CONCEPTUAL DESIGN OF A VTOL REMOTELY PILOTED AIRCRAFT FOR EMERGENCY MISSIONS

Razvan UDROIU, Madalina Ioana BLAJ

Transilvania University of Brasov, Romania (udroiu.r@unitbv.ro, blaj_madalina2006@yahoo.com)

DOI: 10.19062/2247-3173.2016.18.1.27

Abstract: *This paper is focused on the design of a tilt-wing VTOL (Vertical Takeoff and Landing) remotely piloted aircraft. A tilt-X (X being wing or rotor) UAV has a hybrid configuration for taking the advantages of both fixed-wing and rotary-wing aircraft. This paper presents a short overview regarding the tilt-X concept and in the last part it is proposed a conceptual design of a tilt wing UAV, having a main mission of solving the emergency cases. The conceptual design was done with the help of software tools like as XFLR and CATIA.*

Keywords: *tilt wing, UAV, VTOL, conceptual design, emergency mission*

1. INTRODUCTION

In the literature there are many similar terms that can define the commonly known terms of drone. Thus, some similar terms are the following: remotely piloted aircraft systems (RPAS), unmanned-aircraft vehicle system (UAVS), remotely piloted aerial vehicle (RPAV), unmanned air systems (UaS) [10], unmanned aircraft system (UAS) [11] and unmanned aerial vehicle (UAV) [11]. The term unmanned aircraft system (UAS) was adopted by the United States Department of Defense [11], having four main components: the aircraft, the payload depends of flight missions, the control station and the data link. The interaction between operator and the UAS is facilitate through the data link, usually located in the control station.

The Vertical Takeoff and Landing (VTOL) aircrafts combine the advantages of the fixed-wing and rotary-wing aircrafts. Fixed-wing aircrafts take the advantage of high lift-to-drag ratio, fuel-efficient flying, and high-speed flying. Rotary-wing aircrafts can take-off and landing vertically and hover flying. Also, Vertical Short Takeoff and Landing (VSTOL) aircrafts is a more general terms that include VTOL concept.

According to [1], VSTOL aircrafts can be divided in the following main categories, see Fig. 1: augmented power plan for hover, combined power plant for hover, separate power plant and hover and same propulsion system for hover and forward flight. Tilt-X aircrafts are the hybrid vehicle that use the same propulsion system for forward flight and hover.

Basset and all [3] has distinguished the following main categories of rotorcraft or Tilt – X aircrafts, see Fig. 2:

1. Tilt Blade Tip-Path-Plane being the helicopter. The blade of the helicopter main rotor is tilted by using cyclic controls;

2. Tilt-Body can be considered like an multi rotors vehicle that tilted the whole aircraft based on the aerodynamic forces;

3. Tilt-Rotor can be a Rotoprop or Verticopter, consisting in one or more rotors that are tilted entirely. Rotorprop consists in one tail rotor used in hover and low speeds like a classical anti-torque rotor and at higher speeds like a pusher rotor. Verticopter has two tiltable coaxial contra-rotating rotors;

4. Tilt Wing combined, rotors with wings, propellers or other auxiliary propulsion;

5. Combined solutions between rotors and wing functions depending on the flight phase. These include Variable rotor radius (VRR) and Stoppable rotor (SR).

