# INNOVATIVE SOLUTIONS AND UAS LIMITS

**Vasile PRISACARIU*, Mircea BOŞCOIANU**, Andrei LUCHIAN*****

*Transilvania University, Braşov, Romania,
**Henri Coandă Air Force Academy, Braşov, Romania,
***Politehnica University, Bucureşti, Romania

***Abstract:*** *The Unmanned Air Systems technology is matured and is evidenced by the utility and adaptability of vectors used in drones for the last decade. Designing and building aeromechanical drone system focuses on concepts that lead to lower energy consumption during the execution of the mission and a high speed of response. Aerodynamic limits depend directly on the technical characteristics of the flight qualities and properties of materials used in the manufacture of unmanned aerial systems. The article presents an overview of the limits and requirements in the design, production and operation of unmanned systems human on board. This article wishes to point out the main elements of the systems through the drones requirements in the field/domain.*

***Keywords:*** *innovative solutions, UAS, rotary wing, fixed wing*

## 1. INTRODUCTION

Human unmanned systems onboard as aerial machines are subject to a series of limitations that ultimately may affect the flight characteristics and performances.

All stages of the final product are pegged requirements arising from the limits and conditions of that stage; they are pre-defined and / or modified with the design and product realization.

Based on the requirements imposed on aircraft (Preotu, 2001) we can develop a diagram in figure 1 were we can observe the interdependence domain-limits.

The Unmanned Air Systems technology is matured and is evidenced by the utility and adaptability of vectors used in drones for the last decade in various assignments: both military and civilian.

However the limits that arise in any field often lead to compromises.

The most challenging limits are: mass, handling, vulnerability to weather conditions, threats of kinetic and non-kinetic weapons, technological limits (standards of reliability), legislative limits, airspace management limits.

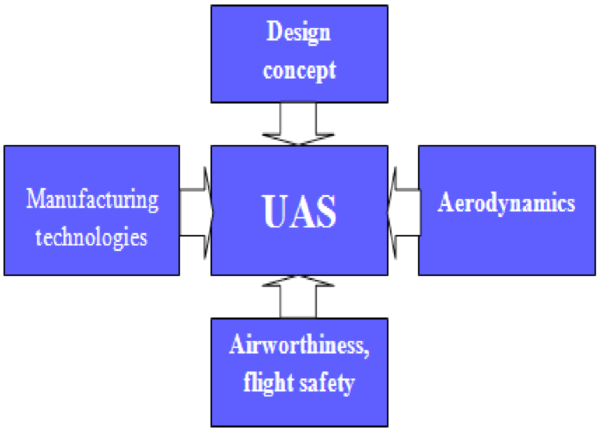


Fig.1. UAS areas

The design and construction of any UAV must follow a series of elements: aerodynamic concept, speed and autonomy, energy, craft sensors, data integration, thermal management and signature acoustic / radar.

Innovative solutions can mark all the stages of making a unmanned air product: conceptual and design, prototyping and manufacturing resources (smart materials, non-conventional energy, propulsion), exploiting (vectors: swarm, autonomy).

## 2. DEMANDS IMPOSED IN REALIZING OF UAV

**2.1. Requirements imposed in designing and manufacturing the aircraft.** The design and construction of robotic aerial systems is focuses on innovative aeromechanical concepts which leads to a lower power consumption in missions and a high speed of reaction, see figures 2 and 3, (***2014a, ***2014b). The aerodynamic requirements depend directly on technical characteristics, flight qualities (stability and maneuverability), operating conditions and the effects that occur in the aero-elastic phenomena during the missions, (Cîrciu, Prisacariu, 2013)

