Integrated UAS system – Single skin textile wing

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ABSTRACT – REZUMAT

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This paper depicts the early phase of development for an integrated system tailored for emergency response actions and remote sensing. This paper focuses on the support system envisioned as an integrated Unmanned Aerial System (UAS) system that consists of one or more ultra light multifunctional aerial units with a configuration that can be adapted to the nature of the intervention: monitoring, mapping, observation and logistics etc.

Starting from wing airfoil and material selection and ending with the experimental model manufacture, the paper will present the development of a single sail paraglider wing that can meet the operational demands for emergency response situations. The wing was designed mainly to have an easy handling and to have a predictable deployment at all times. The entire system and the aerial units were designed with increased modularity in order to be tailored for specific operational requirements of the intervention.

Keywords: *Unmanned Aerial System (UAS), parachute, paraglider*

Sistem integrat UAS – Aripă textilă cu un singur strat

Această lucrare prezintă faza de început a proiectării unui sistem integrat adaptat pentru acțiuni de răspuns în caz de urgență și teledetecție. Această lucrare se concentrează asupra unui sistem de asistență imaginat ca un sistem UAS (Unmanned Aerial System) integrat care constă dintr-una sau mai multe unități aeriene multifuncționale, ultra-ușoare, cu o configurație care poate fi adaptată la natura intervenției: monitorizare, cartografiere, observație și logistică etc.

Începând cu selecția profilului aerodinamic și a materialului textil pentru aripă și terminând cu fabricarea modelului experimental, lucrarea va prezenta dezvoltarea unei aripi de parapantă cu o construcţie dintr-un singur strat care poate satisface cerințele operaționale pentru situații de răspuns la situații de urgență. Aripa a fost proiectată în principal pentru a avea o manevrare ușoară și pentru a avea o deschidere previzibilă în orice condiții. Întregul sistem și unitățile aeriene au fost proiectate cu o modularitate crescută pentru a fi adaptate cerințelor operaționale specifice ale intervenției.

Cuvinte-cheie: *aeronavă fără pilot (UAS), parașută, parapantă*

INTRODUCTION

Emergency response is a series of organized and coordinated precaution and actions during the time between the detection of possible event and stabilizing the situation. An emergency response decision support system needs to assist decision makers to evaluate emergency plans and select an appropriate plan of action during an emergency by supporting heterogeneous emergency response data sources and providing decision makers with access to appropriate emergency rescue knowledge. It also needs to provide differentiated services to meet particular requirements.

Decision making in emergency response is an extremely time-sensitive and challenging task that requires immediate and effective response from decision makers who are surrounded by a variety of uncertain information and are under huge pressure from the need to coordinate action. An emergency response decision support system needs to assist decision makers to evaluate emergency plans and select an appropriate plan of action during an emergency by supporting heterogeneous emergency response data sources and providing decision makers with access to appropriate emergency rescue knowledge. It also needs to provide differentiated services to meet particular requirements.

There are four main emergency response functions – emergency assessment, risk operations, population protection and incident management. The four functions provide a framework for organizing response activities to a wide variety of emergencies, natural hazards, technological accidents, terrorist attacks, and sabotage [1].

Emergency assessment: The emergency response activities in the response phase relate to the understanding of the behavior of the hazard-generating factors but also of the risk to human life and material damage.

Risk operations: Risk operations aim at mitigating emergency situations but are only implemented when needed. Their applicability varies greatly from one hazard to another.

Protection of the population: The information collected during the emergency assessment is the basis for the choice of population protection actions.

Incident management: Incident management involves the development of an incident management policy, a set of consistent, repeatable, measurable processes and procedures and the use of appropriate administrative, managerial, technical or legal means to detect analyze and respond to incidents serious.

Regardless of the emergency structure that acts against the timer, time is the greatest enemy, and the scoring scale is the response time, which must be very low. With the latest Unmanned Aerial Vehicles (UAV) technology, the risks that influence response time can be reduced.

