Selection of low-cost recovery system for Unmanned Aerial Vehicle

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Abstract - *The development of unmanned aerial vehicle in the recent years have imposed the need of a reliable system in all accepts such as design, fabrication as well as recover system for unmanned aerial vehicle. The process of recovering an unmanned aerial vehicle at the completion of the task remains as the most difficult task even today, thus making the designer concentrate more on the recovery system. Recovery system is given more importance in the designing phase of unmanned aerial vehicle because improper landing and other environmental factors leads to the major mishaps. Thus proper and suitable recovery system for unmanned aerial vehicle becomes the highly desirable factor. The main purpose of this paper is to comprehend various recovery systems available for unmanned aerial vehicle and also to understand the advantage and disadvantage of various recovery systems, so that the recovery system which is apt for the unmanned aerial vehicle is selected before designing the vehicle.*

***Key Words*: Unmanned aerial vehicle, Recovery system, Environmental factors, Advantage, Disadvantage.**

1. INTRODUCTION

The Unmanned Aerial Vehicle (UAV) is referred to any vehicle which can operate without the intervention of human pilot and be entirely depended on the computer system and radio-link systems [1]. The development of the unmanned aerial vehicle is rapidly growing day by day over the last decade. Initially the uav's were used for surveillance and reconnaissance as a purpose of military application but now-a-days the application of uav's has reached higher level in civil applications such as news broadcasting, agriculture monitoring, aerial photography for mapping and inspection of pipe lines and infrastructures as a result a wide variety of applications are covered in civilian applications. There are various elements which are combined make up the unmanned aerial vehicle such as the ground control station, flight control station, payload and launch and recovery system. This paper focuses on the recovery systems.

1.1 HISTORY OF UNMANNED AERIAL VEHICLE

The first invention of unmanned aerial vehicle occurred when the Chinese General Zhuge Liang who used paper balloons which were filled with oil-burning lamps to heat the air, which was then used to scar the enemy soldiers. Then in the early years of aviation German aviation pioneer Otto Lilienthal employed unmanned gliders but he was not successful. In 1890's the idea of remotely piloted aircraft was promoted by Nicola Tesla. In late 1916 Elmer Sperry designed a lightweight air-plane that could fly unmanned out to 1000 yards which was used by U.S Navy [2]. The unmanned aerial vehicles were also used in both the world war times but did not have the technology to launch or control the aircraft. In 1998 the uav was used to cross trans-Atlantic. Today's uav's are of advanced technology in which uav's are used in much complex fields of both civilian and military purposes.

1.2 CLASSIFICATION OF UAV

The classification of the unmanned aerial vehicle is as follows such as mini or micro uav's (mini/MAV), typical uav's (TUAV's), strategic uav's and special task uav's. Micro and mini uav's comprise of the smallest platforms that fly at lower altitudes that is less than 300 meters. The application of mini or micro uav's is that they can be used to fly inside buildings and hall ways [3].Tactical uav's comprises of heavier platforms and fly at higher altitudes ranging from 3,000 to 8,000 meters. The primary application of tactical uav is to support military applications [3].Strategic uav's comprises of the High Altitude Long Endurance (HALE) platforms with its maximum altitude of 20,000 meters. The maximum take-off weight of strategic uav's varies from 2.5 kilograms to 12 kilograms. The primary application strategic uav is atmospheric monitoring and remote sensing [3]. Special task uav's are used for various civil and military applications. These uav's are categorized as special task uav's based on their varied application such as re-fuelling and continuous surveillance for more than 24 hours.

2. UNMANNED AERIAL VEHICLE RECOVERY SYSTEM

The method of recovering the uav at the end of its mission is the most problematic job the designer and the operator face even though there are several recovery choices. The primary function of the recovery system is to land the uav in a simple, safe and cost effective way. The necessity to securely recovery the uav has led to the expansion of various recovery systems. The design objective for the recovery system is as follows[4],

1. Necessity to require few or no people to operate.
2. Require reduced time to execute recovery.
3. Recovery system should be flexible to accommodate wide variety of vehicle.
4. Stability in motions to facilitate proper and error free recovery.
5. Recovery system should be modularized.