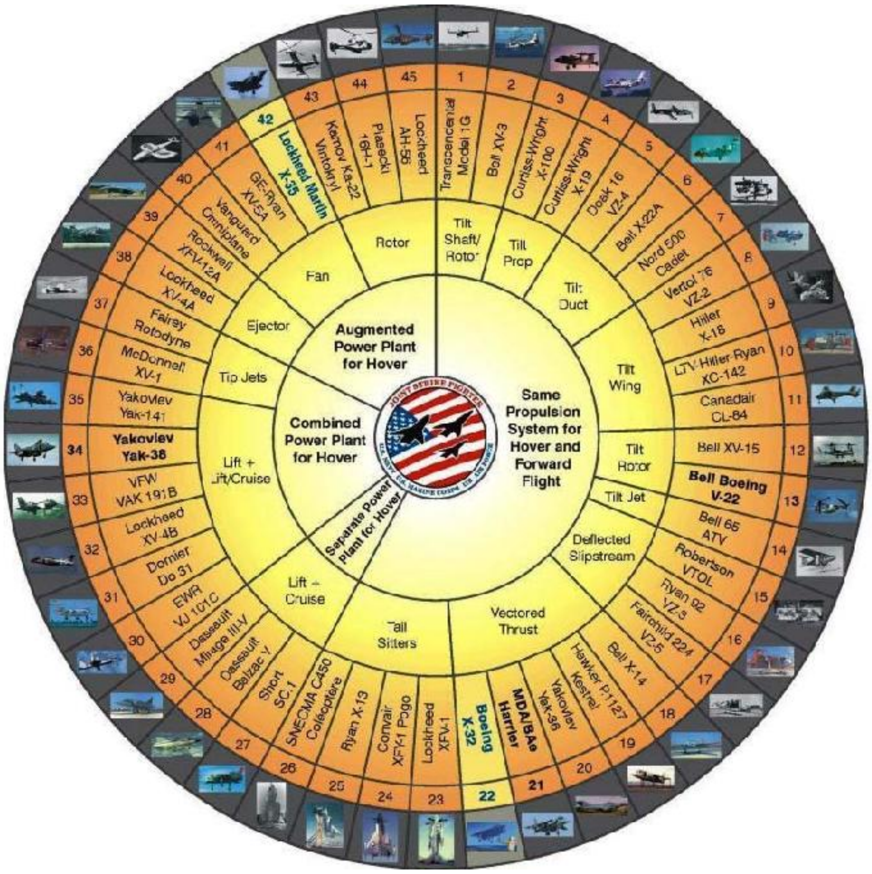


FIG. 1 VSTOL wheel of the aircraft and propulsion concepts [1]

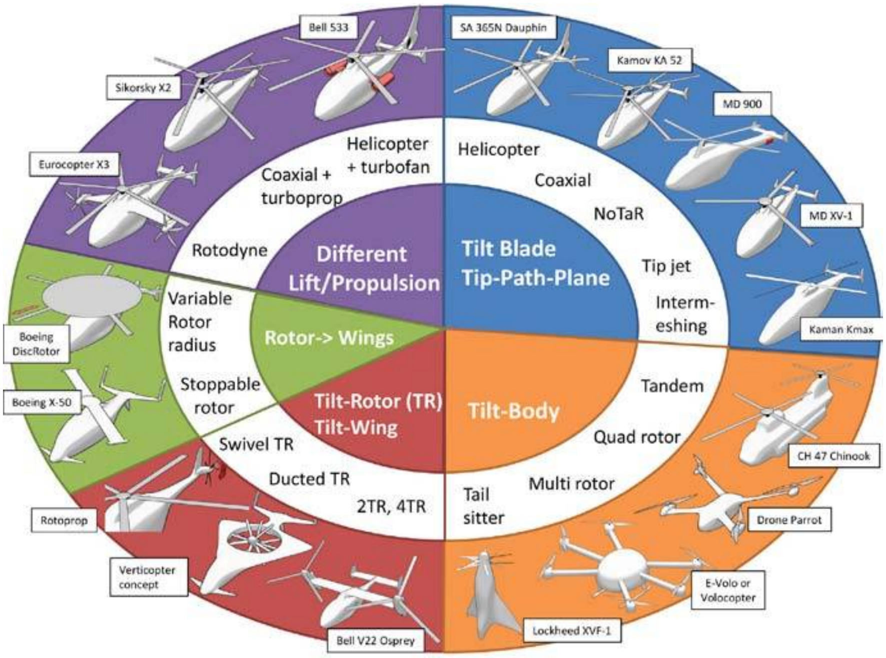


FIG. 2 Rotorcraft concepts [3]

Four categories of Tilt-X concepts are usually used worldwide as follows, Tilt-rotor, Tilt-wing, Tilt-jet and Tilt-duct.

The focus of this paper is on the tilt- wing UAV design.

2. TILT-X ANALYSIS FROM AIRCRAFTS TO UAV

Flight envelope of the tilt-wing is wider flight envelope from hover to high-speed and high altitude range than the flight envelope for Conventional Take Off and Landing (CTOL), Vertical Take Off and Landing (VTOL), as seen in Fig.3.

