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European Strategic Research Agenda on Earthquake Risk: Vision and Roadmap for implementation

SYNER-G Exploitation Plan

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Abstract

The present deliverable contains the Exploitation Plan of the project, which is represented by the European Strategic Research Agenda on Earthquake Risk: Vision and a Strategic Research Agenda, a roadmap for implementation.

Keywords: dissemination, foreground, leaflet, newsletter, workshop, exploitation plan

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EUROPEAN

Strategic Research Agenda

EARTHQUAKE RISK

Vision

Strategic Research Agenda

Roadmap for Implementation

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European Association for Earthquake Engineering

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Content

01 Introduction

The strategic research agenda on earthquake engineering issued in 2007 has stimulated a number of successful research projects in FP 7 (i.e. SERIES, NERA, SYNER-G, SHARE, REAKT…). The decision to step from earthquake engineering to earthquake risk, including seismologists, social and economic sciences, in the process has been the natural evolution. The 2013 version is determined to give an even larger picture, highlighting the demand on global scale. Further, well-coordinated, research and development effort is necessary to save lives and to create a resilient European society.

Devastating earthquakes and tsunamis have caused hefty damage throughout the world (Sumatra 2004, Wenchuan 2008, Haiti 2010, Japan 2011). The tragic losses and frightening accidents showed that the phenomenon is not yet sufficiently understood and that the seismic hazard and risk has to be reassessed. Despite the fact that the recent cases have been outside Europe earthquakes remain a serious threat in many parts of Europe, and have continued to cause major loss of life and destruction in recent years. This may be connected with the fact that there has not been a sustainable investment in earthquake engineering research and development in Europe, especially when compared with U.S. and Japan where in recent years the investments have been much higher - in the order of 10 times greater than in Europe. In order to create a safer Europe it will be necessary to undertake considerable efforts towards a better definition of the hazard and the development of tailored mitigation approaches. This Strategic Research Agenda has been developed to support the process of protecting European citizens and assets against earthquake hazard, and in particular for those actions supporting earthquake risk mitigation.

Earthquakes can no longer be regarded as natural disasters where humans intervene only in the aftermath of the event, as the main cause of damage is the inadequate seismic resistance of the building stock, lifelines and industry. Therefore, much can be done by adequate prevention and preparedness strategies on our built environment to mitigate the adverse consequences or earthquake disasters that we see today.

Earthquake risk has causes and consequences beyond national borders, and the EU has acknowledged its concern to reduce future earthquake risks in many ways, for example through its support for the Eurocodes, the European Standards for Construction, for the coordination and promotion of Civil Protection, and for related research programs. However, much remains to be done in all these directions. Moreover, these actions hardly touch what is now widely regarded as the most critical issue in areas of moderate to high seismicity in Europe: the majority of buildings and infrastructure built prior to the adoption of current standards of practice that are highly vulnerable, and many of which perform vital functions in our cities.

At the European level, this debate was promoted by the EC and a meeting organized by the JRC in November 2000. It made many useful recommendations but there was no follow-up plan. Subsequently, the European Association for Earthquake Engineering (EAEE) has been working with parliamentarians, the Commission and other international organizations to define an affordable and realistic set of policies for earthquake protection across the European-Mediterranean region. Meetings were held in Lisbon in October 2005 and at the European Parliament in Brussels in February 2007. This effort has been somewhat reflected in current funding for projects or retrofit initiatives, but much more needs to be done if the overreaching goal of reducing seismic risk in Europe is to be achieved.

This document presents an overview of the problems of seismic risk in the European Union, and a proposal for a Strategic Research Agenda to support a common European effort to deal with those problems. The document has been compiled jointly by an expert group established by the European Association for Earthquake Engineering in association with other bodies concerned with seismic risk deduction.

The document first establishes in detail the reasons for concern, and identifies the European dimension of the problem. It then sets out a common vision of a future society free the threat of serious earthquake risk, and sets out clear and concise common research agenda for the short term and for longer term.

European integration involves, in many instances, the pooling of national sovereignty in favour of EU institutions, therefore creating a European dimension in many important issues for European citizens, including the reduction of the effects of natural catastrophes. This was clearly recognized by European leaders during the floods of 2002 in central Europe. One of the examples was the declaration of the German Chancellor stating "he was expecting help from Brussels, since the dimension of the catastrophe was beyond the limits of national intervention". The fairness of this view was widely recognized and has already led to the creation of the Solidarity Fund.

The European dimension of the problem of natural catastrophes is also implicit in other EU decisions and policies. Several examples can be given: (i) the support to research in the fields of seismology and earthquake engineering, (ii) the development of European Construction Standards, in particular of Eurocode 8, applicable to the earthquake resistant design of structures, and (iii) the establishment of a centre for coordination of Emergency aid, which can be very useful for the optimization of the application of European Civil Protection resources following large earthquake events. However, despite the importance of these policies, they are not enough as they do not address many of the actions needed for a significant reduction of seismic risk.

The EU cohesion policy aims at promoting sustainable development throughout the EU. However, large earthquakes can cause severe damage and destroy the physical infrastructure that underpins social and economic development. Thus, there is an incompatibility between the objectives of EU policies and the very high levels of seismic risk to which some large European regions and populations are subjected. It is therefore indispensable to fully address the challenge of seismic risk prevention to ensure the sustainability of the benefits of EU policies. **Moreover, it is unacceptable that European citizens are daily exposed to major risks to their life, which are well understood and avoidable.**

Other countries such as the USA (California), New Zealand and Japan have for a long time been enforcing policies for the reduction of earthquake risk, in particular for lifelines, transportation networks and vital points (buildings or other facilities important for running the economy and the public administration or for life saving or social reasons). The EU should not continue to lag behind.

