Date of Submission	March, 29 2017

IPL Project (IPL – 193) Annual Report Form 2017

1 January 2016 to 31 December 2016

1. Project Number (approved year) and Title: IPL-193 (2015)

   INTEGRATED SYSTEMS FOR LANDSLIDES MONITORING, EARLY WARNING AND RISK MITIGATION ALONG MOTORWAYS

2. Main Project Fields:

   Technology Development: Monitoring and Early Warning; Hazard Mapping; Vulnerability and Risk Assessment. **Capacity Building:** Collating and Disseminating Information/ Knowledge. **Mitigation**: Preparedness, Mitigation.

3. Name of Project leader

Prof. Eng. Pasquale VERSACE

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Core members of the Project: Names/Affiliations: (4 individuals maximum)

- **Ing. Giovanna Capparelli / CAMIlab, DIMES, University of Calabria**
- Prof. Giuseppe Di Massa / Department of Computer Engineering, Modeling, Electronics and Systems Science (DIMES), University of Calabria

4. Objectives: the project aims to develop an integrated early warning system (EWS) in order to mitigate the landslide risks along motorways and other transport infrastructures. The final goal is to timely identify the potentially dangerous landslides for define information delivery and activate the necessary safeguard measures.

5. Study Area: The involved test sites are the A3 motorways “Salerno-Reggio”, the A16 motorway “Napoli-Canosa” the A18 motorway “Messina and Catania” - South Italy

6. Project Duration: 2 Years

7. **Report**

1) Progress in the project: (30 lines maximum)

The tested activities herein, relate in particular testing of the data acquisition system (CAED) from experimental sites (a) and functioning example of the various components among the instrument nets (b).

(a) The setting up of the data acquisition and processing center (CAED) and of the traffic control center (CCC) are the core of the integrated system. The CAED acquires and processes data, collected in real time among the different test sites. The Control Center for Road Network (CCC) is meant to integrate the scientific and the management aspects of hydrological risk monitoring and early warning.

The management of data flow from the monitoring network is ensured by according to a communication protocol, implemented by the CAED, and named AqSERV. The latter was designed by considering the heterogeneity of devices of monitoring and transmission networks (punctual and areal sensors) and the available hardware resources (microcontrollers and / or industrial computers). AqSERV was realized to link CAED database (named LewisDB) and the monitoring networks, after validation for the authenticity of the node that connects to the center. Data acquisition, before the storage in the database, is validated both syntactically and according to the information content. The acquired and validated data are then accessible for the mathematical models through a further service, created ad hoc, which publishes all the acquisitions by sensors on a remote server for sharing. The wireless transmission worked fine, even at a distance of several hundred meters. (Figures 1 report example of Caed interface) Data from the satellite receivers are not without problems, also deriving it from not perfectly constant. For this purpose, some improvements have been made: the software and hardware have been revised in order to optimize energy consumption and make constant the power of the various components.

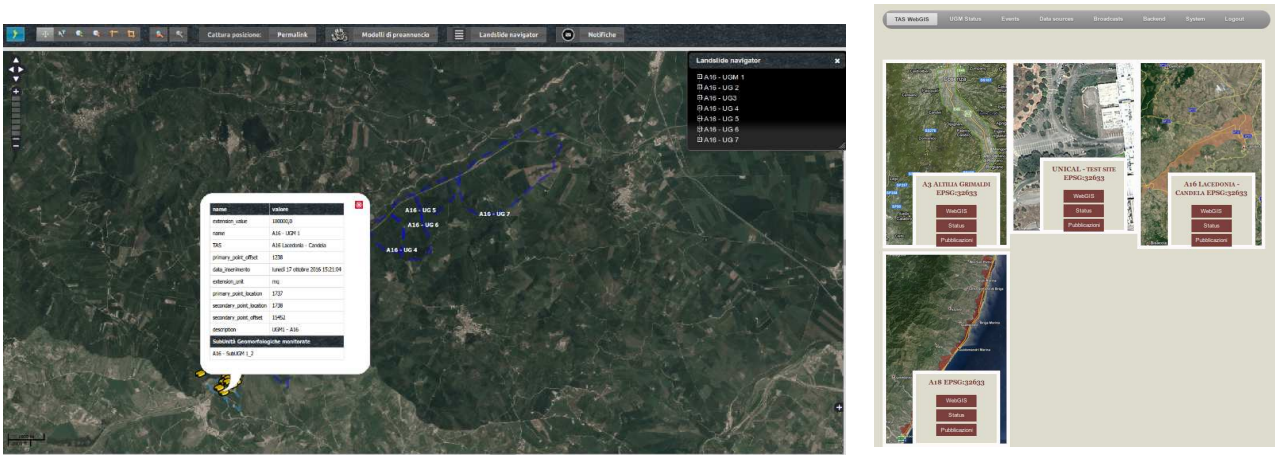

Figure 1 (left) Display of the test sites along the A16 and query attributes in the database. (right) home page

(b) The section presents the preliminary results of studies carried out on an area identified in a narrow range of between Km 97 + 450 and the Candela exit (A16 motorway), straddling the regional border between Campania and Puglia (South of Italy). The area lies at the foot of a large gravitational mass, classified as “ancient landslide deposit” where a system of landslides, with different types and activity states, are present. The site has been instrumented with

a series of automated sensors, both innovative and traditional, which monitor different physical entities. In the selected area, surveys of different nature were carried out. Tab. 1 shows the types of sensors installed while Figure 2 shows their distribution along the stretch of motorway. MUMS (Segalini & Carini, 2013), in particular, is an automatic inclinometer composed by several nodes at defined distances, linked by a Kevlar rope and a quadrupole electrical cable, that collects multi-parametric data. 2 MUMS chains were installed, DT0007 and DT0008; the system converts raw data into physical units and calculates results (displacements, water level, atmospheric pressure, temperatures along the vertical, etc.). Results are provided on a web platform and in CAED system in near real time. Figures 3 show the local displacements recorded and transmitted by DT0007 and DT0008 MUMS inclinometers

