Advancing earthquake risk reduction strategies

Professor Paolo Gasparini, President of the Center of Competence in the field of Analysis and Monitoring of Environmental Risk, tells International Innovation how recent developments in early warning systems have the potential to significantly improve earthquake risk reduction strategies.

To begin, could you outline the key objectives of the Strategies and Tools for Real Time EArthquake RisK ReduCTion (REAKT) project?

The general goal of our work is to improve the efficiency of real-time earthquake risk mitigation methods and their ability to protect structures, infrastructures and people. REAKT aims to establish the best practice for using the wide range of information generated by operational earthquake forecasting (OEF), early warning systems (EEWS) and real-time vulnerability assessments. Decision making in real-time requires this information to be combined in a fully probabilistic framework.

How does REAKT contribute to Europe’s long-term objective of reducing individual vulnerability to a level comparable to that of Japan and the US?

By applying real-time risk reduction measures to a vulnerable system we will help to lower risk in Europe. The best possible decision requires input from earthquake scientists, engineers, impacted stakeholders and end-users, as well as encouraging self-organisation among local inhabitants in preparation for, and response to, an event.

What is the significance of the sites that REAKT is monitoring and what particular investigations are you making into risk reduction in these areas?

REAKT is investigating two types of key site. The first focuses on the study of transient phenomena preceding and accompanying large earthquakes in active areas with differing seismic activity. Sites in Greece, Turkey, Italy and Switzerland have been selected for monitoring microseismicity and minute changes in strain, electromagnetic fields and other parameters within specific fault systems.

The second type of site encompasses the different structures and infrastructures to be defended from earthquakes. They include a nuclear power plant in Switzerland; a chemical industrial complex in Portugal; a school and a local railway system in Italy; a hospital and a port in Greece; two bridges (one in Greece and one in Turkey); a gas distribution system in Turkey; and an electric power generation and transport system in Iceland.

Who are REAKT’s end-users and what is their involvement in the project?

The end-users involved in the project represent civil protection and management bodies of power plants, industries, railway systems, harbours, bridges, hospitals and schools. Our partners and end-users have been engaged in dialogue from the outset, with the goal of concept development and initial implementation efforts using the project’s data products and methodologies. REAKT’s challenge rests in applying real-time risk reduction systems to different and specific contexts by choosing the most suitable method, and developing feasibility studies and initial implementation efforts in collaboration with the end-user.

How important is public communication with regard to risk reduction strategies?

Public participation is fundamental to the efficiency of any real-time risk mitigation action, as success largely depends on how information is communicated and the level of emergency response training individuals possess. Education and training in public risk and earthquake drills must compensate for people’s lack of innate earthquake awareness or past experience, so effective risk communication is vital.

People respond to warnings through a complex social-psychological process that experimental psychologists are better trained to appreciate than scientists. Planning for a sound public response to future emergencies means that this social-psychological process must be understood by those involved in the warning process and addressed by those who plan the dissemination of public warnings. REAKT will propose methods of delivering public communication while recognising the value of self-organisation in community decision making.

Can you outline REAKT’s plans for the forthcoming year?

2014 will see the introduction of a real-time earthquake risk reduction session and a short course on Earthquake Early Warning at the next European Geosciences Union General Assembly in Vienna. As well as an international conference on OEF in Varenna and a session dedicated to REAKT at the next European Conference on Earthquake Engineering and Seismology in Istanbul, the project’s final meeting will be held in October.
In a bid to protect lives and critical infrastructures in Europe, the REAKT project is developing a comprehensive, integrated approach to earthquake risk mitigation that can be applied to a broad range of contexts.

The collaborative nature of REAKT is essential for developing optimal applications tailored to the needs of its end-users, and Gasparini is unequivocal about the importance of this relationship: “The end-users’ feedback throughout the proposal is critical to ensure the developments remain closely targeted to the real-world”. Because the risks associated with damage to a power plant are different to those associated with railways, for instance, REAKT’s end-users have different interests to address. For example, some are interested in real-time information and developing rapid response plans, while others are more concerned with the development of automated control systems that respond to large tremors, such as Japan’s Urgent Earthquake Detection and Alarm System (UrEDAS) whereby high-speed trains are slowed down to prevent them from derailing.