The earthquake in Japan (2011) has drastically taught us that even the country with the highest standards of protection and the widest implementation of mitigation measures is still vulnerable at unacceptable levels. Nevertheless, this incident, and the Kariwasaki-Karima Earthquake (2007) have taught us that our level of understanding of this phenomenon and related consequences lacks much more than even most pessimistic expectations. We learned that properly engineered structures save lives and can convert catastrophes into manageable incidents. Such an earthquake in Europe of comparable magnitude would have considerable worse consequences. Therefore this Strategic Research Agenda and road map is of highest priority and importance.

02 The Impact of Earthquakes

Is earthquake a risk for Europe? Which are its consequences? Is it a global issue? Is research important to reduce its consequences?

Earthquake is a risk and its consequences strongly depend on the preparedness of the society and on the research investments as shown in what follows.

2.1 Earthquakes at a first glance

Earthquakes kill people.

The number of causalties which a society suffers when an earthquake occurs depends to a great extent on the state of preparedness of a society. Europe is poorly prepared as Table 1 shows. Based on these data, despite the highest exposure (human and economic) of Japan (first in the worldwide ranking) or USA (among the first positions), Europe (considering only Italy and Turkey) had in the last 30 years a higher number of people killed or affected by earthquakes as compared to Japan or USA. One of the main reasons for this difference is the major investment into earthquake research in these countries. Their budgets are 10 times bigger than the European budget.

Table 1. Earthquake risk profile and statistics per Region (Source: EM-DAT: The OFDA/CRED International Disaster Database, Université catholique de Louvain, Brussels). Note: In killed people, affected people and economic damage, only earthquakes among the top 10 natural disasters in the years 1980-2010 are considered.

Disaster Risk for Earthquakes 1980-2010

Country	Human exposure (Country ranking)	Economic exposure GPD exposed (billion US $) (Country ranking)	Average disasters per year 1980-2010	Killed people in the top ten events of 1980-2010	Affected people in the top ten events of 1980-2010	Economic damage (US$ X 1,000) in the top ten events of 1980-2010
ITALY	1 483 456 (16th out of 153)	258.04 (4th out of 153)	0.58	5 014	531 363	27 820 900
TURKEY	2 155 233 (13th out of 153)	57.43 (14th out of 153)	1.13	20 387	5 424 460	23 640 800
JAPAN	13 404 870 (1st out of 153)	3 407.71 (1st out of 153)	1.00	5 638	541 636	140 500 000
USA	4 618 586 (6st out of 153)	1 972.93 (2nd out of 153)	0.77	Not among the top 10 events	Not among the top 10 events	30 000 000

The statistics of the 2011 Tohoku earthquake are not included in the list, as most of the damage was due to the Tsunami following the earthquake event, and the present SRA is mainly concerned with actions to mitigate damage resulting from ground shaking.

The strong message sent by the disastrous earthquakes in the 1990s (Turkey 1999 18,900 casualties, Japan 1995 5,400 casualties, U.S. 1994 136 casualties) triggered major research investment in many countries but not in Europe. Figure 1 shows the reaction on these earthquakes in the respective regions and the corresponding investment in research and development.

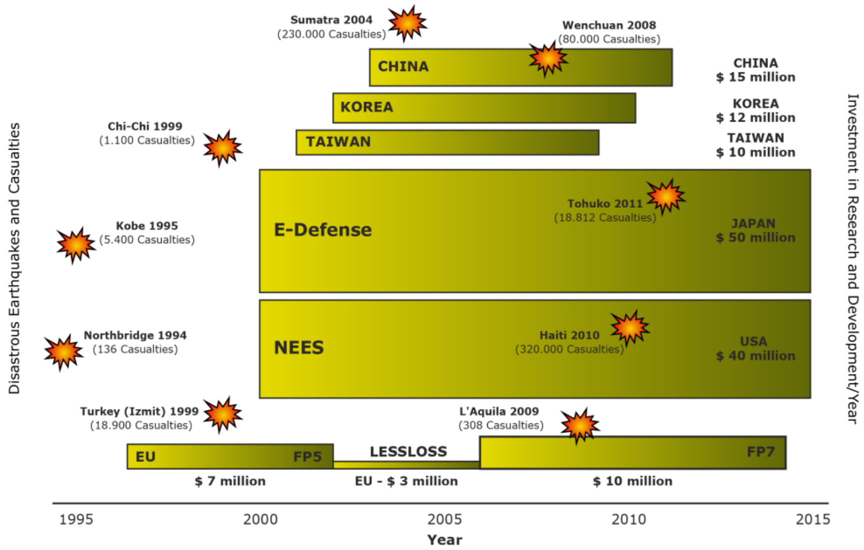

Figure 1. Annual Budget for Earthquake Engineering Research per Region (Source: VCE)

Earthquakes cause significant economic losses.

The direct economic loss has been significant, in the order of 10% to 15% of GNP of individual countries in the European earthquakes of the past 30 years and might reach up to 50% of Turkish GNP for the expected big Istanbul EQ.

