for civil applications into “Experimental” Category owning “Special” airworthiness category compliance. It must be underlined here that FAA basically deals with UAS civil applications, and military applications are far from the main scope of the FAA, i.e. this activity is shifted to the military authorities. At FAA it is possible to gain airworthiness for UAVs for “General” Category. This procedure can be executed under power of the 14 CFR (Electronic Code of Federal Regulations) system 21.181 [5, 6].

The “Experimental” Category means those UAVs having no type certificate yet. This category includes following set of aircraft, events, systems and activities [5]:

1. Research and development (14 CFR 21.191): type of the flight serving for investigation and proof of some scientific hypothesis. This category includes following types of the flight: new missions, new regimes, testing newly set on-board equipment.

2. Compliance flight (14 CFR 21.193): those flights executed after type certification conditions are changed due to modernization and aircraft is evaluated for a new set of requirements, or, certification is planned to be extended.


4. Exhibition, air show: those types of activity and flights of the aircraft or UAV at air tattoo, at film shooting or broadcasting TV or radio performances.

5. Air race: participation at air races (e.g. Red Bull), training flights for races, flights to the competition area and return home flights.


7. Amateur-built aircraft flights and maintenance.

8. Kit-built aircraft flights and maintenance.

9. Light sport aircraft maintenance.

10. Unmanned aerial vehicle systems (UAS).

The FAA declared temporary regulations upon UAS maintenance in memorandum of AFS-400 [7]. The Chapter 6 of AFS-400 defines the UAS type – and airworthiness certification criteria. There
are basic norms defining maintenance staff necessary to fly the UAS safely. In this understanding of memorandum the UAV is flown by pilots, supported by co-pilots and observers responsible for flight safety of the UAV and UAS. The memorandum defines special requirements met by piloting staff members.

3.2. The Australian CASA (Civil Aviation Safety Authority – CASA) and UAV/UAS airworthiness certification

The Australian Civil Aviation Safety Authority (CASA) “CASR (Civil Aviation Safety Regulation – CASR) Part 21 (Certification and Airworthiness Requirements for Aircraft and Parts)” document based on circular CASA AC 21-6(0) in 1998 established the “Limited” Category of the aircraft. The project established in 2005 called “Project CS 05/01 – Certification Requirements Related to the Design, Manufacturing and Airworthiness of UAVs” had main result of advisory circular of AC (Advisory Circular – AC) 21-43(0) dated from 2006, dealing with „Experimental Certificates for Unmanned Aircraft”. In 2011 there is a new circular called AC 21-10(2) defining airworthiness certification procedure for „Experimental Certificates” dealing with airworthiness certification of the experimental aircraft. This activity has been successfully finished in 2012 [8].

In 2002, ten years before CASA created a new circulars coded “CASR Part 101 (Unmanned Aircraft and Rocket Operations)”, having three items inside, such as [8]:
1. AC 101-1(0): Unmanned Aircraft and Rockets: Unmanned aerial vehicle (UAV) operations, design specification, maintenance and training of human resources (July 2002).
3. AC 101-3(0): Unmanned Aircraft and Rockets: Model Aircraft (July 2002).

If to read carefully these circulars it is easy to understand that solid propulsion aircraft airworthiness certification is very close to that of the UAV’s.

There is a classical question existing long time what is the relationship of the model aircraft and the UAV?! Since 1981 is well-known the FAA AC 91-54 circular defining model aircraft, in general. The very early, single-page regulation served as basis for the CASA AC 101-3(0) circular, which is much more detailed. The CASA AC 101-3(0) circular defines model aircraft as follows [8]:
1. Model aircraft is for sport- or for entertainment purposes with MTOW (Maximum take-off weight) less than 150 kg with the exemption of balloons and kites.
2. All other flight purposes and missions must be considered for UAV flights with necessity of the type – and airworthiness of the UAV.
3. The model aircraft is free from regulations defined for all other aircraft types (i.e. type registration, type worthiness, airworthiness certification, training of the maintenance staff members etc.)
4. The CASA classifies the model aircraft by theirs MTOW as follows
   a. 100 g: not classified;
   b. 100 g ÷ 25 kg: model aircraft;
   c. 25 kg ÷ 150 kg: large model aircraft.