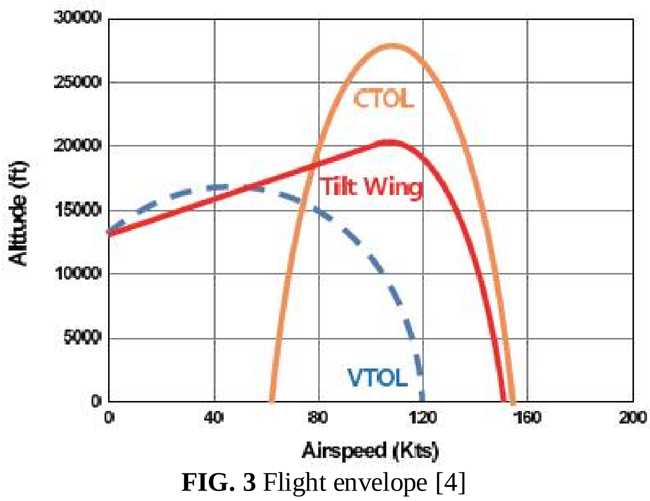


FIG. 3 Flight envelope [4]

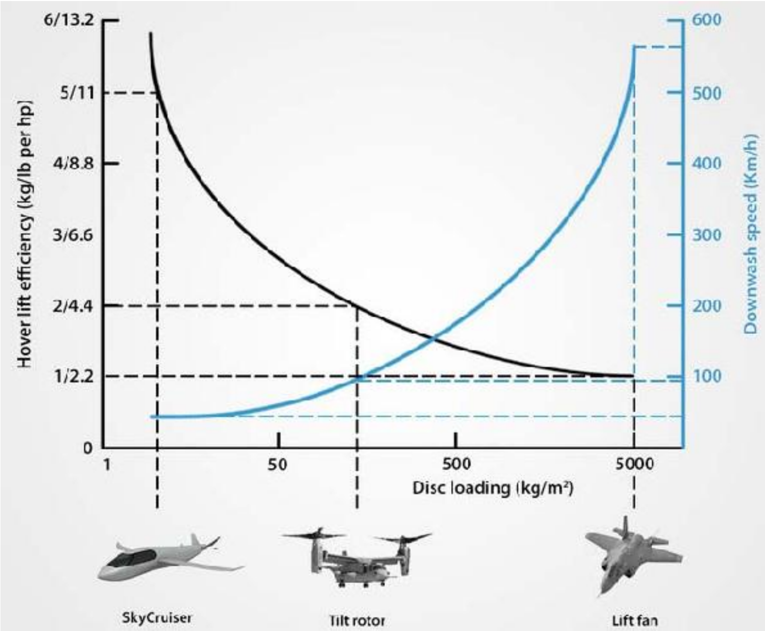
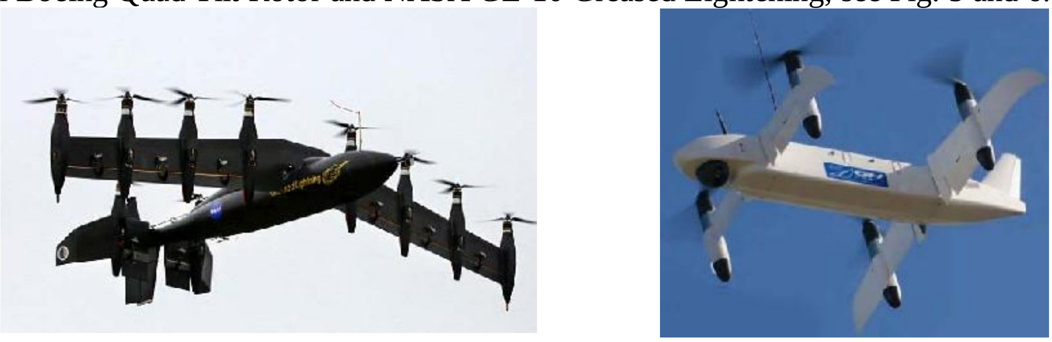


FIG. 4 Hover efficiency versus disc loading. Lower disc loading is more efficient, meaning less power is required to hover. [2]

Typically, the helicopter or multicopter have a lower disc loading and the lift fan systems have massive disc loading and typically require all the power of their powerful jet turbine engines to take off and land vertically [2]. Tilt- X aircrafts have a medium disc loading and a medium hover lift efficiency, see Fig. 4.

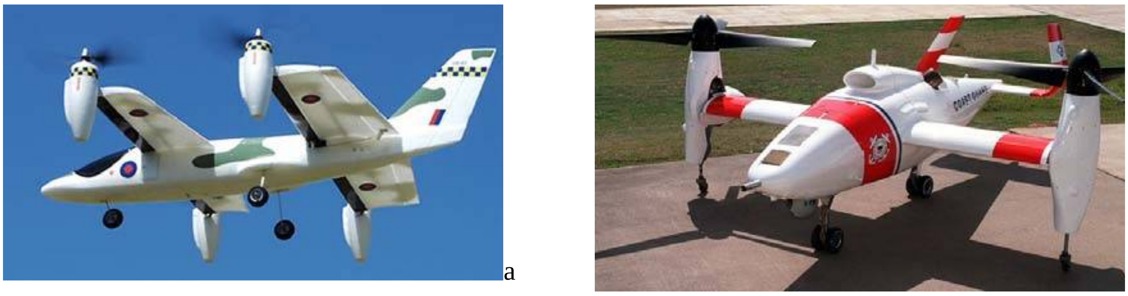
Some most popular example of tilt-X aircrafts are the following: Hiller X-18, XC 142, Canadair CL 84, Agusta Westland AW609, Bell Boeing V-22 Osprey etc.