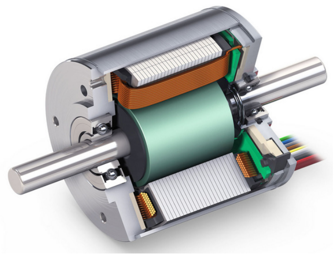

Fig.2. Brushless motor

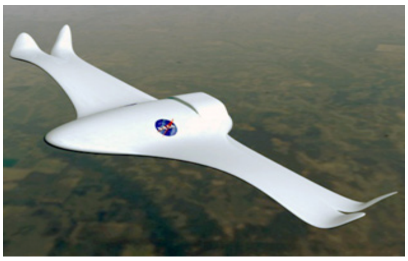

Fig.3. NASA morphing concept

Aircrafts are designed, manufactured and tested in accordance with specific conditions and are used in areas of interests with a permissible operating load factor (us) without any permanent deformation that may occur or may break if the specified factor breaking load is exceeds, (Costăchescu, 1993).

Aerodynamically speaking, the chosen geometry should provide maximum performance with minimum installed capacity and in terms of maniabillity aircrafts must perform movements around the gravity center with minimal effort (minimal) on the flight controls.

Technologies for robotic air system (serial) must ensure technological fractionation schemes, modular shortening manufacturing cycle with extensive use of materials and parts at minimum cost at global level (Preotu, 2001; Reicheneder, 2011) by using CNC manufacturing lines (fig. 4 and 5).

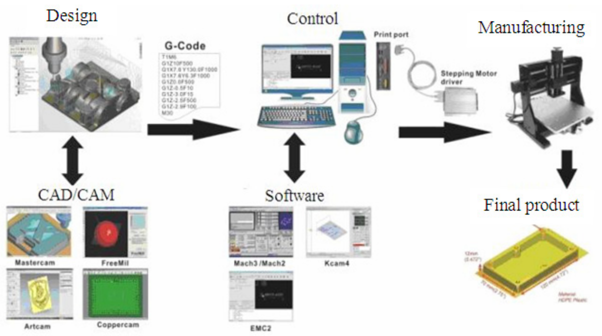


Fig.4. The design and manufacturing diagram

As specific requirements imposed on manufacturing we can mention: the use of standardized parts, minimal use of materials, use of low cost materials and alternative technologies.

**2.2. Requirements for flight safety.** The safety of operation can be improved either by increasing the reliability of the components of the UAS or to build redundant.

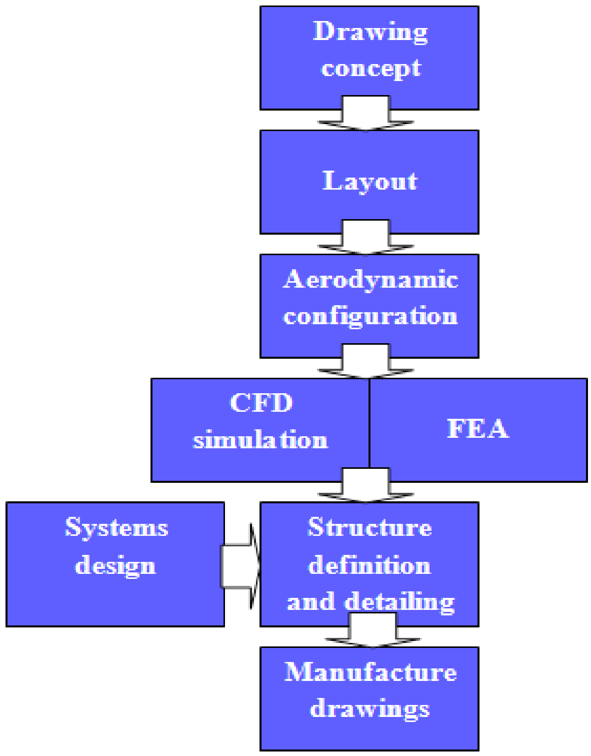


Fig. 5 Design Methodology (Reicheneder, 2011)

To improve safety and to keep costs down we can trace several goals: the use of standardized systems and practices, simplicity in design, redundant design, use of materials certified in aviation, maintain quality control of materials and subsystems which are used, (Seletron, 2007)