Also, unmanned aerial devices allow convenient remote sensing with the convergence of many technologies like micro-electronics, auto-piloting, high-charge batteries, super materials that are strong yet lightweight, wireless communication, compact digital cameras, image-processing software, miniaturization of GNSS and INS, and so on – all of these novelties created synergy. However, the key to the success of an UAS for remote sensing lay not only in the hardware and electronics but also in the ability of today's software to automatically derive orthoimages and DEMs from overlapping digital images and airborne Lidar point clouds. The scientific fields of computer vision and artificial intelligence have definitely contributed to the development of the backbone of UAS through fundamental research. Indeed, today's photogrammetric software supports high automation of the entire chain, from flight planning, self-calibration of consumer-grade cameras and aero-triangulation through automatic block adjustment up to the creation of DEMs and orthomosaics as well as their confluence: 3D city models and 3D virtual landscapes in which a surveyor can place a cursor, as if it were a rod, over a terrain point from the comfort of an office. Field survey is only necessary when high-precision georeferencing is required, and this is done by measuring through differential GNSS the coordinates at sub-centimetre level of around half a dozen ground control points (GCPs) evenly distributed along the borders of the area. As a result, the full survey, from flight planning up to the final georeferenced products, can be conducted in just one or two days.

Starting from the premise that the way of manifestation of the emergency situations and their management system in the future will be very different from the past context, we have proposed to develop an integrated support equipment and systems that respond to the challenges and needs of these field that need to be addressed in an organized and integrated manner.

MATERIALS AND METHODS

Operational and performance requirements for an integrated system

The Emergency Assessment is the first phase with the following operating requirements:

A1. Collecting information from where events occurred: fires, explosions, industrial accidents, floods, etc.;

A2. Detection of the NBC contamination level of an area;

A3. Patrolling of some areas (border, communication routes, infrastructure – electrical networks, transport pipelines etc.) for the purpose of preventive detection of emergency situations or mapping duty in case of environments with changing topography.

On the basis of the collected data, it is possible to move to the second phase of efficient incidents management through:

B1. Persistent surveillance of the area where events occur that have a continuous spatial and temporal evolution (fires, floods, natural disasters, industrial accidents, etc.);

B2. Appropriate equipment for intervention staff with PPE tailored specifically to the event produced;

B3. Locating and tracking in real time intervention teams;

B4. Search for missing persons in natural environments covered with dense vegetation;

B5. Temporary provision of radio communication coverage of mobile radio communications networks in isolated/hard-to-reach areas or where terrestrial networks are unavailable/degraded;

B6. Small-scale logistics transport in remote areas.

Component and capabilities of the integrated system support

The conceptual block scheme of the integrated support system for emergency interventions is presented in figure 1.

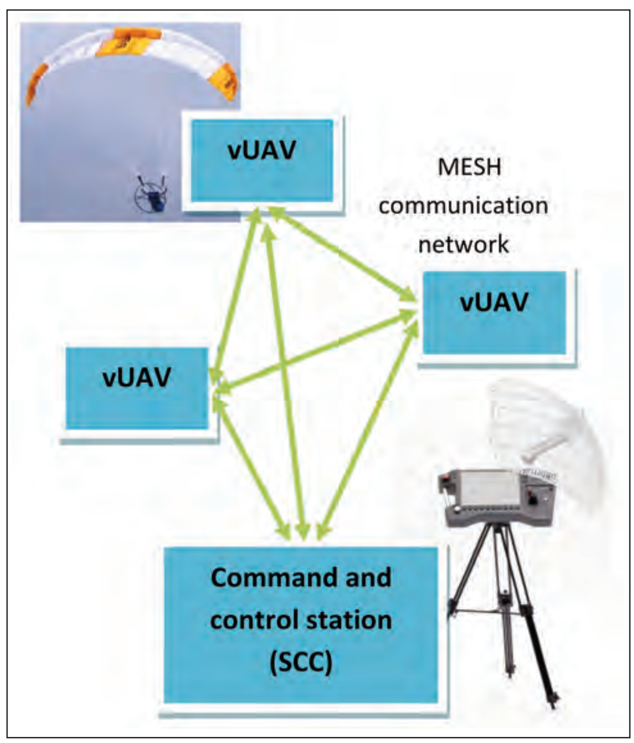

Fig. 1. The conceptual block scheme of the integrated support system for emergency interventions