ACCOUNTING FOR UNCERTAINTY

At the heart of REAKT’s endeavours to improve risk mitigation strategies is the probabilistic framework in which information from earthquake forecasting, early warning systems and vulnerability assessments is gathered together. In order to provide the most comprehensive picture of events before, during and after an earthquake, a Bayesian strategy has been successfully employed to include realistic uncertainty estimations using the combined information.

In EEWS, Bayes’ theorem dictates that estimations of earthquake sources are most...
probably a combination of relevant data prior to the event and the limitations of real-time observations in ground motion and arrival. All EEWS have a blind-spot regarding the source of an earthquake, so faster estimations mean longer warning times but far less accuracy. With the Bayesian approach, all the unknowns present in the chain of real-time risk mitigation are delivered to the end-users where, as Gasparini states, “decisions need to be taken in the light of uncertain knowledge.”

Studies of dynamic earthquake processes and their associated transient phenomena help to reduce the uncertainties present in this chain. Already at key sites in the Turkish Sea of Marmara, Corinth and Valais, observational capacities have been dramatically improved by the addition of extra seismic stations, magnetic and geochemical sensors and the installation of borehole strainmeters.

With the information obtained from these advanced investigations, several EEWS currently under implementation and experimentation are showing remarkable results. Formulated at the Swiss Federal Institute of Technology, Zurich (ETHZ) in 2007, the Virtual Seismologist (VS) uses regional algorithms to estimate earthquake magnitude, location, time of origin and the distribution of peak ground shaking. Originally calibrated using the Southern California Seismic Network (SCSN), REAKT has proven that VS performs equally well in Switzerland. Over a two-year period, 50 per cent of seismic events of magnitudes greater than 2.5 were detected, while 100 per cent were detected with a magnitude greater than 3.0.

In addition, AMRA’s free, open-source platform PRESToPlus (PRESTo) represents a cutting-edge probabilistic and evolutionary early warning system. As a self-contained piece of software, PRESTo needs nothing but ground-motion data from a seismic network in order to work. By continually processing real-time accelerometric data streams, PRESTo can deliver estimates of the location and magnitude of detected earthquakes while they occur along with predictions of intensity and shaking at a regional scale. Using past and simulated recordings, six earthquakes of magnitudes between 4.0 and 6.9 were played back into PRESTo, which was able to provide reliable estimates within five to six seconds of the first detected P-wave. With this capability, early warning messages sent over the internet will be able to reach target sites before the destructive waves to enable automatic safety procedures.

**EFFECTIVE COMMUNICATION**

Decision making is a key aspect of EEWS and forecasting but it is not simply a case of ringing the alarm bell once an earthquake is detected; the process involves a number of societal issues which have not been studied in-depth with regard to earthquakes. REAKT’s review of analogous case studies shows that executive decision making without public participation can be counter-productive, meaning that some form of participatory decision making (PDM) is necessary. While data from EEWS relates to situations where every second is vital and decisions are required without delay, within a context of longer-term earthquake forecasting, individuals are their own decision makers. Indeed, PDM has been shown to improve the quality and enhance the legitimacy of the decisions that a community makes.

The technical innovations achieved by REAKT – of which further improvements are yet to be implemented – will provide the public with the best information available when faced with the uncertainty that comes in the event of an earthquake. The impact on the prevention of catastrophic damage to Europe’s power plants, transport systems and hospitals, to name a few, could see relative levels of vulnerability drop significantly, meaning a safer Europe and a safer world.

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**Network Based (or Regional) Approach**

- Seismic Network
- Detection and location
- Magnitude estimation

**Single Station (or On Site) Approach**

- Early Ground Motion Measurement
- Peak Ground Motion Prediction

**Lead-time**

- (S-arrival time at the target) - (first-P at the network)
- (S-arrival time at the target) - (P arrival at the network)

Earthquake early warning system approaches and their basic concepts and measurements. REAKT proposes a new approach that integrates network-based and on-site systems, providing real-time mapping of alert levels, defined by early warning parameters.