The is no doubt that rulemaking activity of CASA is very valuable from point of view of the design of the UAV/UAS systems, form the point of view of the type- and airworthiness certification of the UAV and UAS systems. The CASA regulated in deep details the relationship of the model aircraft and the UAV with defining model aircraft and UAV, too.

3.3. The European EASA (European Aviation Safety Agency – EASA) – regulations and main features

The EASA is found in 2008 by decision of the European Parliament and European Council coded 216/2008/EC
resolution with the purpose of establishment of the common regulations in Europe in civil aviation [9]. This resolution declares rights and obligations of the community and the member-state. The EASA is the organization responsible for the strategy of the flight safety in Europe. The EASA proclaimed following important regulations having close connection to the main topic of this article.

The first is the “C.Y001-01 – EASA Airworthiness Directive Policy” document prepared by EASA Certification Directorate. The second one is the “E.Y013-01 – Policy Statement – Airworthiness Certification of Unmanned Aircraft Systems (UAS)” prepared by EASA Rulemaking Directorate dated from 2009. This policy has main elements as follows below [9]:

1. Definition of the UAS.
2. Definition of the methodology of the type – and airworthiness of the UAV with MTOW less than 150 kg.
3. Support application of green technologies in compliance certification of the UAS, if it is possible;
4. Based on French military air authorities best practice of the UAS airworthiness certification NATO had established own military system of certification of the UAS airworthiness. By request of the applicants EASA is ready to certify the UAS by the NATO STANAG 4671 [10].

As it was mentioned above the EASA keeps guard upon European flight safety in civil aviation. The question how to relate with those new initiatives designing and producing new types of the UAV and UAS and trying to seep into public UAV market, can be answered quit difficult. Evolution of the technologies applied in UAV and UAS systems goes ahead very fast, designers close enough to newest principles, methods, materials etc. to produce competitive UAV on the market. The tools are designed in non-regulated sphere. After one gained UAV the only remaining problem, and question is: how to get type – and airworthiness certification to be certified, what is necessary to sell the product.

4. The MIL and STANAG Regulations Applied to Certify Automatic Flight Control Systems of the UAV

The automatic flight control of the aircraft or UAV is evident today. Flight control supports pilots, improves flight safety, and extends service life of the aircraft. Piloted airplanes are augmented by flight controls since the early 50’s. The US Navy established specifications for Navy aircraft with MIL–C–18244A standard [14], the Navy VSTOL aircraft is detailed in MIL–F–83300 standard [16]. Helicopters flying and handling qualities are outlined in standard MIL–H–8501A [15].

The fixed-wing aircraft flying and handling qualities are defined in MIL–F–9490D [13], and in specification of MIL–F–8785C [12], what is later, from 1997 called as DoD handbook coded by MIL–HDBK–1797A [12].

Table no. 1 shows evolution of the standards and regulations, how they transferred into the up-to-date regulations.

### Table 1: Evolution of Military Standards and Specifications

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<td><strong>1955:</strong> MIL-C-18244 (AER)</td>
<td><strong>1964:</strong> MIL-F-9490C (UASF)</td>
<td><strong>1969:</strong> MIL-F-8785B</td>
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Due to successes of regulations of the civil UAVs the Military – based upon French military best practice – started to create a new system of norms of the UAV airworthiness certification. In 2007, first edition of the NATO STANAG 4671 (Unmanned Aerial Vehicles Systems Airworthiness Requirements (USAR), NSA/0976(2009)-JAIS/4671) has been proclaimed to be ratified by NATO-member countries [10].