In the field of tilt-X UAV concept has been developed some studies for military and civil application. As results of these we mention some UAV, like as Bell Boeing Eye, Bell Boeing Quad Tilt Rotor and NASA GL-10 Greased Lightening, see Fig. 5 and 6.



a b

FIG. 5 Tilt-wing UAV, NASA GL-10 Greased Lightening (a) [6], Quad Tilt Rotor (b) [9]



a b

FIG. 6 Tilt-rotor UAV, Ripmax VTOL (a) [7], Bell Eagle Eye (b), [8] A tilt-wing aircraft operates in two main flight mode: airplane mode with the wing in horizontal position (conventional forward flight) and helicopter mode (vertical takeoff and landing) with the wing rotated up. It is similar to the tilt-rotor design where only the propeller and engine rotate.

The tilt-wing design offers certain advantages in vertical flight relative to a tilt-rotor but less control during hovering flight. Thus the tilt-wing is able to apply more of its engine power to lifting because the slipstream from the rotor strikes the wing on its smallest dimension. The tilt-rotor generally has better hover efficiency than tilt-wing, because the tilted vertically wing represents a large surface area for crosswinds to push.

3. ONE TILT-WING UAV FOR EMERGENCY MISSIONS

The main purpose of this work is to design an UAV like a ambulance-delivery drone that can improve global health. This UAV should be enable to automatically flown to any emergency situation and quickly delivery to any location a first aid payload box. This payload can consists in the following components: an automated external defibrillator (AED), medical toolkit, drugs, blood bag, insulin injection etc, as shown in fig. 7. An automated external defibrillator (AED) is a portable electronic device that automatically diagnoses the life-threatening cardiac arrhythmias of ventricular fibrillation and ventricular tachycardia in a patient. The firs aid toolkit can be used to guide citizens to make non-technical lifesaving procedures. Also, the ambulance-delivery UAV can automatically flown to villages with / without medical staff.

Generally the UAV development process consists in the following main steps: market analysis and customer requirements, mission specifications, conceptual design, preliminary design, detailed design, prototype manufacturing, flight test, and UAV production.

FIG. 7 Ambulance-delivery UAV

The UAV conceptual design was started by analysis the market needs, the current competitors and the applications in some emergency fields. First step has consisted in choosing the best configuration from several possible configurations.

Also, the establishing of the mission specification is an important input data to design a new aircraft or UAV. Usually, UAV mission specifications come depending on customer requirements.

The preliminary design of an UAV supposes using some software products like as Profili, XFLR, Advanced Aircraft Analysis (AAA) [12] etc. The parameters resulted after the preliminary design are used to define the geometry of the UAV and used as input data to 3D computer aided design of the UAV.

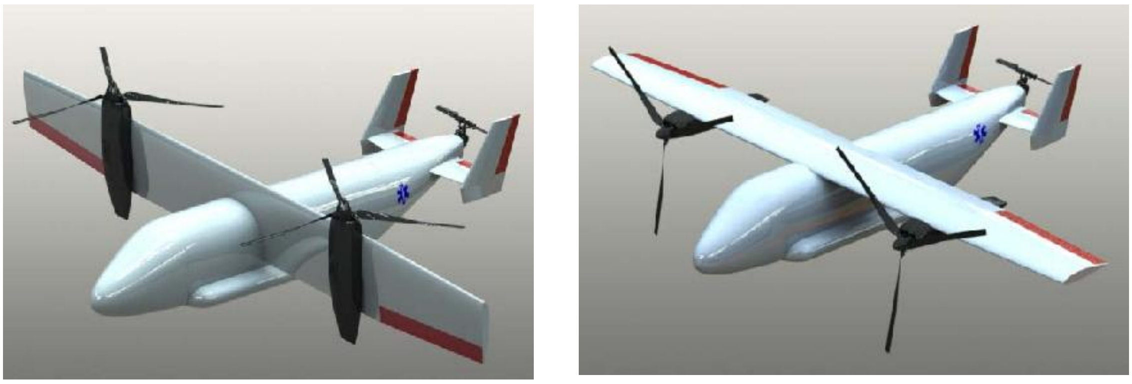
The UAV presented in this paper using a contra-rotating rotors, have the general characteristics as shown in the table 1. The mission specification of the ambulance-delivery UAV consists in the following main segments: take-off, climb, tilting the wing, cruise, tilting the wing, descend and landing.