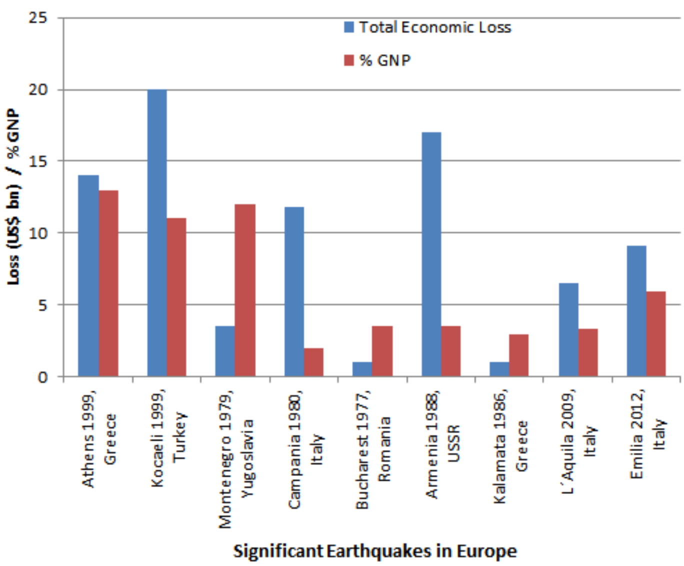

Figure 2. Display of Economic Losses of recent European Earthquake events (1975-2005)
(Source: Arup Geotechnics, GeoTechNet & VCE)

Earthquakes are a global issue.

The development of mega cities in earthquake prone areas increases the exposure of population to earthquake disasters. Europe has an obligation to help by exporting know-how and technologies.

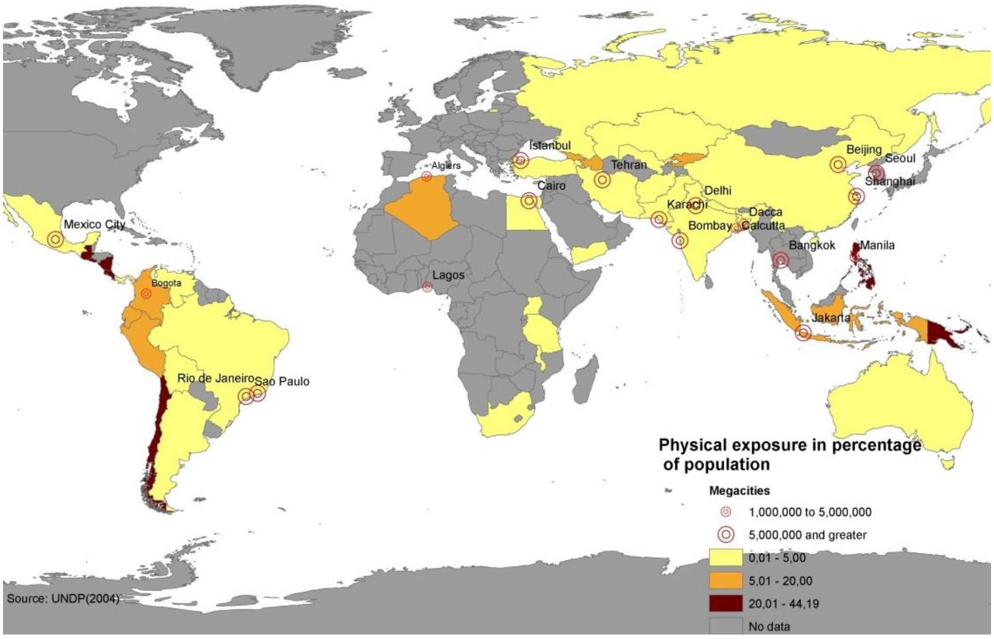

Figure 3. Countries and Mega Cities worldwide where European Earthquake Engineering Know How could assist in earthquake protection (UNDP 2006. Reducing disaster risk)

Earthquake Engineering depends on research results.

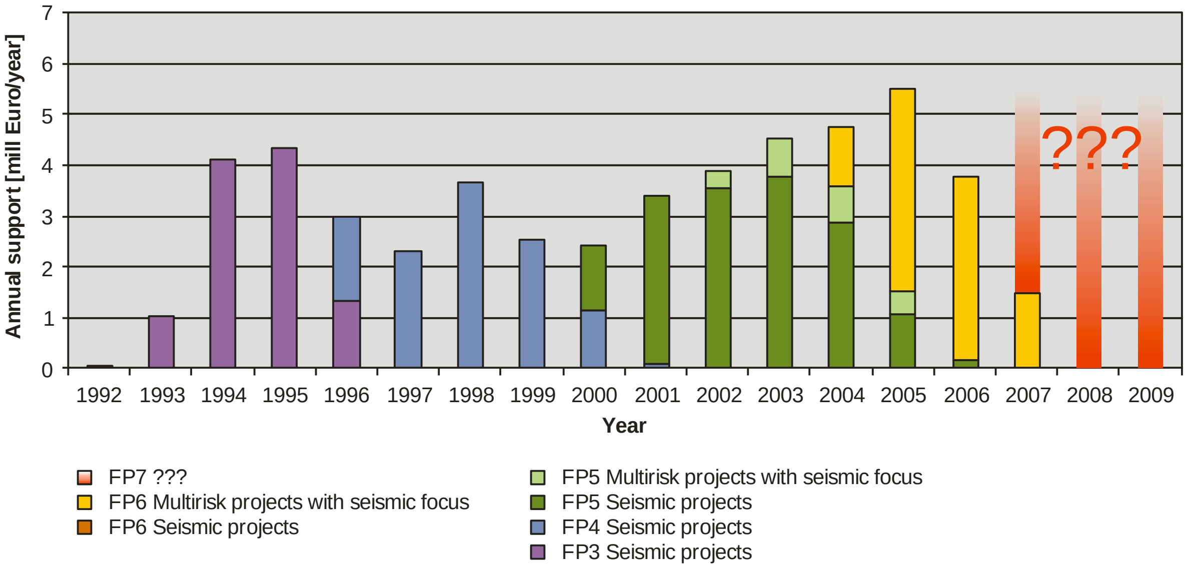

Figure 4. Annual Budget for Earthquake Engineering Research in Europe (EC DG Research Environment)

The current level of funding in Europe lags dramatically behind all other initiatives. In the Framework Programs of the European Commission this topic is seriously under-represented at only a fraction of the spending levels of the US and Japan. Figure 4 shows the annual research budgets of the EU over recent years.

