RECOVERY SYSTEM OF THE MULTI-HELICOPTER UAV

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Abstract: *The developments of UAS over the last decades have imposed approaches regarding the recover and rescue segment for aerial vectors. Operational and research requirements for UAV impose the use of recover systems due to the nature of the missions. The main purpose of the paper is to offer a global image regarding the recover and salvation systems used of the UAVs.*

Keyworks*: Unmanned aerial vehicles/sistems (UAV/UAS), recover system, multi-helicopter, paragliding*

1. INTRODUCTION

The sudden development in the last decade regarding unpiloted aerial system has imposed an increase in the reliability through a series of necessities: design, fabrication, flight insurance for the exploration and operation of the aircraft, economical, rules for flight acceptance, [1, 2, 6, 23, 24, and 25]. Operational and exploration requirements for UAVs impose in particular cases the use of rescue and recover systems. These systems could possess a large range of constructive solutions, such as: recover parachutes, recover bags, recover thread, and pneumatic cushions boats. The rescue and recover systems must allow a safe landing in case of emergencies and could become a solution to a standardization regarding landing in extreme weather and geographical conditions, [4, 5]. According to "goggle patents" around 1000 invention applications have been submitted till today, only for the UAV multi-helicopter salvation system. This type of UAV is mostly used due to the recoverable parachute.

1.1. HISTORY AND EVOLUTION

The first concept of recuperation from the air according to specialty references were applied during the Renaissance period in 1470 and the concept of the modern parachute were used in 1783 and 1787, see figures 1.1b and 1.1c. According to specialty references [16, 17, and 18] a series of rescue and recover systems were approved starting with 1950.

a b c

Fig. 1.1. First concept of recoverable systems: parachute [2]

1.2. SOLUTIONS REGARDING THE UAV RECOVERY

In the UAS domain, sustained increase of investments regarding, 3500 mil. $ 2016 [6] led to new implementation for the concept and design for reliability of the UAS. Recover systems are used in a wide range of constructive solutions, which may be classified as: manual and automatic command, standard or emergency procedure; destructive or nondestructive recover; shock or without shock (mechanical, pyrotechnical/pneumatic); maneuverable or non-maneuverable, mounted on aerial vector or system on ground systems (parachute, airbag, recover bag/thread, see figure 1.2a, 1.2b, [12, 13 and14].

a. Recoverable parachute and airbag [4]

b.Recovery mesh [5]

Fig. 1.2 Types of the recover systems

According to [7] the functionality of (ballistic) recover systems with parachutes are composed of four distinctive steps represented in figure 1.3.