2.1. TYPES OF RECOVERY SYSTEMS

There are various types of recovery system available for the unmanned aerial vehicles which are as follows [5],

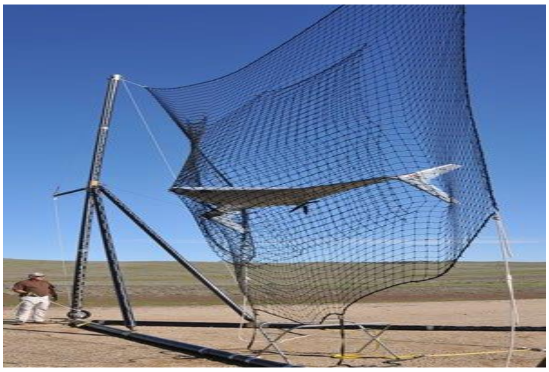
i) Conventional landing or wheeled landing.
ii) Skid or Belly Recovery.
iii) Vertical - Net Recovery Systems.
iv) Parachute Recovery.
v) Mid -Air Retrieval.
vi) Shipboard Recovery.

Now let's discuss the types of recovery system in detail to clearly understand the concept so that the reliable and least expensive recovery system is selected.

i. Conventional landing or wheeled landing: Conventional landing or wheeled landing is the recovery system which is used when there is a runway for landing the unmanned aerial vehicle. This type of recovery is the simplest option to land the uav on road, smooth track, runways and also landing on automobiles like truck or ship. Conventional landing option is most desirable when landing area is large and is one of the least expensive options. In some cases when there is no or less availability of space or area required to land the uav, this method of recovery cannot be applied. Conventional or wheeled landing is preferred for long-range uav's.

ii. Skid or Belly Recovery: Skid or Belly is same as that of conventional or wheeled landing systems but the only difference is that the landing gear systems are removed and the uav lands on its belly. Belly landing or Skid recovery is used since the designing is less complex when compared to conventional or wheeled landing. Skid or Belly landing recovery method is also less expensive and is preferred to be used in uav's where the position of cameras or other type of payload is not positioned under the belly. When Skid or Belly landing is preferred as the recovery system one should always remember belly landings are hard on uav surface and airframes due to the sudden impact of the uav on the terrain. Thus a strong belly construction which is capable to withstand the impact along with shock absorbers is necessary [5]. Skid or Belly landings are preferred for mini or micro uav.

iii. Vertical - Net Recovery Systems: The Vertical – Net Recovery system is the system in which nets are used for recovering the uav's. Generally the net is suspended between two poles and is always placed above the ground level with the help of structures to make sure it is held above ground level. This type of recovery system is chosen by keeping in mind the location of the propeller because the propellers may damage the net or due to the impact of net the propeller may also get damaged. The main aim when selecting Vertical – Net recovery as the recovery option is that it is desirable that the net properly distribute the retarding forces so that the uav does not get damaged. Another important criteria in selecting the Vertical – Net recovery system is keeping in mind about the wing span of the uav since uav's with large wing span require lengthy net to recovery the uav [5]. In areas where landing is restricted such as on ships Vertical – Net recovery system can be utilized [6].



iv. Parachute Recovery: In the case of Parachute recovery the parachutes carry the uav gently to the ground. The parachute recovery has a long history of use with target drones and other uav's. Numerous parachute configurations are available and are usually designed to have a relatively low rate of descend [5]. The main disadvantage of parachute recovery is that it adds weight to the uav system. There are various methods to pack the parachute such as traditional hand packing, vacuum packing system or pressure packing [7]. Furthermore, if the parachutes are not properly packed it may cause problems when they are deployed. Parachute recovery system has the risk of getting affected by environmental changes such as high winds may drift the parachute to greater distance and drag the uav's into undesirable ground causing a great damage to the uav as a whole.

v. Mid-Air Retrieval: The Mid – Air Retrieval recovery system is used as it provides the opportunity to perform recovery operations away from the ship in case the uav has to be recovery in such terrain, this method reduces the risk of the ship being damage due to improper landing or malfunctioning of the recovery system. The Mid – Air Retrieval operations are generally performed when there is good visibility and during daylight [5]. In the case of night recoveries the parachute of the uav should be illuminated so as to perform this kind of recovery. This type of recovery eliminates the need for guidance system in the last stage of the uav mission.

vi. Shipboard Recovery: Shipboard Recovery is another type of recovery system which is used for uav's which fly over the seas or other water terrain. The main aim in Shipboard Recovery is that during the process of recovery the ship or the personnel on-board should not be threatened. Unlike other recovery methods in this method space to land the uav is limited therefore reliability is necessary. The path of the ship should not be altered for the uav to be recovery because it may disturb the whole process. Shipboard recovery requires the uav to perform its task in an efficient way even at various sea state conditions [5].

