SAFETY EQUIPMENT FOR UNMANNED AERIAL VEHICLES

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The key factor that influences air traffic is safety. The article deals with safety of Unmanned Aerial Vehicles (UAV), with UAV forced landings and safety equipment and also systems that have been developed in connection with normal but also emergency situations including sense and avoid systems, parachutes, airbags, nets and flight termination systems. Nowadays the most discussed safety issue is the UAV sense and avoid system designed to detect and avoid other traffic and obstacles during the flight. The UAV parachute landing systems are used to soften and cushion impact with the ground and can be also fitted with airbag recovery systems. Nets can serve as a protection from people injuries and property damage during trainings or performances. This kind of nets was installed also in the Hall for UAV testing at our Department of Aviation Technical Studies (DATS). In some specific situations also flight termination systems are used to destroy the UAV using a self-destruct mechanism. For the overall overview of safety equipment emergency locator transmitters and data loggers are mentioned and contribution of the DATS to the UAV safety is introduced.

K e y w o r d s: unmanned aerial vehicle (UAV), forced landing, parachute, airbag, net, flight termination

1 INTRODUCTION

Unmanned Aerial Vehicles (UAVs) are often defined as powered, aerial vehicles that do not carry a human operator, use aerodynamic forces to provide vehicle lift, can fly autonomously or be piloted remotely, can be expendable or recoverable and can carry payload. Originally were UAVs designed almost exclusively for military purposes. But nowadays UAVs are also used for many civil applications mainly for surveillance, monitoring, surveying and securing purposes in police, border control, search and rescue, fire fighting departments, in cartography, geography, geology, agriculture, energy etc. When considering that there are so many possible UAV applications it is obvious that many types of UAVs have been developed. They have different dimensions, weight, configuration, equipage and they use different navigation systems, communication, command and control standards. Those differences make the generalization of UAV technological characteristics, mission planning, navigation, operation, guidance, control, endurance and design very difficult. It is the main reason why standards and regulations are still missing in this area, although safety issues plays in connection with UAV integration into the civilian airspace a very important role.

The presented article gives an overview in the current state of safety equipment that can be, but don't have to be used by the UAV, because of the lack of standards in UAV safety equipment that can vary according to the UAV type and mission.

2 FORCED LANDING

An emergency or forced landing of a UAV is an unscheduled event that can occur at any time during a flight and it is required if there is an emergency on board that requires the aircraft to land immediately [1]. Emergency landing is possible if there is still a certain level of control and the UAV is able to manoeuvre to a desired landing location. According to the UAV level of autonomy the forced landing can be performed:

- **manually** by the UAV pilot or operator;
- **semi-autonomously** following a pre-defined forced landing scenario. It means that emergency procedures are pre-defined and there is a database of location suitable for landing or one pre-defined landing location;
- **autonomously** using a system that is able to autonomously decide on a safe landing site, and is able to navigate the UAV to land on that site [2]. A safe landing site for a UAV forced landing is considered to be one (according to the priority) that will not cause any injury to a person, not damage property and minimises damage to the UAV. An example of this would be that a UAV forced landing system would choose to land a UAV in a lake instead of landing onto a busy road. The important point to note for a UAV forced landing compared with a conventional (piloted) forced landing is that a UAV may intentionally crash into an area that causes minimal risk of injury to people on the ground without concern for the UAV platform. This is a stark contrast from a conventional forced landing case where one of the pilot's main concerns is to try and save the lives on-board the aircraft.

Based on the literature review, no autonomous UAV forced landing system currently exists. It is proposed that there are two distinct problems to solve. The first problem is the selection of suitable forced landing locations. The second problem involves the process of navigation to and landing on the selected landing site. The other steps involved in the system such as the decision on whether to activate the forced landing system, initiating emergency communications to UAV operators etc.

2.1 Autonomous landing location selection

Criterion for UAV autonomous landing location selection is based on the elements that a human pilot considers when selecting a landing site during a forced landing commonly known as the 'six S': size, shape, slope, surface, surroundings and civilisation (Fig. 1).

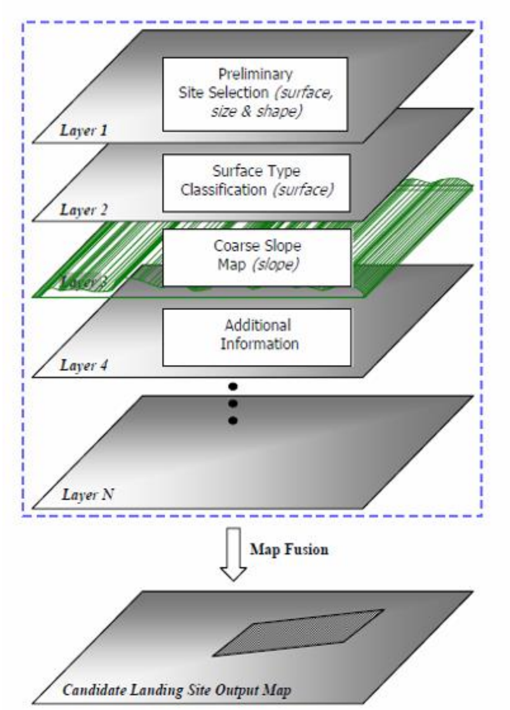

Figure 1. Safe landing place selection architecture [3]

