**UAV ADDED VALUE FOR ROCKFALL SURVEYING AND MONITORING**

**INTRODUCTION**

With the use of UAV technology we can successfully survey forest and natural hazards in the mountainous areas, and provide the necessary information about the protective role of forest against different natural hazards (e.g. rockfall, avalanches, and landslides). Those areas are not only hard to access, but can also be time-consuming and dangerous for field surveying. Therefore by using UAVs the working conditions and safety conditions for field workers can improve (Figure 1). The usage of UAV can be applied in three ways when studying natural hazards and their impacts on people, infrastructure and forests namely for 1) data acquisition of pre- and post-environmental/geomorphological events, 2) operational support during the emergencies in a case of the catastrophic event, and 3) monitoring of damages in critical infrastructure and the protection forests.

![Figure 1: Perspective view of the texture-mapped 3D surface with the camera positions and orientations during image acquisition by the UAV (Photo: M. Kobal, 2017).](image1)

**APPLICATION OF UAV FOR ROCKFALL MONITORING**

UAV can provide studying and monitoring of unstable slopes (Figure 2), evaluation of risk after a rockfall event (e.g. estimation of the volume of displaced material) (Figure 3), reconstruction of block trajectories, evaluation of the damage on buildings/infrastructure/vegetation (Figure 4). High-resolution images can be used for recognizing and characterizing the most unstable sectors. By using the high resolution digital terrain models (DTM) it is possible to generate accurate data of volumes, areas, surfaces, cross sections and contour lines and with that replace traditional methods of mapping such areas.

![Figure 2: With UAVs a detailed geomorphological analysis of potential rockfall release zones can be done (Photo: M. Kobal, 2016).](image2)

**MAIN ADVATAGES OF UAV**

There are many advantages of using UAV for rockfall surveying and monitoring. The costs of surveying are lower compared to traditional field methods and conventional remote sensing techniques. Therefore the surveying can be repeated in shorter time period which is crucial in monitoring rockfall activity. Collection of series of high resolution images enables the generation of high resolution DTMs. The UAV can come closer to studied objects without risk and can consequently improve the safety conditions for field workers. Even more, with their use it is possible to access remote and hardly accessible areas as mountain areas usually are. Videos and photos of unstable areas can be immediately available on site without any post processing and can be used in support in the field as the analysis of these data allows the portrayal of unstable areas from different points of view. UAV is also a suitable solution to support qualitative evaluations during emergencies where the survey results have to be available in a rapid and straightforward manner.

![Figure 3: True orthophoto image and DTM of Belca rockfall, Slovenia. The two zones are the rockfall release area that were determined by comparing DTM before (lidar data - 2014) and DTM after the rockfall (UAV data – 2018) (Photo: M. Kobal, 2017).](image3)

![Figure 4: 3D models of two rockfalls in Slovenian Alps (Photo: M. Kobal, 2017).](image4)