Figure 2 . Location of instrument installed down the stretch considered

Station	Sensor
Station 1	Weather sensors
Station 2	1 piezometer at a depth of 15 m; 3 in place inclinometers at a depth of 14, 17 and 20 m.
Station 3&4	System for measurement of moisture and suction in the soil: 5 tensiometers at a depth of 1.2 m; 5 TDR at a depth of 1.2 m.
Station 5&6	1 piezometer at a depth of 12 m; 1 in place inclinometer at a depth of 17 m.
Chain 1&2	2 MUMS chains (automatic inclinometers)

Table 1. Sensors installed.

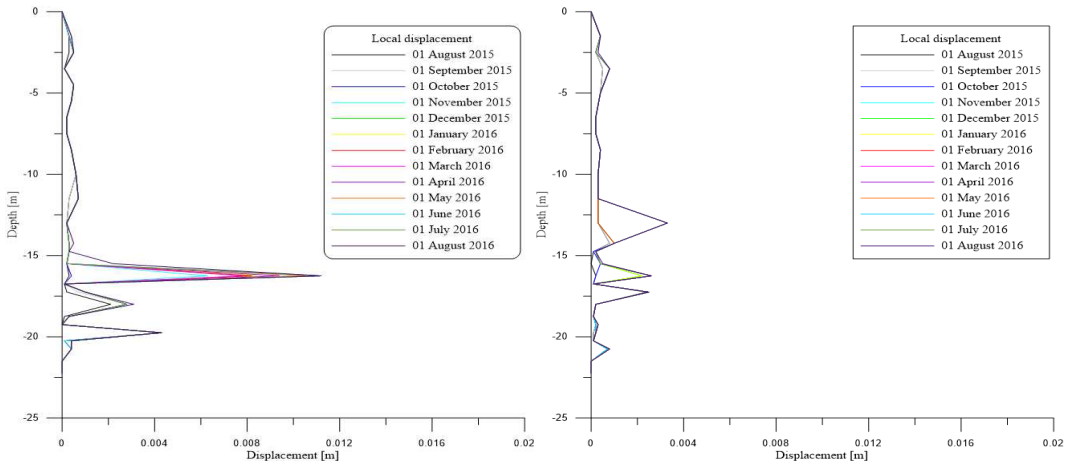

Figure 3 Local displacements recorded by DT0007. - Local displacements recorded by DT0008.

2) Planned future activities or Statement of completion of the Project

Given that System constantly being tried out, each component will be subject to new and continuous checks, including those here discussed. Then, testing of the data acquisition system and the functioning of the various components are included in planned future activities too.

In addition to these listed above, the activities also include the verification of the radar's ability to monitor a landslide and its performances in the early warning system; verification of the forecasting of the mathematical models; likely extension of the monitoring network to other sites and other contexts.

3) Beneficiaries of Project for Science, Education and/or Society (15 lines maximum)

The research promotes innovation in the field of environmental monitoring and of mathematical modeling of landslides, improvement of services to support mobility, the enhancement of skills of involved research groups, who will improve their level of excellence in the railways scientific community. The main beneficiaries could be the managers of motorways and national roads; the managers of the railways; the national civil protection; the manufacturers of the various components of the integrated system.

4) Results:

Formetta G. Capparelli G. & Versace P. (2017) ”Quantifying the performances of simplified physically based landslide susceptibility models: an application along the Salerno-Reggio Calabria highway”. Proc. 4th World Landslide Forum.. Advancing Culture of Living with Landslides. Vol. 5 Landslides in Different Environments.: Mikos, M., Vilimek, V., Yin, Y., Sassa, K. (Eds.).

Capparelli G. Spolverino G. Versace P. (2017) “Physical modelling of the rainfall infiltration processes in pyroclastic soil responsible of landslide trigger.” Proc. 4th World Landslide Forum Vol. 3 Advancing Culture of Living with Landslides Vol. 4 Diversity of Landslide Forms: Mikos, M., Casagli, N., Yin, Y., Sassa, K. (Eds.)

A. Carri, C. Grignaffini, A. Segalini, G. Capparelli, P. Versace, G. Spolverino (2017) “Study of an active landslide on A16 Highway (Italy): modeling, monitoring and triggering alarm”. Proc. 4th World Landslide Forum Vol. 3 Advancing Culture of Living with Landslides Vol. 4 Diversity of Landslide Forms: Mikos, M., Casagli, N., Yin, Y., Sassa, K. (Eds.)

Costanzo S., Di Massa G., Costanzo A., Morrone L., Raffo A., Spadafora F., Borgia A., Formetta G., Capparelli G, Versace P. (2015). Low-Cost Radars Integrated into a Landslide Early Warning System. In: New Contributions in Information Systems and Technologies. *Advances In Intelligent Systems And Computing*, p. 11-19, Springer International Publishing Switzerland, ISBN: 978-331916527-1, ISSN: 2194-5357, doi: 10.1007/978-3-319-16528-8_2