03 The Large European Testing Facilities

3.1 Why are large scale testing infrastructures needed for research in Earthquake Engineering?

It is widely recognized by the Earthquake Engineering community that the availability of experimental facilities is essential to meet the objectives of earthquake risk mitigation worldwide and progress towards the performance based seismic design and assessment of buildings and civil infrastructures. Such facilities allow the studying of a large variety of structures and systems, and constitute an indispensable tool to calibrate the numerical models developed for analysis and design. In particular, some of these facilities, which fall into the category of large scale infrastructures, allow the handling of near to full-scale models of complex structures, helping to improve the understanding of the global response of building and bridge structures, and the effects of real phenomena such as soil-structure interaction.

In order to significantly improve their capacities, testing infrastructures should also allow the combination of physical testing with numerical simulation, online and offline, in a sort of 'real-virtual testing environment', where local and global, point and field measuring/visualization systems and corresponding processing can provide detailed information on demands and performance.

3.2 The panorama of the large testing facilities

Europe counts with a number of experimental test facilities distributed among the different Member States which support research in the field of Earthquake Engineering. These facilities vary both in type and size. Among the different types of testing facilities it is possible to classify them in the following groups: shaking tables, reaction walls and centrifuges, as well laboratories in structural mechanics and field testing. All these facilities have provided so far support to the understanding and progress in earthquake resistant design and practice.

Shaking tables are used for the study and verification of the dynamic behaviour of structural elements and reduced scale models of structures, allowing the reproduction and simulation of vibration phenomena, like those induced by earthquakes. Reaction walls, on the other hand, are used to test structures quasi-statically, whereby the earthquake effects are represented pseudo-dynamically. Centrifuges generate artificial gravitational fields with high accelerations acting on specimens fixed on a rotating arm and are mainly used, in parallel with shear stack facilities, for studies on soil-structure interaction.

Shaking tables, reaction walls and centrifuges are all complementary, and are used to study the earthquake behaviour of the structure and of its interaction with the soil. While shaking tables allow representing the behaviour of specimens of limited size and weight, reaction walls permit to study the earthquake response of full-scale models, providing valuable information that balances the technical limitations of each of the test methods. Most of these facilities, which are large in size and are usually associated with high operating costs, constitute a group of large scale infrastructures that have provided important progress in earthquake resistant design and practice in Europe, essentially in the development and calibration of Eurocode 8.

These large facilities have offered since March 2009 coordinated Transnational Access to users in Europe through the FP7 Project SERIES (Seismic Engineering Research Infrastructures for European Synergies), a four-year integrated activity financed by the European Commission. The SERIES project, through a transparent, fair and impartial peer-review process, selected talented European researchers with good ideas providing them access and in-person use at a portfolio of seven high-performing world class research infrastructures, comprising:

- EU's largest Reaction Wall and Pseudodynamic testing facility (ELSA) at the JRC, Ispra
- Unique Centrifuge Test facilities, the largest in the EU, at:
  - LCPC, in Nantes (FR)
  - Cambridge University (UK)
- EU's four largest earthquake Shaking Tables, each one with diverse capabilities, at:
  - TAMARIS laboratory of CEA, in Saclay (FR)
  - LNEC, in Lisbon (PT)
  - Bristol University Laboratory for Advanced Dynamics Engineering (UK)
  - EUCENTRE, in Pavia (IT),

The geographical location of these infrastructures is given in Figure 5 and is summarized in Table 2. From the figure is clear that with the exception of EUCENTRE and LNEC all the large scale infrastructures are located in regions of low seismicity and more technologically advanced Member States, whilst there is a lack of advanced RTD infrastructures in regions of high seismicity (Southern-Mediterranean and Eastern Europe). The SERIES project, through Transnational Access, promoted access of users from those Member States lacking advanced RTD infrastructures in earthquake engineering.