In Hungary, this standard has been accepted as joint, common standard for NATO-member countries, but it was not included into the Hungarian legal system. During airworthiness certification of the new UAV types, such as METEOR-3MA TUAV (Tactical UAV) drone this situation generated extra loads for experts of evaluation of the compliance of the UAV.

4.1. The NATO STANAG 4671 standard and its main elements

The military standard coded NATO STANAG 4671 (Edition3) has been accepted by all NATO-member countries in 2009, and it is in force present moment. The introductory chapter defines scope of this document of those UAS having MTOW between 150 kg and 20.000 kg fixed wing aircraft used for military purposes using non-segregated airspace simultaneously with other civil aircraft [10].

The NATO STANAG 4671 (ed3) standard based upon documents coded 14 CFR Part 21, and EASA CS-23 (earlier coded for JAR 23). There is unique set of standards compiled into STANAG 4671, such as [10]:
1. TSO C23d – Minimum Performance Standards for Parachute assemblies and Components, Personnel, USA, 1992;
5. Design Standards UAV – Civil Aviation Safety Authority, Australia, 2000;
6. Design and airworthiness requirements for UAV systems – DEF STAN 00-970 Part 9, UK MoD, 2002;

Although the existing standard of STANAG 4671 regulates in general the UAS systems airworthiness certification it cannot be used for unconventional design, for UAVs of having extremely unconventional flight envelope. The standard misses definition of the term ‘unconventional’ stands for what. It is obvious that this standard can be used for conventionally designed and conventionally operated military UAVs and military UAS systems.

The NATO STANAG 4671 standard consists of two books. The first one is a book of the general rules of the UAV and UAS airworthiness certification process. The second book is devoted to measure of the compliances to those minimum requirements defined in Book No1 of the same standard.

The minimum MTOW of 150 kg of the UAV predicts that this standard is for certification of the medium-weighted or large UAVs. There is the new trend in UAV design and production driven by miniaturization. There are many new applications both in public and civil UAV sphere excluded from the scope of the NATO STANAG 4671 standard. It means that the regulatory work goes behind the technology platform producing new UAVs, and there is a constant push on regulatory activity to catch the technology platform, or at least to minimize the gap between two platforms.
4. Closing Remarks, Results, Future Work

The UAV and UAS systems development can be monitored both in the public, governmental UAV sphere, and in civil, private sphere. The new hardware, the new software technologies are available for many interested individuals trying to solve theirs problem using UAV or UAS technologies. There are many extremely new applications of the UAV. In Japanese agriculture rest of the spraying activity is executed by UAVs.

If to design and produce UAV the market is unreachable having no type- or airworthiness certificate of the given UAV or UAS. The flight automation today is the expected value of the UAV, cannot be avoid. The regulatory work in this field dated from early 50’s focused attention to the piloted aircraft, i.e. having individuals, or living organisms (pilots, passengers, and living cargo) on the board.

Due to this flying qualities of the manned/piloted aircraft were very strict, and were determined for ride comfort, or for ride discomfort indices. It is supposed by the author that it was the reason why NATO STANAG 4671 standard omitted to define the dynamic performances of the UAVs. In Book N°1, Chapter ’143 Controllability and Manoeuvrability’ the longitudinal and lateral/directional control is cconsidered for ‘Not applicable’.

If to take into consideration of the automatic flight control systems starting with basic augmentation functions to improve dynamic characteristics it is easy to agree that automatic flight control system cannot be neglected during conceptual design of the UAV, or UAS. It can improve many technical data of the UAV, and can reduce costs of the maintenance. If to apply it the load on piloting staff can be reduced, and it can increase level of the flight safety what is primarily important for UAVs.

The future work of the author will be targeted to establish a brand-new system of dynamic performances of the automatic flight control systems of the UAV applied both in longitudinal and lateral control of the UAVs. This new proposal now is elaborated by the author.

REFERENCES