Component elements of the support system:

a) *UAS vectors (vUAV)*

Flexible wing type paraglider, with hybrid electric and/or thermic engine propulsion and interchangeable load [2–4]:

C1. Video stabilized support: HD day-night and/or FLIR (Forward Looking Infrared) camera and/or LiDAR (Light Detection and Ranging) sensor;

C2. NBC sensor suite including: gas detector and volatile organic compounds; ionizing radiation detector and aerosol sample collector;

C3. Detection and location unit for multiband and telecommunication relay in GSM band;

C4. Cargo unit.

b) *Command and Control Station (SCC)*

This station is used for controlling and monitoring the air vectors and transmitting the data in real time to the command point of the intervention and consists of: antennas (a fixed antenna and a tracking antenna); data transceiver; microcomputer; HID (Human Interface Devices); rechargeable battery and generator. Transmission of these data is encrypted by high-speed terrestrial data transmissions in the 5 GHz or 4G GSM band if there is no access to a terrestrial telecommunication hub.

From the analysis of the operational and performance requirements [5], the best wing configuration for the flight module is chosen to be a single skin ram-air paraglide (figure 2). This configuration significantly has less weight then the classic ram-air construction.

This type of flexible wing UAV has major cost advantages over a fixed wing UAV. A UAV with flexible wing does not have the flight speed of a fixed wing and cannot fly in a fixed position as a rotor type UAV. If we are to enumerate the pros/cons of a flexible wing UAV, they would look like this:

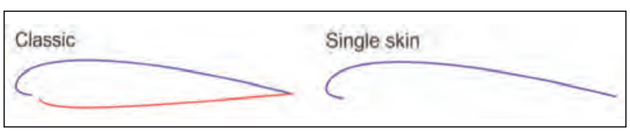

Fig. 2. Types of flexible wing profiles

Pros:
- Low cost;
- Low complexity;
- High reliability;
- High cargo capacity.

Cons:
- Low flight speed;
- Low flight dynamics;
- Weaknesses facing adverse climatic factors.

The last disadvantage is to be minimized by developing a fabric that exhibits superior characteristics of resistance to adverse climatic factors: rain, heat and UV radiation.

RESULTS AND DISCUSSION

Figure 4 depicts a possible construction option for the primary UAV control module:

Main UAV vector features (vUAV):
- All up weight of the UAV vector: max. 50 kg;
- Maximum payload: 30 kg;
- Projected wing span [6]: 6.8 m;
- Flight endurance:
  - 1h (electric);
  - 3h (internal tank ICE);
  - +12h (external tank ICE).
- Speed: 25–65 km/h, 35 km/h cruise speed;
- Dual electric/thermal propulsion:
  - The experimental model powered by a small block two-stroke internal combustion engine of > 24 cc (~2.2 HP @ 9000 rpm) that drives the main propeller through a dog-clutch and a transmission belt;
  - A starter-motor-generator (MG) also attached to the propeller shaft;
  - The experimental model can be powered in three ways:
    - ICE only;
    - MG only;
    - Powered by both engines (ICE + MG).
- Environmental operating conditions for any UAS vector:
  - Temperature: –30 °C + 50 °C;
  - Altitude: < 3000 m;
  - Normal operation in rain, snow and dust conditions (> IP54).