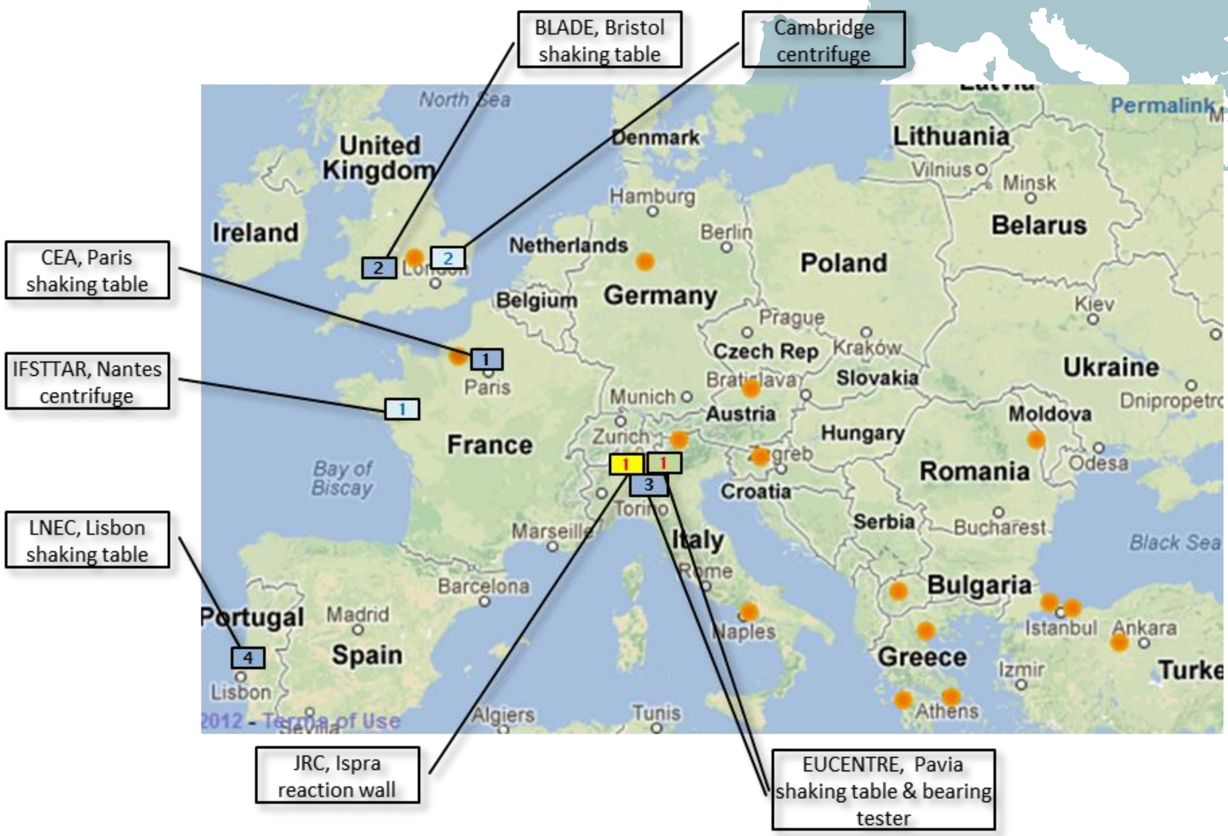

Figure 5. Map of Research Infrastructures providing Transnational Access to researchers in the framework of SERIES FP7 project.

Table 2. Research Infrastructures providing Transnational Access to researchers in the framework of SERIES FP7 project (shaking tables, reaction walls, centrifuges and bearing tester facilities).

Shaking Tables Labs		Reaction Walls Labs		Centrifuges Labs		Bearing Tester	
1	CEA, Saclay (France)	1	JRC–ELSA, Ispra (EC – Italy)	1	IFSTTAR, Nantes (France)	1	EUCENTRE / Unv. Pavia, Pavia, (Italy)
2	BLADE, Bristol (United Kingdom)			2	Unv. of Cambridge (United Kingdom)		
3	EUCENTRE / Unv. Pavia Pavia, (Italy)						
4	LNEC, Lisbon (Portugal)						

The research activities carried out by these large scale infrastructures are complemented by the work developed by a large number of experimental facilities, in general structural mechanics laboratories located in Universities and Research Institutions across Member States.

Apart from these facilities an important field test site located in the Mygdonian basin in Northern Greece, EURO-SEISTEST (http://euroseisdb.civil.auth.gr), allows conducting detailed theoretical and experimental studies on ground motion, site effects, soil and site characterization and wave propagation and detailed studies on the effects of surface geology on seismic ground motions. It consist of a 3D strong motion array of 21 modern accelerographs and "EuroProteas", a large-scale prototype soil-foundation-structure system dedicated to study soil- foundation- structure interaction (SFSI) phenomena and wave propagation in three dimensions in the soil due to structural oscillation. Excitation on the "EuroProteas" can be either free or forced-vibration. EUROSEISTEST is the longest running (for 20 years) test site of its kind at global scale and operates in, most probably, the best known valley in the world, both from the geometrical and the geological-geotechnical point of view. It is an excellent site for testing and validating various numerical and analytical methodologies and has already generated more than 200 scientific publications in peer review bibliography.

Table 3 provides a list of such facilities, partners of the SERIES project and not providing transnational access.

Table 3. Experimental facilities partners of the SERIES project.

Facilities			
1	University of Patras, (Greece)	6	National Technical University of Athens, (Greece)
2	Aristotelio Panepistimio Thessalonikis, (Greece)	7	Universita degli Studi di Napoli Federico II, (Italy)
3	Technical University of Istanbul, (Turkey)	8	Universität Kassel, (Germany)
4	Institute of Earthquake Engineering and Engineering Seismology, (FYROM)	9	Universitá degli Studi di Trento, (Italy)
5	Middle East Technical University, (Turkey)	10	The Chancellor, Masters and Scholars of University of Oxford, (United Kingdom)

Concerning large scale infrastructures at a global scale, there is quite a balanced distribution of shaking table and reaction wall facilities between American, Asian and European continents, which would indicate that the research communities are backed by a suitable set of such facilities, providing support to the progress on understanding and advancing earthquake resistant design and practice, training and education worldwide. However, outside of Europe, most of these infrastructures are essentially concentrated in a small number of countries, namely USA, Japan, Taiwan, China South Korea, and a large part of the earthquake research community does not have access to these facilities. Moreover, the recent initiatives in the USA (NEES), Taiwan (NCREE), Japan (E-Defence) and China (Multi-functional shaking tables, Tongji University) for the upgrading and construction of new facilities are shifting the geographical balance on research infrastructures in favour of these countries.

3.3 Collaboration between European Research Infrastructures

The different experimental facilities and research institutions in Europe have been collaborating since the early 90's with the financial support of the European Commission across several Research Framework Programmes through various research projects and contracts that have focused in three main areas: networking among the existing facilities and research institutions, transnational access providing access to researchers and industry to the experimental infrastructures, and carrying out research activities to improve and enhance the quality and capabilities of the existing facilities. On Table 4 the various research programmes carried out between 1993 and 2012, from RTD Framework Programmes 3 to 7 are summarised.

