UAS deployment and data processing during the Balkans flooding

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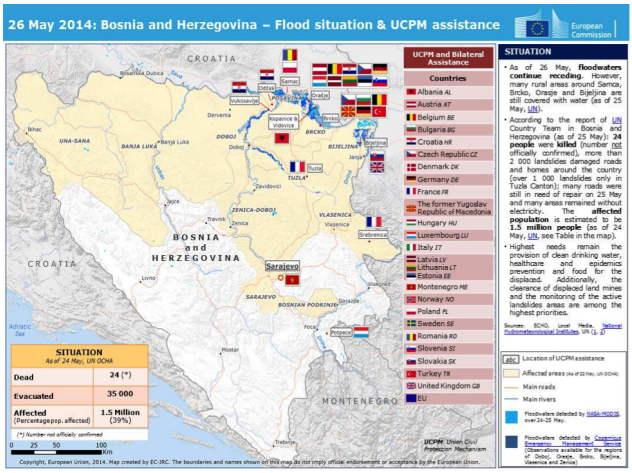

Fig. 1: Bosnia flood map (source: EU Commission)

***Abstract*—This project paper provides a report on a real relief operation mission, jointly conducted by two European research projects, in response to the massive flooding in the Balkan in spring 2014. Un Unmanned Aerial System was deployed on-site in collaboration with traditional relief workers, to support them with damage assessment, area mapping, visual inspection and re-localizing the many explosive remnants of war which have been moved due to the flooding and landslides. Novel robotic technologies and data processing methodologies were brought from the research labs and directly applied onto the terrain in order to support the relief workers and minimize human suffering.**

I. Introduction

In the period between end of May and beginning of June 2014, Bosnia and Herzegovina and Serbia were hit hard by catastrophic massive flooding after abundant rainfall over a few weeks causing floods and landslides. The rain was the heaviest in 120 years of recorded weather measurements and the countries suffered great damage. Only in Bosnia and Herzegovina, an estimated 1.5 million people were affected (39% of the population). Flooding has led to at least 53 deaths in both countries [1]. The EU Civil Protection Mechanism has been activated due to the catastrophic crisis 22 Member States have offered assistance through the Mechanism. Figure 1 shows the flood situation (on 26 May 2014) and the deployment of international teams through the EU Civil Protection Mechanism. The whole northern and partially central region of the country were at that moment heavily affected.

Among many other international SAR teams the Belgian First Aid and Support Team (B-FAST) was deployed to Bosnia to help with relief operations. Along with the B-FAST team, two EU-research projects decided to bunle their forces to support the relief operations:

- **ICARUS** - The ICARUS project [2] deals with the development of a set of integrated components to assist search and rescue teams in dealing with the difficult and dangerous, but lifesaving task of finding human survivors. The ICARUS tools consist of assistive unmanned air, ground and sea vehicles, equipped with victim detection sensors. The unmanned vehicles collaborate as a coordinated team, communicating via ad hoc cognitive radio networking. To ensure optimal humanrobot collaboration, these tools are seamlessly integrate into the C4I equipment of human crisis managers and a set of training and support tools is provided to learn to use the ICARUS system [3].
- **TIRAMISU** - The objective of the TIRAMISU project [4] is to provide the Mine Action community with a toolbox to assist in addressing the many issues related to Humanitarian Demining, thus promoting peace, national and regional security, conflict prevention, social and economic rehabilitation and post-conflict reconstruction.

Assets of the two projects were jointly deployed. The Belgian Royal Military Academy (RMA) sent an Unmanned Aerial System (a MicroDrones MD4-1000 [5]) along with 3D mapping tools, in order to assist the teams for task such as damage assessment, dike breach detection, mapping, aerial inspection and for re-localizing the many Explosive Remnants of War (ERW) which have been displaced due to the landslides. In Bosnia, the presence of many ERW created an extremely dangerous situation for the local population and the relief workers. Therefore, on the field, the mission also assisted a team of the Bosnian Mine Action Centre which was deployed to multiple regions of the country in order to localize the displaced ERW. The relief efforts were rendered very difficult due to the destroyed infrastructure, broken telecommunication links, blackouts, etc. The problem of shifting minefields also hampered the provision of aid and relief and debris clearance.

Flight permits up to a flight altitude ceiling of 150m for the complete Bosnian territory were granted with the support of the Ministry of Security of Bosnia and Herzegovina and the national Directorate of Civil Aviation (BHDCA). Due to the crisis situation and thanks to the fact that all application documents for the flight permits were readily available (as they

were prepared for previous operations), these flight permits were issued within half a day after a coordination meeting in the capital Sarajevo with the Bosnian Ministry of Security. During this meeting, the UAS mission received the full support from the Federal Civil Protection of Bosnia and Herzegovina, the Ministry of Security and the Bosnian Mine Action Centre.

In a period of two weeks, we operated with a Vertical Take-Off and Landing Remotely Piloted Aircraft System on 13 locations (in the north and central part of the country). We performed around 20 flights within Visual Line of Sight in urban and semi-urban areas. In general, two types of operations were performed:

- *Manual Flights*. End-users (rescue or demining teams) indicated points of interest they wanted to see investigated by the UAV, mainly for damage assessment and visual inspection. The flights were then executed by a trained operator.
- *Waypoint-based mapping flights*. An area to be mapped by the UAV was indicated by the end-users. A flight plan was then set up to map this area using an autonomous waypoint-based flight. Also under these conditions, a trained pilot always operated the remote control station.