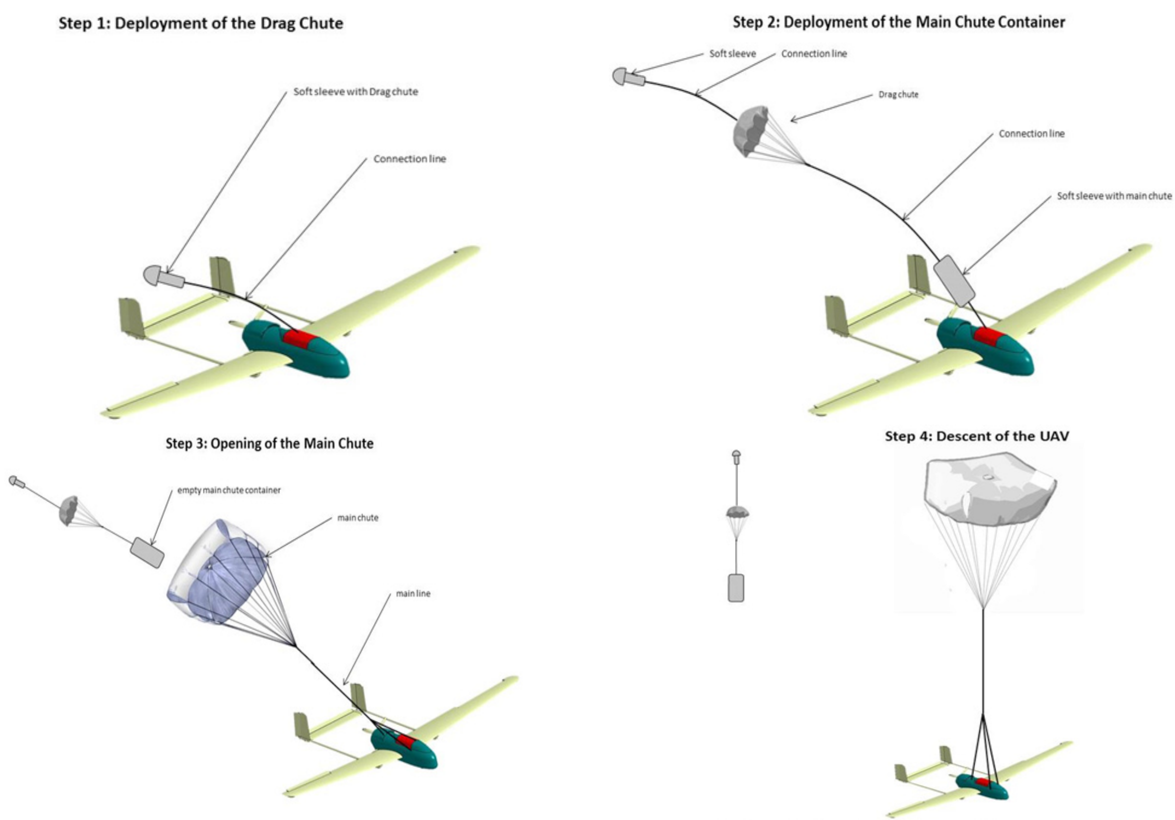


Fig. 1.3 Operating stages of a recovery and rescue system [7]

2. UAV RECOVERY SYSTEMS

In this chapter we represent the state regarding the recover system. According to specialty sources there are a series of companies which developed a salvation and recover system with a high success on the UAV market, [8, 9, 10, 11, 14, 20 and 22].

In 2013 MARS Company developed a series of units to enhance the safety of air operations and accident prevention for recover systems. This was only for UAV that had a weight between 1.8 and 11 Kg, see figure 2.1, [8, 9].

MARS 120 Mars mini

Fig. 2.1 MARS recoverable systems [9]

Opale-Paramodels offers recover containers with servomechanism action, see figure 2.2, and the opening of the parachute reduces instantaneously the altitude opening, [11].

Fig. 2.2 Multi-rotor recover kit and recovery parachute [10]

Sky-graphics offers recovery solutions of the UAV for segment from 45 to 100 kg see figure 2.3, [11].

Fig. 2.3 Protect-UAV recover kit [11]

Lithuanian company “My Research UAB” produces and sales recover modules since 2007 [20] see figure 2.4. The module has two pyrotechnic injectable portents, which offer high stability on the recover trajectory and the mass of this module has 0.5 kg which can be used by any multi-helicopter that has a weight between 5 at 9 kg.

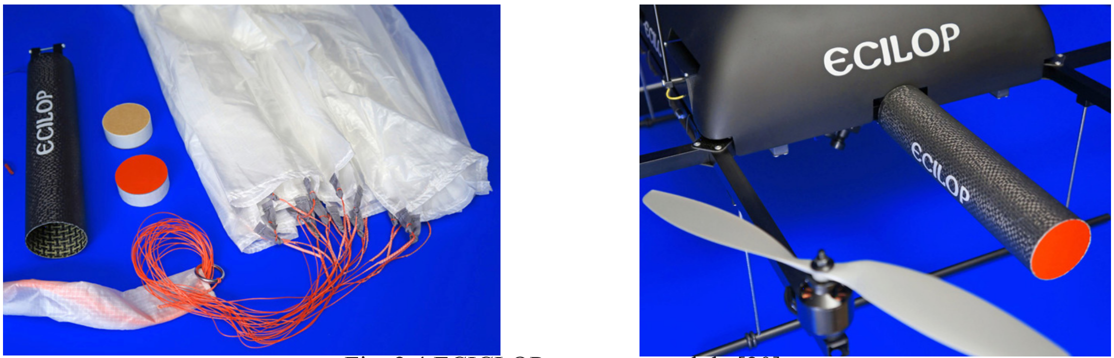


Fig. 2.4 ECICLOP recovery module [20]

Ballistic Recovery Systems produces four types of rescue modules for UAV and piloted aircrafts, container (figure 2.5a), kit rescue module (figure 2.5b), rescue bag (figure 2.5c) and recover and rescue system (figure 2.5d).