As a result of the joint research activities carried out by the European Earthquake Engineering Infrastructures, a major step forward has been made in the fidelity and accuracy with which these facilities, in particular, the large scale infrastructures, are now used, leading to significantly enhanced performance. These major advances have ensured that European earthquake engineering infrastructures play a leading role at international level, opening up several new research areas for experimental study, while allowing significant progress towards the validation of many aspects of Eurocode 8 and the mitigation of seismic risk.

Table 4. Earthquake Engineering Infrastructure Contracts (Framework Programmes FP6 andFP7)

Title	Acronym	Framework Programme	Number of Partners
Network of Research Infrastructures for European Seismology	NERIES	FP6	25
Risk Mitigation for Earthquakes and Landslides	LESSLOSS	FP6	47
Seismic early warning For Europe	SAFER	FP6	22
Network of European Research Infrastructures for Earthquake Risk Assessment and Mitigation	NERA	FP7	28
Design study of a European facility for advanced seismic testing	E-FAST	FP7	5
Performance-based approach to the earthquake protection of cultural heritage in European and Mediterranean countries	PERPETUATE	FP7	11
Systemic seismic vulnerability and risk analysis for buildings, lifeline networks and infrastructures safety gain	SYNER-G	FP7	14
Seismic hazard harmonization in Europe	SHARE	FP7	18
New integrated knowledge based approaches to the protection of cultural heritage from earthquake-induced risk	NIKER	FP7	18
Seismic Engineering Research Infrastructures for European Synergies	SERIES	FP7	23

The main achievements of the activities of the programmes listed in Table 4 can be summarized as follows:

- Building-up of a European Earthquake Engineering Community (Experimental testing facilities, Europe-wide Users Community, Training of Young Researchers)
- Worldwide role of Europe in Earthquake Experimental Testing
- Conduct of key pre-normative tests in support to Eurocode 8
- International collaboration with similar facilities
- Anticipation of the FP6 approach (I3)

Due to the insufficiency of resources in the EU during the period 2002-2006, the leadership has been undertaken by the USA with the NEES programme set up by the National Science Foundation (NSF).

In the meantime, European seismic engineering research suffered from extreme fragmentation of research infrastructures (RI) between countries and limited access to them by the S/T community of earthquake engineering, especially that of Europe’s most seismic regions.

The FP7-SERIES consortium made by 23 partners among the key actors in Europe’s seismic engineering research addressed these problems in a sustainable way via a 4-year programme of activities at an annual cost to the EC of less than 1.35% of the total present value (€190m) of the RIs’ material resources. SEIRES main aim was “*bridging the Gaps of RTD in Experimental Earthquake Engineering and Structural Dynamics*” by laying the foundations for the development of a **European distributed database, distributed testing capabilities, and virtual laboratories**.

The achieved results represent a **significant step forward** for the seismic engineering research in Europe but there is now the need to update/expand and above all **maintain** them as time goes by.

3.4 Enhancing Synergies among Existing Facilities

Compared to the situation in other regions of the world at the forefront of Earthquake Engineering Research, need of an EU wide plan is expressed, in order to fulfil the needs of the scientific community in earthquake engineering for the next two decades.

The feedback gathered from the results of research projects and the experience from recent earthquakes, had shown the need to simulate large velocities, displacements and accelerations. The FP7 E-FAST European project aimed at defining the essential characteristics that a new testing facility should have in order to allow testing of large size specimens with large relative displacements up to one metre.

Nevertheless, one testing infrastructure alone, even well equipped, cannot answer to all the needs of earthquake engineering research. Centrifuges, reaction walls, computer simulation infrastructure can provide the complementarities required and bring the know-how gathered in years of experience.

Only with a strong synergies and collaboration among all the existing facilities, European Earthquake Engineering Research can be optimized and reach excellence.

In this direction, the platform for collaboration set up in SERIES represents a crucial step in this direction:

- The *distributed database* will improve the dissemination and use of experimental results and foster the impact of earthquake engineering research on practice, innovation and earthquake risk mitigation.
- The *telepresence* will enhance the potential of carrying out more ambitious and complex tests by optimizing the available resources in different facilities and will facilitate distributed testing.
- The *distributed testing* will allow to better taking advantage of the main capabilities of different and disseminated laboratories.

3.5 Strategy for FP7 and onwards

Both the operators of the European testing facilities and the user community feel the need to integrate their research activities and make a coherent use and development of the existing infrastructures. A coordinated and collaborative research strategy has to be adopted to take full advantage of the continuous advance of IT technologies. The latter allows the evolution towards global connectivity to support interoperability, to ensure remote access of the laboratories and to provide access to a common data base of experiments and results. Such evolution will greatly facilitate international collaboration and provide industry and SMEs easier access to performing testing infrastructures.

Under its "Capacities" priority, FP7 provides a specific instrument (I3) to support in an integrated way the research activities in the large facilities as outlined by Table 5.

Table 5. I3 specific instrument in support of existing research infrastructures

Networking	Joint Research Activities	Trans-national access
Stimulate use of available resources Tackle fragmentation of available research in the EU Enhance efficiency and effectiveness of existing facilities	Optimise the use, development and enhancement of existing research infrastructures Assist implementation of new high performance testing facilities	Provide a bottom-up approach Provide access to ECTP research projects in areas where large scale testing is essential

Summarising, the vision for a strategy for FP7 on research infrastructures aims at promoting education and training by providing an adequate level of access, supporting research activities to maintain and upgrade the existing facilities, and improving efficiency by enhancing communication through the setting up of a common protocol for exchanging experimental results (distributed database) and the development of distributed testing capabilities and virtual laboratories. The activities should also promote the integration of the New Member States, as well as the Neighbourhood Countries, into a comprehensive and highly effective network of research infrastructures in Europe.