The safety issue of an aircraft is directly related to the proper functioning of the components, subsystems and the systems components. Theoretically flight safety is the probability that failure-free operation time exceeds the prescribed time, meaning:

$$S(t)=\frac{N}{N_0}=\exp\left(-\int_0^t \lambda(t)dt\right) \quad (1)$$

Where:

N - number of elements in operation at time t

N0, the number of elements in running at the time t0

λ - Proportionality factor that depends on the time t or the likelihood of a correct execution of a task in a given period is defined as the average time reliability better functioning - ATRBF:

$ATRBF=\frac{1}{\lambda}$ , reliability is:

$$S(t)=e^{-\lambda t}\cong 1-\lambda\cdot t \quad (2)$$

we can point out on the chart (figure 5) the probability of good operation during a mission.

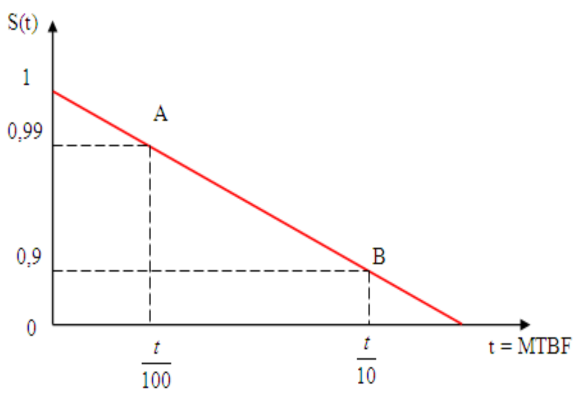


Fig. 5 ATRBF dependence during a mission

Flight safety depends directly on the strength / stiffness vector trim level with air and its redundancy level (duplication flight control, vital equipment).

**2.3. Requirements for the use and operation of UAV**. Operation of the aircraft in ground and flight involves both a series of maintenance operations and ground control and activities during the missions. For operation and maintenance activities, the aircraft must meet a number of conditions: (figure 10) to allow a simple maintenance operation during a short flight, to allow quick preparation, easy to maneuver in flight be designed, to ensure the safety of maintenance personnel.

Unmanned airborne system requirements for operation airspace needs to posses a modern equipment embarked with functions to assure safety and flight trajectory control (cruise control, Sense and Avoid) depending on the type of missions. Control architectures and control board must fulfil at least the first two functions of the three: Stability and Control (3D stabilizer), navigation (autopilot), autonomy (autonomous system integrated).

**2.4. Economic requirements.** Unmanned Air Systems are used in various domains and mission due to the reduced resource consumption (operating costs) compared to the piloted aircrafts. For instance the demand for UAV in the U.S. air force is growing (six times since 2004) not only as a replacement for manned aircraft but mostly because of their versatility, and in 2010 more than one third of the planes that were purchases are UAV, comparative data is presented in table 1.

Table 1. Comparative dat

| Features | UAV | Manned MH-53 |
|---|---|---|
| Autonomy | 24 | 2,5 |
| Personnel (24 h) | 3 | 25 |
| Acquisition cost | $ 1 mil. | $ 175 mil. |
| Per hour cost | $ 336 | $ 15.800 |
| Risk (lives) | 0 | 1 |

**2.5. Requirements imposed by the acceptance flight.** Although they are trying to harmonize human legislation for on board unmanned aircraft (EASA, ICAO), (Seletron, 2007; ***2014d), accepting unmanned aircraft flights are different in every country, depending on the category of the aircraft and the operating conditions.

European aviation regulations of EASA are developed, (***2014)c, and in effect there are a series of documents on the operating conditions of the UAV over 150 kg in the European Union, which have a mass less than 150 kg, subject to aviation regulations of each state EU membership.

Current national aviation regulations define UAV in RCAR-AZAC, (***2007), and in two other recent national rules which refers to the use of national airspace by civil aircraft which are powered by unmanned systems, (***2014) e, (***2014)f.