Table 1. Tilt – wing UAV characteristics

Tilt – wing UAV characteristics	**Value**
Length	2000 mm
Wing span	2800 mm
Wing mean aerodynamic chord	334 mm
Wing airfoil	MH 44
Aspect ratio	8,4
MTOW	40 kg
Payload capacity	10 kg

The ambulance-delivery UAV was 3D designed using the advanced computer aided design (CAD) software, CATIA by Dasault Systems [5].

The 3D CAD model of the ambulance-delivery UAV, in the main flight configurations, is shown in fig. 8.



(a) (b)

FIG. 8. Flight configuration of the ambulance-delivery UAV (a) helicopter configuration mode (take off/ landing/ hover) (b) airplane configuration mode

CONCLUSIONS

The development of UAVs having Vertical Takeoff and Landing is crucial for operating in populated areas.

In the first part of this paper is presented a short review about VTOL unmanned aircraft system. The second part of the paper propose a new tilt-wing UAV focused on emergency missions. The main advantages of the proposed concepts are the following:

1. automatically flown to any emergency situation and quickly delivery to any location a first aid kit;
2. the possibility of operate on short distance in town, delivering first aid kit in order to operate without specialized personnel, coordinated by video-call;

3. the possibility of operate on long distance (around 70-120 km) in villages, delivering first aid kit, drugs, etc in order to operate with medical staff;
4. flight capability of takeoff / vertical landing.

The next steps in order to develop the ambulance-delivery UAV are, the aerodynamic optimization for different flight configurations, building a prototype from composite materials, flight tests and implementation of this UAV in the medical system.

REFERENCES

[1] ***, VSTOL Wheel of Misfortune, International V/STOL Historical Society, available at http://vertipedia.vtol.org/vstol/wheel.htm, accessed on 20 Apr. 2016;
[2] ***, Disc Loading and Hover Efficiency, Krossblade Aerospace Systems LLC, available at http://www.krossblade.com/disc-loading-and-hover-efficiency/, accessed on 15 Apr. 2016;
[3] P. M. Basset, A. Tremolet and T. Lefebvre, Rotary Wing UAV Pre-Sizing: Past and Present Methodological Approaches at Onera, *Journal AerospaceLab*, issue 8, pp. 1-12, 2014;
[4] S. Hong, J. Jeong, S. Kim, J. Suk and Ji In Jung, *Longitudinal Flight Dynamics of a Single Tilt-wing Unmanned Aerial Vehicle*, 19th IFAC Symposium on Automatic Control in Aerospace, 2013;
[5] ***, User manual for Catia v5, Dassault Systems, 2014;
[6] ***, Ten-Engine Electric Plane Completes Successful Flight Test, NASA, available at http://www.nasa.gov/langley/ten-engine-electric-plane-completes-successful-flight-test, accessed on 20 Apr. 2016;
[7] ***, Ripmax Transition VTOL ARTF, available at http://www.ripmax.com/Item.aspx?ItemID=A-RMX200, accessed on 20 Apr. 2016;
[8] ***, Bell Eagle Eye Tilt-rotor UAV, United States of America, available at http://www.naval-technology.com/projects/belleagleeyeuav/, accessed on 20 Apr. 2016;
[9] ***, Unmanned aerial vehicle, available at https://en.wikipedia.org/wiki/Unmanned_aerial_vehicle, accessed on 20 Apr. 2016;
[10] Prisacariu V., Boşcoianu M., Luchian A., *Innovative solutions and UAS limits*, Review of the Air Force Academy, 2(26)/2014, Braşov, Romania, ISSN 1842-9238; e-ISSN 2069-4733, p51-58;
[11] ***, Unmanned Aircraft System (UAS) ROADMAP 2005-2030, US, Washington DC, 2005, 213p, available at https://fas.org/irp/program/collect/uav_roadmap2005.pdf;
[12] ***, Advanced Aircraft Analysis software, DAR corporation, available at http:// www.darcorp.com/ Software/AAA/ accessed on 20 Apr. 2016.

REMOTELY AND PILOTED AIRCRAFT SYSTEMS / LAW AND POLICIES