04 Framework for a Strategic Research Agenda on Earthquake Engineering

4.1 Physical and Scientific Background

Earthquake occurrence

Earthquakes are geological phenomena, associated to a rupture in the solid exterior part of the Earthquakes were the cause of about 2.5 million deaths worldwide during the 20th century (The CATDAT damaging earthquakes database, J. E. Daniell, B. Khazai, F. Wenzel, and A. Vervaeck). A number of the most deadly earthquakes have occurred in Europe. Earthquakes have also caused huge economic losses that can severely impact the economy of a society, especially in the more developed countries.

Earthquakes are geological phenomena, associated to a rupture in the solid exterior part of the Earth (lithosphere), triggering relative displacements along active faults, and are to a large extent unpredictable. It is not possible to predict where the next large earthquake is going to be triggered (and the affected zones), when it is going to happen, or its magnitude. However, science has identified the generation mechanisms, which show that the zones where large earthquakes have taken place in the past are continuously subjected to the possibility of the occurrence of large earthquakes. It is therefore possible to identify the zones where strong earthquakes will happen in the future. In Europe these zones are essentially in the south of Europe (the Alps and the regions south of the Alps) close to the fault zone that separates the Euro-Asian plate from the African tectonic plate. This fault zone stretches from the islands of Açores, across the Mediterranean Sea as far as Turkey and the Middle East. In northern Europe lower magnitude earthquakes can also take place, affecting smaller areas, with a potential for serious damage.

With the support of the SHARE FP7 project, the DISS - Database of Individual Seismogenic Sources has been developed. It reports an updated version of potential sources for earthquakes larger than M 5.5 in Italy and surrounding areas (Figure 13). It shows clearly the high seismicity of large parts of Italy and Greece, Slovenia and Bulgaria. Austria presents also potential sources of hazard and areas of equally high and even higher risks are identifiable in some of the bordering (accession) countries, notably Turkey, which is already part of the European Research Area.

The re-evaluation of the seismic risk in what has been known as quiet areas such as Austria, Switzerland and Germany has created a situation where a huge building stock, not at all designed for seismic input, needs to be re-evaluated and retrofitted wherever necessary. This imposes a major challenge to society, the construction industry and the research community. There is special demand for research in areas with rare but damaging events.

Figure 6. DISS Working Group (2010). Database of Individual Seismogenic Sources (DISS), Version 3.1.1: A compilation of potential sources for earthquakes larger than M 5.5 in Italy and surrounding areas.

4.2 Earthquake Consequences

In order to give an overall view of the task of earthquake risk reduction, the different types of earthquake effects at the earth's surface are identified and possible actions to reduce their consequences are indicated:

Ground motion / ground shaking

This affects all the zones within a certain radius of the epicentre, therefore it is impossible to avoid its consequences only with territorial and urban planning instruments. Ground motion is also the cause of the vast majority of the human and economic losses caused by earthquakes, typically more than 80%. Therefore it is essential to reduce the consequences of ground motion if it is intended to avoid most earthquakes consequences. Since seismic waves travel at several kilometres per second, no action that depends on human intervention is possible in the time interval after an earthquake occurs and the time when the motion is felt. Only some automatic actions –shutting down lifelines, factory equipment or opening the doors of fire brigades facilities, based on Early Warning Systems (EWS) – can be done in some cases. And after the earthquake has happened it is too late to avoid most of the damage or reduce significantly the number of victims. Therefore it is absolutely necessary to act before earthquakes happen, building constructions and infrastructures that resist earthquakes. This is possible by building up on existing scientific knowledge, making use of the capabilities of modern seismology and earthquake engineering, as follows:

(i) by studying the historical earthquakes, the recorded earthquakes (essentially during the last 100 years), and the faults that can generate earthquakes, seismologists can estimate the probability that earthquakes of certain characteristics affect given zones during given periods of time. This information forms the basis for the definition of design earthquakes, embodied in structural codes all over the world, including Eurocode 8 for the design of structures for earthquake resistance.

(ii) by applying modern earthquake engineering knowledge, which has the capability to design and build new constructions and equipment, and to assess and retrofit existing ones, to resist to those earthquakes.

The main actions needed against this effect are:

- Evaluate the seismic performance of existing buildings and strengthen those with insufficient seismic resistance. This is relevant in many European countries, where large parts of the building stock are old with many buildings built prior to the enforcement of modern seismic design (approximately by the beginning of the second half of the 20th century). Many buildings built afterwards, particularly during the 1960's and 70s and before the 80s are also highly vulnerable.

- Ensure the quality of construction: this applies both to new construction as well as to the strengthening of existing ones. Experience shows that in recent construction, designed to withstand earthquakes, the level of damage is inversely proportional to the quality of construction. The existence of scientific knowledge and good codes of practice is not enough to ensure the construction of earthquake resistant structures. It is fundamental that knowledge and codes are properly applied in design and construction.

- Evaluate the seismic resistance of lifelines (power, telecommunications, gas, water and sewage) and transportation networks and strengthen where necessary. In the early stages of the development of modern earthquake engineering attention focused essentially on the safeguard of human life, therefore on buildings and civil engineering structures. The lifelines did not have the importance they have today and did not receive as much attention. As a consequence, the equipment associated with lifelines were not designed for earthquake resistance, with a high potential of loss of service in case of an earthquake.