Selection of suitable location for landing involves two partial problems:

- finding a suitable ways **how to segment the images of the ground into potential landing areas** – problems arose from the large images requiring segmentation coupled with the presence of a large number of small objects from the given altitudes. The images requiring segmentation are complex natural scenes. Large segmentation times are unsuitable as the time to make a decision for a landing site is critical for this application. That are some of the reasons why many different image segmentation techniques are developed: research on adaptive image segmentation techniques using genetic algorithms [4]; c-means clustering algorithms [5]; colour clustering techniques [6]; histogram clustering [7]; indexing techniques with colour histograms [8]; maximum likelihood segmentation [9] and histogram based region merging methods [10]; pixel based k-means clustering based on colour, intensity and pixel location [11]; a region growing approach based on colour and intensity – random seed location; a hybrid approach using methods from Deng et al [12]; homogeneous image regions using neural networks.
- finding a suitable ways **how to use the information to output a suitable representation of the area below the UAV** – following the segmentation, the next step is to test whether the different regions in the segmented image are large enough for a UAV forced landing. Only on selected areas the surface type classification of the individual areas is performed and also obstacles including moving objects (for example vehicles, people) are analyzed. Information are then used in the decision making process and the areas are classified as suitable and unsuitable or safe and unsafe so that a higher level process can augment other information such as glide slop distance, and landing areas tracked over time to choose the best possible landing site out of the candidate landing areas identified (Fig. 2).

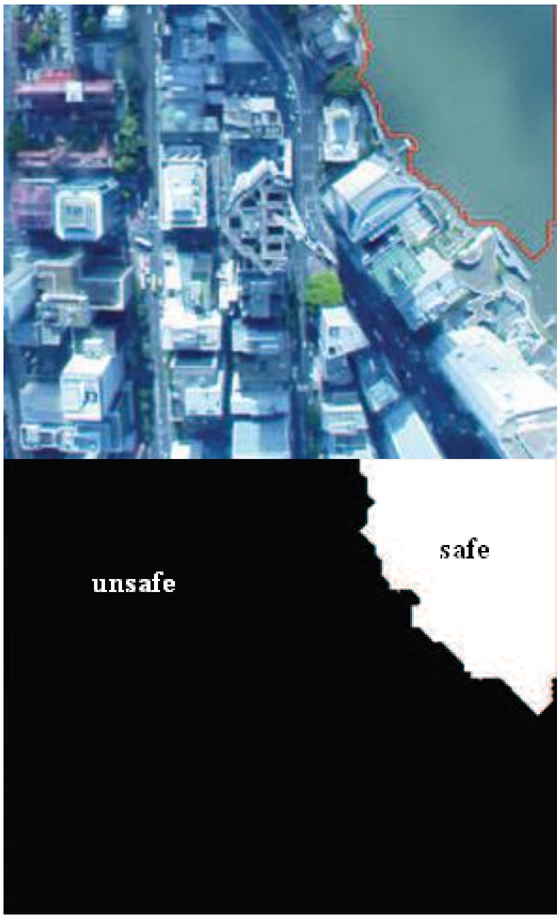

Figure 2. Safe landing place selection [3]

2.2 Autonomous navigation

Autonomous navigation systems for UAVs are usually based on inertial measurement units consisting of accelerometers, gyroscopes and magnetometers often integrated with GPS and barometric information. To ensure the autonomous navigation also sense and avoid system has to be used. There are many types of sense and avoid system. While larger UAVs might effectively implement radar or other existing system, such a solution is problematic for smaller UAV. Therefore many new technologies have been developed, using for example small passive electro-optical, infrared or acoustic sensors to search and detect the traffic. But choosing the sensor and the detecting method is not the only problem. There are also many different methods of avoidance that can be implemented. And the last barrier is that there are no existing standards for UAV sense and avoid system, only some recommendations.

3 SAFETY EQUIPMENT

There is a number of complimentary approaches that have be proposed and implemented on UAVs and used in the event of a system failure. These complimentary approaches often include parachutes and flight termination systems as passive safety systems that could be used in specific UAV operations; however an active forced landing system would be the safest approach across a broader range of applications.

3.1 Parachute safety system

Parachute safety system for the UAV can be used for routine landing or for emergency only. That is the main issue that should be taken into the consideration when choosing the parachute for the UAV. But there are many other problems that should be considered, for example UAV type, configuration, weight, speed, rate of descent, operation conditions (rain…), place of landing (water, dirt…), landing attitude (right side up, upside down, nose up, nose down…). Important are also characteristics of the parachute safety systems, for example its dimensions, weight, opening limit, stowing (internal, external) and of course there is a question of parachute reusing – if so, which components will be recycled and where will be the parachute repacked (in the field or sent back to manufacturer). Other issue is to integrate system for parachute into the UAV control unit. Main problems that have to be solved are manual or automatic parachute activation and prevention from parachute opening into the propellers.