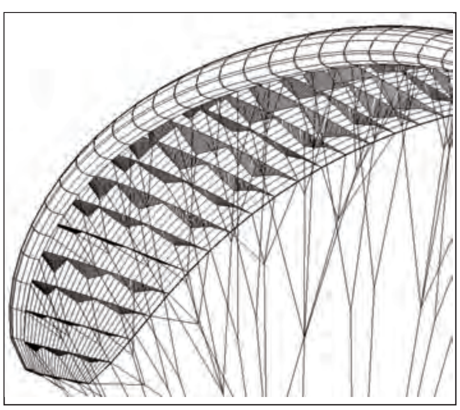

Fig. 3. Wing – single skin construction

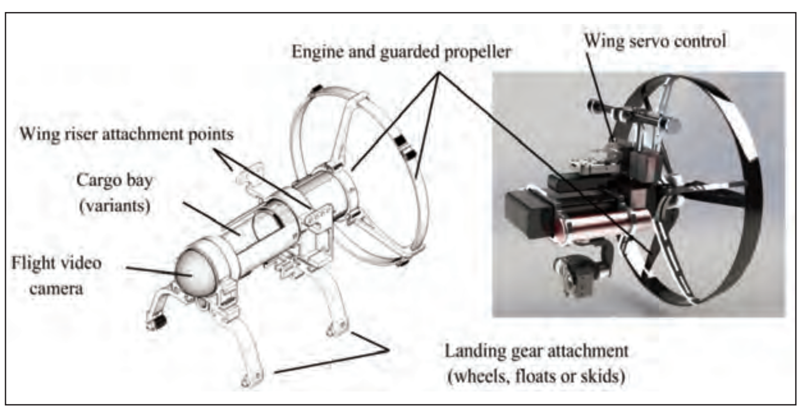

Fig. 4. Main UAV airframe and support structure

CONCLUSIONS

The flexible ram-air wing will be a single skin ram-air glider with 6.8 meter projected wing span.

The fabric used in the manufacture of the wing has superior characteristics of resistance to adverse climatic factors: rain, heat and UV radiation. In particular double rip-stop nylon 6.6 fabrics with urethane amino modified poly siloxane coating for UV protection and plasma treatment for advanced hidrophobization.

The propulsion system will comprise of a small block internal combustion engine coupled thru a mechanical power selector to an electrical motor/generator and to the propeller.

The modular configuration of UAS support system and load variants of the UAS support system are:

- Video suite: permanently mounted (for observation, monitoring, cartography and GIS);
- NBC sensor set: if necessary (for investigation area, NBC hazard detection);
- Sensor detection and localization sensor set: if necessary (for locating missing persons, fire detection and wind direction detection);
- Cargo unit: if necessary (or emergency transport, medicines and supplies in remote areas, small cargo, up to 10 kg).

REFERENCES

[1] Green, L.V., Kolesar, P.J., *Improving emergency responsiveness with management science*, In: Manage Sci, 2004, 50, 8, 1001–1014, 173–187

[2] Günaydin, K.G., Çeven, E.K., *A research on tensile and abrasion properties of fabrics produced from conventional and fire resistant type polyester yarns*, In: Industria Textila, 2017, 68, 6, 407–414, http://doi.org/10.35530/IT.068.06.1484

[3] Mihai, C., Ene, A., Jipa, C., Ghimus, C.D., *Structure with controllable permeability for vertical aerodynamic stabilizers-decelerators*, In: Industria Textila, 2018, 69, 2, 146-151, http://doi.org/10.35530/IT.069.02.1530

[4] Mengüç, G.S., Temel, E., Bozdoğan, F., *Sunlight exposure: the effects on the performance of paragliding fabric*, In: Industria Textila, 2018, 69, 5, 381-389, http://doi.org/10.35530/IT.069.05.1406

[5] Knache, T.W., *Parachute recovery systems – Design Manual*, Para Publishing, Santa Barbara, California, 1992, 287–288

[6] Poynter, D., *The Parachute Manual – A Technical Treatise on Aerodynamic Decelerators, Vol. 2*, Santa Barbara, California, 1984, 473

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