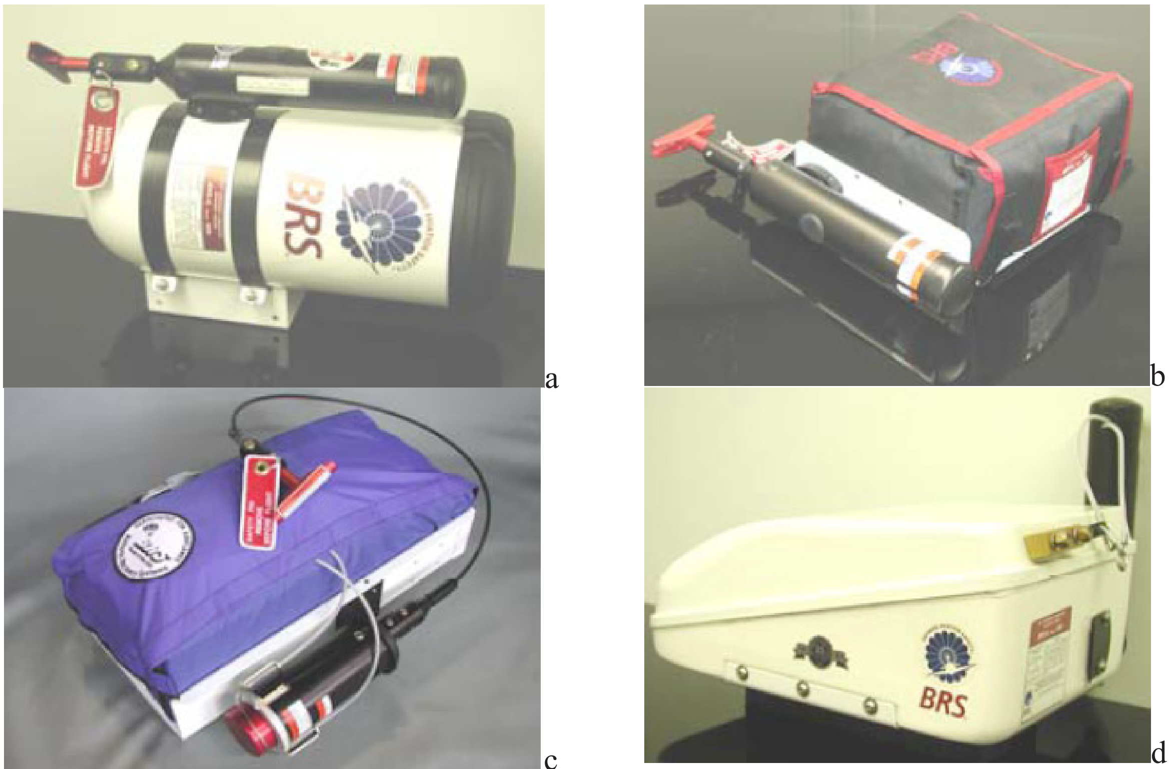


Fig. 2.5 BRS rescue and recover systems [14]

According to [22] even the French company *Arctic Parachute* developed a series of salvation modules with portent surfaces from 2.5 m^2 for 16 m^2 for UAVs with weight between 4 at 25 kg. Specialists from the French company recommend the use of a descend speed of 4 m/s while the system is in descend configuration.