UAV parachute recovery systems may comprise of the following main components:

- an **extractor parachute**, which may be connected to one of the doors of the vehicle or extracted by means of a mechanical system or pyrotechnic mortar; its function is to deploy the deceleration system in the air;
- a **drogue parachute**, which is a ribbon-type parachute, whose purpose is to gain control of very fast descents, in order to enable the deployment of the main parachute without unduly stressing the parachute canopy fabric;
- a **main parachute** to slow down the vehicle's descent to within the pre-established speed; this can be of various shapes ("polifonico", ring-shaped, square) as needed;
- a **container** made of fabric, metal or a mixture of both, its function is to contain the deceleration system in the smallest possible space and to allow the proper deployment of the system.

Several parachute recovery systems for UAVs are provided with a device that separates the parachute from the vehicle on impact with the ground, to prevent the vehicle from being dragged on the ground, by the parachute, for example in the windy conditions [13].

3.2 Airbag recovery system

The UAV recovery systems are often fitted with airbags (Fig. 3) too, to soften and cushion impact with the ground and protect the vehicle's electronics. The device is activated when a landing signal is transmitted.

Figure 3. UAV parachute recovery system fitted with airbags [13]

3.3 Nets

Many UAV are able to take off and land without using runways on airfield. One of the ways how to accomplish the emergency landing is to use a capture net, sized and designed according to the specific UAV characteristics.

Figure 4. Nets in the Hall for UAVs testing

A net can be responsible for arresting the vehicle and damage minimisation in the landing phase of flight. But there is also another possibility of using nets. If they are placed vertically they can serve as a safety element to separate viewers during UAV air shows or performances. Vertical nets can be useful also during trainings. This kind of nets is used also in our Hall for unmanned aerial vehicles testing. All planned and also accidental net reliability tests ended successfully without threat of persons and without property and even UAV damage (Fig. 4).

3.4 Flight termination systems

Flight termination systems are explosive devices that are used in specific situations, for example in the event of a system failure. These types of systems are used for the containment of UAVs within specific airspace under specific conditions. For certain missions or experimental tests, UAVs can be allocated a region of airspace by regulatory authorities that they are allowed to operate in. If the UAV has some kind of failure that threatens the breach of this airspace, ground operators can engage the flight termination system to destroy the UAV before it leaves the allocated airspace.

Nowadays only few UAVs have built a self-destruction mechanism. It would be possible to put such a mechanism on most UAVs, but in some cases it could be very dangerous and also impractical. Flight termination could be programmed to either be manually commanded, or to occur in the event of communication loss after a predetermined time. The problem with this scenario is that UAVs loose link with their ground controllers frequently due to many reasons. Nevertheless, probably lot of UAVs would end up blowing up needlessly and that would make their use very expensive.

UAVs used in military, governmental and some safety, security, monitoring and observation application have built a self-destruct mechanism more often and it is usually because of the fact that sensitive or secret information are stored on the vehicle.

Some of the UAVs have built only a function to erase data if a seal is broken on a component in an attempt to tamper or gather information held within.

3.5 Emergency locator transmitter

Emergency locator transmitter is a device capable of automatic or manual operation designed to withstand forced landing and crash environment conditions and survive in an operable condition, which transmits a unique identifying message with a unique ID. Other message types may be custom-programmed.

The inertia switch is designed to be activated when the unit senses crash-specific longitudinal inertia forces. If properly installed, parallel to the line of flight, the transmitter will not be activated due to turbulence, normal operation, or aerobatics.

3.6 Data logger

Data logger is an electronic device employed to record any instructions sent to any electronic systems on the UAV. It is a device used to record specific UAV performance parameters and also for incident and accident investigation, as well as for analyzing air safety issues, material degradation and engine performance. Due to their importance in investigating, these devices are constructed to withstand the force of a high speed impact and the heat of an intense fire.

4 CONTRIBUTION OF OUR DEPARTMENT TO UAV SAFETY

The Department of aviation technical studies has dealt with magnetometry on a long-term basis. As it was already mentioned one of possible magnetometer utilization is their use in inertial measurement units. But there are also other possibilities how to use magnetometer on UAVs that is directly regarding to the UAV operation safety. Magnetometers using microwire-based sensors are particularly convenient for UAV application because of their dimensions and low manufacturing cost and can be used for example as a part of system that can initiate warnings to pilots or operators if the UAV approach electric power transmission lines. This information could be useful in many applications that require flight in low altitudes and out of line of sight or using autonomous navigation systems. Another possibility how to use microwire-based sensors is in the health-monitoring systems to monitor UAV construction and to detect risks or even damage in the mechanical construction.

5 CONCLUSION

Emergency landing of the UAV is considered to be safe if during the landing no injury to any person is caused. The second safety priority in connection with emergency landing is the damage on property. Nowadays more attention is paid to minimisation of the UAV damage, because UAVs became more sophisticated and expensive and can carry important payloads or valuable information.

For these purposes UAV safety equipment and whole range of systems including mainly sense and avoid systems, parachutes, airbags, flight termination systems have been developed. But the issue of emergency landings and safety equipment has to be solved from the both technological and also legislative point of view.

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