## 3. INNOVATIVE SOLUTIONS

Current status on growth performance focused on two main areas of research: air vector rotary wing and fixed wing. Research on UAS reveals a series of research on innovative solutions (aeromechanical equipment), solutions at various stages of research (concept / design, manufacturing, experimental models), some examples are briefly described in the following lines.

### 3.1. UAS with rotating and hybrid wings.

**a Boeing X-50 Dragonfly.** In the 1990s, McDonnell Douglas studied a VTOL aircraft design concept called CRW (Canard Rotor / Wing). CRW is a hybrid vector air mobile canard empennage configuration of a vertical double-free anti-torque propeller and a turbofan powered by a nozzle equipped with a mobile, see figure 6 and table 2, (Simonsen, 2002; Parsch, 2006). Aero revolutionary concept combines the capabilities of a helicopter with those of a fixed-wing jet.

Table 2. X-50 Dragonfly characteristics

| | |
|---|---|
| Span (wings/rotor) | 2,71 / 3,66 m |
| Length / High | 5,39 / 1,98 m |
| Payload /empty/total | 91/ 574 / 645 kg |
| Speed crz./max. | 278/700 km/h |
| Propulsion | Turbofan Williams F112 |

Fig. 6 Dragonfly, ***(2014)g

Fig. 7 Eagle Eye, ***(2014)h

**b. Bell Eagle Eye.** Eagle Eye Program (tilt rotor) began in 1993 with the prototype TR911X powered by gas turbine Allison 250-C20, with the debut flight in 2006, currently marketed in Europe in partnership with Sagem and Rheinmetall, see figure 7 and table 3.

Table 3. Eagle Eye characteristics, ***(2014)h

| | |
|---|---|
| Span / Length | 7,37 / 5,57 m |
| Pazload / total mass | 90 / 1000 kg |
| Max speed | 360 km/h |
| Autonomy / ceiling | 6 h / 6000 m |
| Propulsion | PW207D Canada |

**3.2. Fixed wing UAS**. Aurora Flight Sciences - SunLight Eagle. The demonstrator flew in tests on May 12, 2009 in Las Cruces, New Mexico airport, been powered by an electric motor and solar cells mounted on the bearing surface, see figure 8 and table 4, (Coppinger, 2009).

Fig. 8 SunLight Eagle, [16]

Fig. 9 MicroFalcon I

Tabel 4. SunLight Eagle characteristics

| | |
|---|---|
| Span | 34,7 m |
| Mass | 75 kg |
| Speed max. | 360 km/h |
| Autonomy / Ceiling | 6 h / 6000 m |

**b Innocon - Micro Micro Falcon Falcon I**. I is a mini-UAV missions ISAR for a single operator. Designed joint wing configuration, the vector is powered by an electric motor-driven traction acquisition sensor mounted on the ventral side, see figure 9 and table 5, ***(2009).

Table 5. Micro Falcon I Characteristics

| | |
|---|---|
| Span | 1,6 - 2 m |
| Speed crz. | 65 km/h |
| Mass | 6 -10 kg |
| Autonomy/ ceiling | 2 h / 3000 m |

**3.3. Research prototypes. a. Fixed / rotary wing.** The key to this innovative design is the ability to switch modes rotary-wing flying fixed wing (rotor 1800), a transformation that takes only 1-2 seconds, see figure 10, ***(2014) h. Battery-powered prototype has limited autonomy to 30 min for a cruising speed of 185 km / h.



Fig. 10 Stop rotary wing

**b Airship Endurance UAV VTOL Transformer**. Endurance is an airship with two turbines developing to operate completely autonomously, which can provide superior aerodynamic qualities necessary data acquisition missions (ISR), see figure 11, ***(2014)i.