3. A PROPOSAL REGARDING THE USE OF RESCUE AND RECOVER SYSTEM FOR UAS WITH ROTATE WING

Rescue systems with recoverable parachutes have a series of aspects regarding the weight of the aerial vector and the recovery system that was used.

The concept and design of these systems must contain o series of requirements, such as: simplicity in design, simplicity in exploration, safety and reliability during its functionality, volume and weight reduce, reduced force for action mechanism, automation capabilities, precision for landing (for missions), reduced cost for acquirement and exploration, [15].

According to specialty references, the portend surface of the salvation and recover parachute is direct proportional to the mass of the aerial vector, see table 3.1, [3, 15].

Table 3.1. Caracteristics of the rescue and recovery system (m/s)

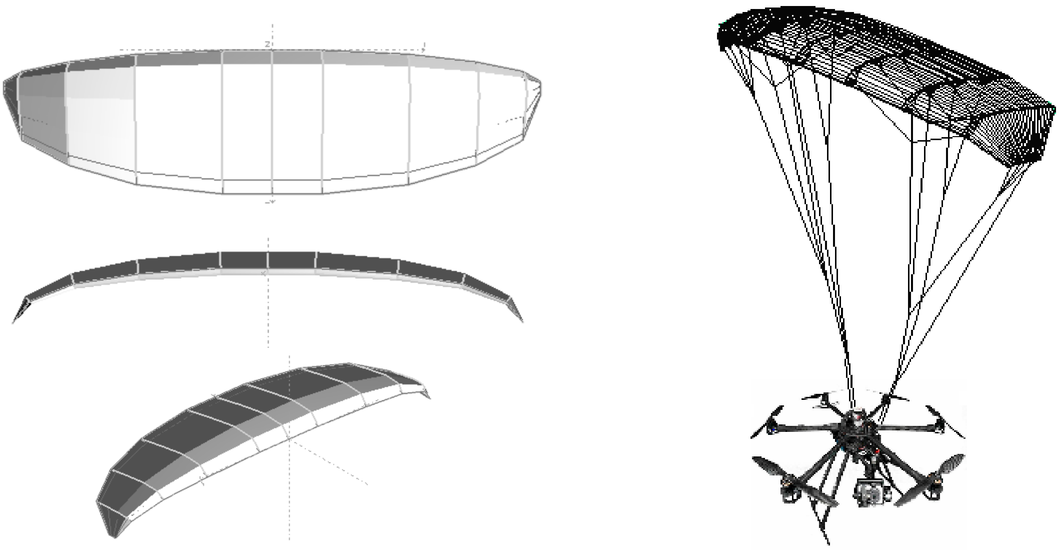
Mass / surface	**2**	**2,5**	**3**	**3,5**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**12**	**14**	**16**	**18**	**20 kg**
1,8	4,6	5,0	5,7													
2,5			4,0	3,6	5,1											
4,0				3,4	4,0	4,5										
6,0						3,6	4,0	4,2	4,4							
12,0									3,2	3,4	3,6	4,0	4,2			
15,0 m^2												3,5	3,8	4,0	4,1	4,2

The rescue and recovery module type paragliding is composed of: lifting surface with suspension lines, the arc mechanism to pull out the veil is conceived with a servomotor.

The form and characteristics of the rescue and recovery module are highlighted in figure 3.2 and table 3.2, the module is dimensioned for a multi-helicopter with a weight of 3 kg having a descent speed of 5.7 m/s, according to table 3.1.

Table 3.2 Technical characteristics of the lifting surface [21]

Span	2,99 m	X_{Cp}	31%
Aspect ratio	5	Cell numbers	8
C_0 / C_e	0,66 / 0,21 m	Surface	1,79 m^2
Angle of attack	5^0	Projected surface	1,58 m^2



canopy wing
Fig. 3.2 Lifting surface of the rescue and recovery module [19, 21]

A series of simulations with software XFLR5 have pointed out a satisfactory behavior of the flying with the form as in figure 3.2. The simulation conditions are noted in table 3.3., considering a trajectory planation at an angle of 45^0, [19].

