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Rockfall Alarm System with Automatic Road Closure/Reopening and long-term Slope Monitoring for major European North-South Route (Axenstrasse)

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We present an operational innovative early warning system for real-time rockfall detection with automatic road closure and simultaneous slope monitoring for a rockfall prone section of Axenstrasse in Central Switzerland. The comprehensive monitoring system combines various technologies, including interferometric radar, Doppler radar, seismic sensors, high-resolution deformation cameras, combi-motion sensors and various webcams, to achieve maximum detection reliability at minimal closing time for waiting traffic.

The Axenstrasse is a scenic road section along Lake Lucerne with an average traffic volume of 16,000 vehicles a day. On 18 July 2019, heavy rainfall triggered a small debris flow in the steep Gumpisch valley and released a large boulder. The 12-ton boulder crossed the road fortunately without causing any significant damage. The road operator closed the route immediately for safety reasons; large debris accumulations of a previous rockfall remained in the upper Gumpisch valley and further similar events are very likely. In an effort to reopen the important traffic axis as soon as possible, we developed, installed and commissioned an alarm system with automatic traffic control within only a few weeks.

The system combines two different types of technologies: First, sensors for real-time detection of fast movements and second, techniques for long-term monitoring of surface deformation. For reliable rockfall detection, we use a combination of long-range Doppler radar technology and high-sensitivity seismic sensors to minimize false alarm rates while maintaining high probability of detection. The rockfall radar remotely detects moving debris or large boulders whereas the seismic sensors recognise rockfall based on ground motion. Both technologies work in real time and independent of visibility conditions (day/night, fog, snowfall). At a suitable rock spur, we installed two rockfall radars, one facing up and one down the valley, and three seismic sensors in an array.

Given the short warning time of around 20-30 seconds, it is vital to close the road immediately once an event is detected. However, many events remain small and never reach the road. In order to avoid unnecessary road closures for minor events, we equipped the protection nets above the road with combi-motion sensors that automatically detect an impact by a boulder or a debris flow passage. The system automatically reopens the road after 2 minutes, if an event was detected in

the upper part, but no impact was recorded in the nets. In this way, we can guarantee road safety and avoid long closure times.

For long-term slope monitoring, we installed an interferometric radar with autonomous power supply for permanent, sub-mm monitoring of the rock face where rockfall initially occurred. Further, two deformation cameras observe the gully and provide daily surface deformation analyses through automatic comparison of high-resolution imagery. This type of data allows to identify unstable zones and detect a potential acceleration early.

All sensor data and camera imagery are continuously transmitted to an online data portal for user access at any time via PC, tablet or smartphone.