



## **Off-shore Laser Scanning of coastal cliffs for rockfall hazard assessment by IMU/GNSS coupled Lidar**

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The off-shore laser scanning (OLS) is a new development of laser scanning used for coastal cliff stability assessment. An Applanix POS MV system was coupled with a LiDAR Optech ILRIS-3D-ER to combine an accurate dynamic positioning and orientation system with a long range LiDAR. The main particularities of this system is to be mounted directly on a marine vessel and to be able to acquire in motion georeferenced LiDAR point clouds. The high resolution digital elevations models (HRDEM) derived of these point clouds are an important data for rockfall assessment along the shores of lakes and fjords.

Usually, static LiDAR emit laser pulses in directions defined by two internal angles. Long range Lidar systems record the times of flight (TOF) that the pulses take to go forth and back. Then, for each pulse, the TOF and the direction angles are converted in Cartesian coordinates, and a 3D point cloud of the topography is generated. When a scan is acquired from a moving platform, such as boats, the directions of sight cannot be known with only the two internal angles of the LiDAR. But it is possible to correct the direction of each pulse by coupling the laser scanner with an inertial measurement unit (IMU) and two GNSS (Global Navigation Satellite System) antennas. The IMU/GNSS system used for this project is designed to compute vessel position, velocity, attitude, and heave, together with acceleration and angular rate vectors. The IMU records the angles of roll, pitch and heading of the platform on the boat, according to three fixed orthogonal axes, and the GNSS antennas localize the instrument. Thus, the LiDAR position and attitude, the direction of sight and the TOF are known for each pulse.

Thanks to its ability to provide a continuous record from an extended area along a coast, this new OLS system is useful for large and small coastal rockfall hazard assessment. This technique has been used on the eastern cliffs of the fjord of Sunndalsfjord (Møre og Romsdal, Norway). Here high and steep cliffs dominate an important road following the shore line. Several detailed scans have been acquired from a ship and a full structural analysis has been carried out using COLTOP 3D. Then, kinematic tests are coupled with a probabilistic propagation assessment to provide a susceptibility map for rockfalls of the area.