3. ADVANTAGE AND DISADVANTAGE OF RECOVERY SYSTEMS

In the previous chapter various methods of recovery systems were discussed. In this chapter various recovery system along with its advantage and disadvantage are listed below [5], so that the designer acquires a clear idea about each recovery system.

Conventional landing or wheeled landing:

Advantage
- → Gentle retrieval of payload and sensor equipment.
- → Smooth landing of uav.
- → No additional equipment such as parachute or net required.

Disadvantage
- → Large landing area required.
- → Smooth landing area without obstacles.
- → Require manual landing or automatic landing.
- → Complex design.
- → Skilled operated not required.

Skid or Belly Recovery:

Advantage
- → No large landing area required minimum area is sufficient.
- → No additional equipment such as parachute or net required.

→ Landing sites can be easily hidden.
→ Skilled operated not required.

Disadvantage

→ Hard landing may sometimes cause structural damage.

Vertical – Net Recovery Systems:

Advantage

→ Zero - length Recovery.
→ Soft landing.

Disadvantage

→ Additional equipment required.
→ Increases the total cost of uav due to addition of additional equipment.
→ Landing site visible to enemy.

Parachute Recovery:

Advantage

→ Soft landing.
→ Easy to be deployed.

Disadvantage

→ Large volume needed to place the parachute inside the uav.
→ Adds weight to the uav system.
→ Hard landing.
→ Landing the uav in exact site in challenging.

Mid -Air Retrieval:

Advantage

→ Recovers system intact.
→ Small area required for landing.

Disadvantage

→ Requires additional communication system.
→ Requires manned aircraft to assist the uav to the landing site.
→ Expense due to the requirement of manned aircraft.

Shipboard Recovery:

Advantage

→ Soft landing.
→ Save landing of uav.
→ Recovers system intact.

Disadvantage

→ Landing the uav in exact site in challenging.
→ Requires additional communication system.

4. COMPARING THE RECOVERY SYSTEMS

The various recovery systems are compared based on the cost, safety, skill, design complexity, recovery failure rate. The table below expresses the comparison between various recovery systems. The rating of the recovery system is done which help us to identify the best recovery system for unmanned aerial vehicle in the table below:

Table -1: Rating of conventional and Skid recovery

Classification	Conventional or Wheeled landing	Skid or Belly Recovery
Cost	High	Low
Safety	High	Medium
Operator skill requirement	Average	Low
Design complexity	High	Low
Recovery failure rate	Low	Medium

Table -2: Rating of Vertical – Net and Parachute recovery

Classification	Vertical – Net Recovery system	Parachute Recovery
Cost	High	Medium
Safety	Average	Medium
Operator skill requirement	Medium	Average
Design complexity	Medium	Medium
Recovery failure rate	High	Medium

Table -3: Rating of Mid-air Retrieval and Shipboard recovery

Classification	Mid-air Retrieval Recovery system	Shipboard Recovery
Cost	High	Average
Safety	Average	Low
Operator skill requirement	High	High
Design complexity	Average	Average
Recovery failure rate	Average	Average

Table 1, 2 and 3 provides the rating for the recovery systems used in the uav. From the above mentioned tables it is clearly understood that the Skid or Belly landing recovery system covers the entire requirement for a successful and low – cost recovery system.

5. CONCLUSION

To accomplish an effective design of the uav recovery system plays a vital role, because without successful landing of the unmanned aerial vehicle the design is unproductive. High rate of durability and reliability of the recovery system is required to complete the mission of the uav. The discussion on the advantage and disadvantage of various recovery systems has given the idea to choose the best and apt recovery system for the uav. Mission requirements and the uav airframe design will provide the clear idea to choose between the numerous recoveries. Thus this paper gives the clear idea that the Skid or Belly landing recovery system full fills the entire requirement for a successful and low cost recovery system even with the untrained operator.

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