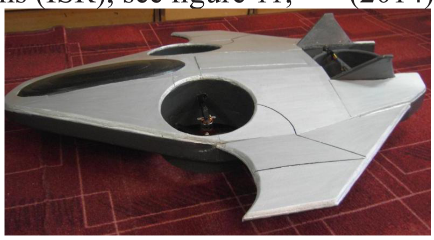

Fig. 11 Transformer V2

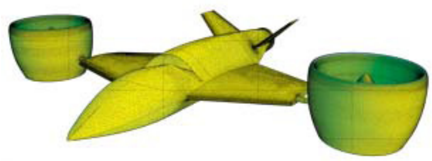

Fig. 12 AD-150

**c AD 150.** Manufactured by American Dynamics, the tilt duct VTOL concept has been developed for future requirements of the U.S. Marine Corps for a high-speed VTOL UAV capable evolve maritime environment on board, figure 12, ***(2011).

**d Vortex.** Chinese designers market profile presents innovative concepts for VTOL unmanned aircraft configuration in Zhuhai Air Show 2012, see figure 13, ***(2012).

Fig. 13 Vortex UAV

**e. Aesir's UAV.** A UK company has developed a VTOL UAV that has no external rotating parts, instead relying on a phenomenon known as the Coanda effect to generate lift, mobile surfaces arranged circular allow air flow control device and control the trajectory, see figure 14, (Quick, 2009; Cîrciu, Dinea, 2010)

Fig. 14 AESIR UAV

Fig.15 Cyberquad

**f. Cyberquad.** It is a recognition platform for use in urban environments and indoors. Can carry high-resolution video camera and biometric sensors (gas, chemical), see figure 15, (Brandon, 2009).

## 4. CONCLUSIONS AND FUTURE DEVELOPMENTS.

The presence of UAV systems, under modern airspace in the coming years is supported on all levels (research, manufacturing, usage), specialized comparative data on HALE UAV market and forecasts for global investment, presented in figures 16 and 17, (Lucintel, 2011).

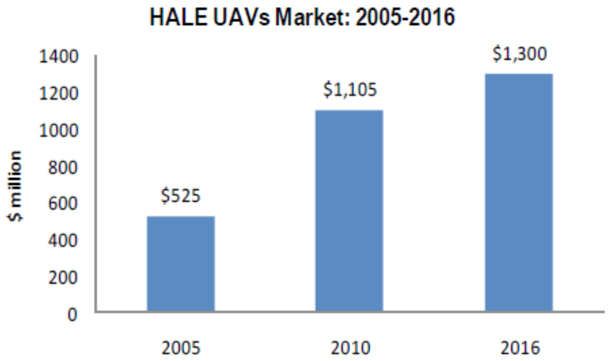


Fig. 16 UAV-HALE evolution in mondial market

Implementation, development and differences in equipment implicitly lead to a difference in costs and capabilities of these aircraft which already have a history and their own evolution with other categories of aircraft known. Research studies state that surveillance missions, reconnaissance and electronic warfare, manned performed onboard will be taken completely by UAS.

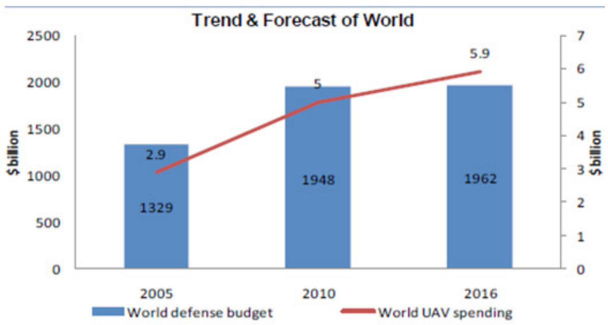


Fig. 17 Forecast invest in UAV market

Three distinct ways of integrating executable tasks are analyzed UAV systems now, (Agafiței, 2007), together with combat systems belonging to other categories of aircraft: combat systems associating a, b through dedication / operational resource allocation specialized c by mixing weapon systems.

Currently three defining factors are combined to motivate the use of UAV: technological advances that provide a significant operating level, the evolving state of the world which is changing and the UAV attributes systems which enable the new benefits and operational capabilities.

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