A typical flight had a duration of 25 to 30 minutes, which enables to cover an area of about 1 hectare. Multiple mapping missions were performed, gathering 200 to maximum 500 images with a resolution of 24 megapixels and mapping areas as large as $1km^2$.

II. UAS DEPLOYMENT FOR RELIEF OPERATIONS SUPPORT

One of the cities which was hit most by the floods was the city of Orasje (located north-east) where B-FAST was deployed. The UAV was first deployed here to assist the B-FAST team for assessing the optimal location to install their high-pressure pumps and to monitor the water levels, as shown on Figure 2a to 2c. The problem with the installation of the water pumping system was that water levels were not decreasing after multiple days of pumping, due to an undetected dike breach. The ICARUS-TIRAMISU UAS was able to locate this broken dam, as shown on Figure 2d. Expert analysis indicated that this dam breach could not have been caused by natural means, so the Bosnian Ministry of Justice has started a justice case against the individual(s) who may have caused it and commissioned the ICARUS-TIRAMISU UAV image material as evidence. The UAS proved very useful in support here to quickly detect dike breaches and to map the area quickly. Landing on dry land was a challenge, however, as there were virtually no spots of clear and open land suited for takeoff and landing. As a result, all takeoff and landing operations were done on remote control by a trained pilot.

Next to the operations in support of the B-FAST team, the UAS was also deployed on request of the German Federal Agency for Technical Relief team and Austrian relief workers working on the incident site. These teams asked for assistance of our UAV system for aerial inspection, damage analysis and improving their situation awareness and for selecting the optimal location for the installation of the high-pressure water pumps. The Ministry of Security and the Federal Civil

(a) City of Orasje

(b) UAS used for the operations

(c) Optimization of the location for the B-FAST water pumps

(d) Broken dam on the Sava river detected by the UAS

(e) Damage assessment for mapping infrastructure damage

Fig. 2: UAS used for relief operations support

Protection of Bosnia and Herzegovina also asked for UAV aerial support in the region of Kopanice (Southeast of Orasje), where the flood waters from Sava River broke the dams. The flood waters flowed through these breaches and completely submerged the agricultural lands and all the people needed to be evacuated. This mission was especially risky because the location of the broken dam area was in a mine suspected region. During the mission, we often faced the problem to get around from one place to another, as this was very difficult due to the damaged infrastructure (see Figure 2e).

III. UAS DEPLOYMENT FOR DEMINING OPERATIONS SUPPORT

Bosnia and Herzegovina was contaminated with land mines due to the war from 1992 to 1995 and as a result the country has one of the most serious land mine problems in the world. By the end of the war, around two million land mines and unexploded munitions littered the country. By September 2013 land mines and unexploded munitions remained scattered in 28.699 locations. From 1992 to 2008, 5.005 people were killed or injured by land mines or unexploded munitions [6], [7]. Before the floods, approximately 540.000 citizens (of around 4 million total population) were affected by mines, and around $1.230,70km$ $(2,4\%$ of the country's territory) was mined [6].

One of the cities which was hit hard by the floods was the city of Maglaj, as shown on figure 3a. An additional problem in this region was the presence of many ERW, rendering the deployment and work of the relief teams extremely dangerous. As a result, it was decided to deploy the UAV system for inspection flights, especially into areas where the relief teams could not access due to the high risks. The UAV was used for aerial assessment and mapping of the mine-suspected areas and to find indicators of where the minefields were shifted due to the floods and landslides. Figure 3b shows a re-allocated minefield due to landslides. The data of the UAV was mostly important in assessing the ground movement due to landslides.

Figure 4 shows the first post-processing results of the region Zavidovici- Dolac (central Bosnia and Herzegovina). The UAV was used for providing 3D-maps of the environment to analyze the effects of the landslides on mines and ERW. Fusing the obtained data from the UAV (3D Digital Terrain Models) with pre-existing data (mine risk maps from satelite imaging and the Mine Action Centres), it was possible to predict the movement of the landmines and to generate updated mine risk maps and maps of mine-affected areas.To give an indication of the scale of the problem, it can be reported that mines were found up to 23 kilometers from there original location. This means that the search area is huge and that the effectiveness of area reduction techniques like the use of the UAV, combined with 3D mapping predicting the ERW-movement and thereby limiting the search area, can be dramatic.

(a) City of Maglaj

(b) Re-location of mines due the landslides

(c) Detected Anti-Personal Mine (re-allocated mine due to the landslides)

Fig. 3: UAS used for demining operations support

IV. CONCLUSION

In this paper, a report on the operational deployment of novel technological tools for crisis relief in an actual crisis situation has been presented. An unmanned aerial system equipped with sophisticated 3D data processing algorithms was deployed to help with the relief efforts after the 2014 floods in the Balkans. The tools were used in support of relief teams for damage assessment and for helping to localize landmine-suspected areas. The response from the response teams brought into contact with the unmanned tools was very positive, as they see the clear advantages of the system. On the other hand, the end-users do struggle with the management, procedural and legal aspects of including UAS tools into their toolset, which is an area requiring more attention. As a closing remark, one of the end-users (the B-FAST team leader), noted that the aerial assessment done by the UAS in 2 hours saved the team 3 days. Such important time-savings can be a matter of life and death in crisis response scenarios.

(a) High-resolution orthomosaic

(b) Digital terrain model of a landslide

Fig. 4: Post-processing of UAS data for demining

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