Table 3.3 Simulation conditions

Speed	5,7 m/s	Simulation method	VLM
Gliding angle	-1… 10^0	Reynolds (central axis) Re	$2{,}85x10^5$

In figure 3.3 two cases of gliding are selected and we reveal the flight characteristics for a UAV system type multi-helicopter with a mass of 3 kg. According to the simulation cases at AoA 0^0 we have C_z=0,1295 and at AoA 5^0 we have C_z=0,4766. This rescue and recover module, optionally can be equipped with two commands for maneuverable flight on recovery section in case we use a multi-helicopter in difficult zones.

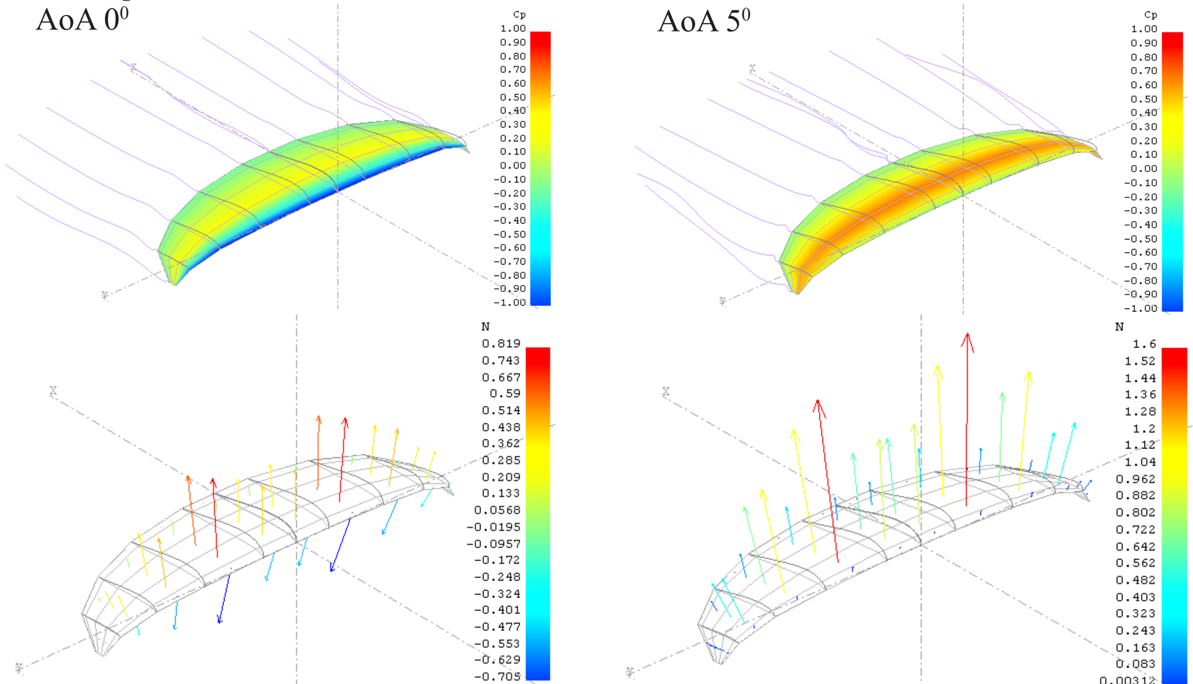


Fig. 3.3 Pressure coefficient C_p (up), force distribution on canopy (down)

The costs for this module are highlighted in table 3.4, acquiring approximately 5% of the price of the multi-helicopter.

Table 3.4 Cost of the rescue and recovery module

Container module	10 lei	Servo standard (2 buc)	100 lei
Paragliding wing	90 lei	Accesories	10 lei

CONCLUSIONS

Specific missions require high reliability from the UAS. The recover solutions are a way to complete the global reliability; these solutions can be conceived, analyzed and realized in accordance with the global performance indicators. The fabrication costs are important only when selecting the strategy for the salvation and recover of the UAS.

The principals of designing recover systems for UAS are adaptable so it can open a new approach generated by the cost of the systems onboard and the flight parameters at the beginning of the recovery stage.

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