- Evaluate the seismic resistance of industrial facilities and strengthen where necessary. What applies to the equipment of the lifelines also applies in industry. And some types of industrial buildings, especially pre-fabricated structures, that have shown poor seismic performance in the past, may need strengthening (as in Emilia-Romagna earthquake in 2012).

- Strengthen monuments and buildings of high cultural value. This is an important part of Europe's invaluable cultural heritage and an important component of national identity. Special care has to be taken when intervening in these structures so as not changing their original "character". This requires the application of techniques that are as less intrusive as possible, and often reversible.

Fault Rupture

This effect takes place when the fault along which rupture takes place extends and appears at the Earth surface; it accounts for only a small fraction of losses.

Possible actions against the advers effects of fault rupture include not building across potential active faults, and by taking adequate precautions during the design and construction of a structure. The second option is only applicable to extreme situations, for instance when building a tunnel or a bridge crossing an active fault. Both actions involve research to identify and map the active fault and the application of restrictions to construction using territorial and urban planning instruments. In some cases this may not be possible or economically feasible. Therefore, when building roads and railways, some repairable damage should be accepted in the event of a major earthquake

Landslides

These involve changes in the topography, usually associated to displacements of large masses of soil in slopes that become unstable during an earthquake. These effects account, on average, for less than 10% of the losses.

Possible actions against the asverse effect of landslides: avoid building in these zones or build taking adequate precautions, for instance by stabilizing the soil, if technically feasible and economically justified. This involves identifying and mapping zones with risk of landslides and restrictions to construction using territorial and urban planning instruments

Tsunamis

These only take place if the epicentre is at sea, if the displacement between the faults involves a change in the morphology of the sea bottom, and if the magnitude of the earthquake is large enough to induce a significant change in the morphology of the sea bottom. Tsunami waves travel at high sea at hundreds of km/hour but near the coast (at smaller depths) the speed reduces to tens of km/hour. Depending on the distance between the epicentre and the coast, there is a time gap between the occurrence of the earthquake and the arrival of the tsunami to the coast. The tsunami is a long length wave and is stopped essentially by the force of gravity. This means that zones a few meters above sea level are not reached by the tsunami waves and only coastal areas are affected. In most cases tsunami losses are small. But in certain circumstances (such as the Indian Ocean Tsunami of 26.12.04 and in the Tohoku earthquake of 11.04.11) they can be the predominant cause of loss.

Possible actions against the adverse effects of a Tsunami: in the coastal zones close to the epicentre the time gap between the earthquake and the arrival of the tsunami at the coast may be small (maybe 10 or 20 minutes). It may not be enough for the authorities to issue a warning and organize a large-scale evacuation. However if (i) the population is well informed and knows how to recognize the signals of danger, this is, the earthquake itself, and (ii) prepared to act in such a situation, then a large scale evacuation can take place. In the coastal zones further from the epicentre, where the earthquake is not felt, the tsunami will arrive with a long delay with respect to the earthquake that triggered it. If earthquakes are properly monitored, a few minutes may be enough for scientists to evaluate the probability of triggering a tsunami. A warning may then be issued with enough time before the tsunami arrives at the coast for civil protection authorities to organize the evacuation. The above actions may save the lives of the vast majority of the potentially affected populations, especially if there are no facilities with large concentrations of people (for instance hospitals, schools for young children, homes for elderly people) and facilities with the potential of causing environmental disasters. However, most material losses in the affected zones cannot be avoided. Actions to decrease the consequences of tsunamis comprise (i) the creation and maintenance of monitoring systems for the Mediterranean and for the Atlantic (in Europe), (ii) information and preparation of the population, (iii) avoid the construction of sensitive facilities using territorial and urban planning instruments, and (iv) design for the predictable levels of tsunami action.

Fires

These are not a direct effect of the earthquake, but often take place during and after the earthquake and can be a major cause of damage and loss of life. Fires are caused mainly by the disruption on the gas and electrical networks and gas leakage on the final users. The proportion of fire losses has diminished over recent decades.

Possible actions against the adverse effect of fires: education of the population to minimize the risks of triggering fires at private houses and offices and proper design of the gas networks (electrical networks usually contain safety devices that shut down the networks a few seconds after strong earthquakes start), including adequate location of large deposits of gas, etc

4.3 The Role of Codes in the Reduction of Earthquake Risk

EUROCODE 8

The European Standards for Construction, The Eurocodes, constitute today a coherent set of 57 standards, based on a unified philosophy of safety and reliability.

In the set of Eurocodes, Eurocode 8 – Design of Structures for Earthquake Resistance - plays a particular role, since it brings additional provisions to other Eurocodes to ensure the resistance of structures and the limitation of damage in seismic situations. Eurocode 8 covers on a rational basis a large variety of civil works conceived with the types of structural materials (i.e. reinforced concrete, steel, etc.) covered by the other Eurocodes.

By leaving to the National Authorities of Member States appropriate choices to adapt to the seismic hazard and to local economic conditions and practice through the so called Nationally Determined Parameters, Eurocode 8 makes it possible to cover the whole of Europe, within the limit of the structures and situations which it covers.

Compared to other existing codes in Europe, Eurocode 8 brings substantial progress, on the one hand by covering structural and geotechnical aspects, not covered until now, and on the other hand by introducing recent methods such as pushover analysis and displacement based assessment and retrofitting of existing buildings

Standards as Engineering Tool for the Seismic Design

The Eurocodes constitute a technical and a contractual tool facilitating the free movements of construction products and the uptake of the Single Market in Europe. Eurocodes were thus conceived as a conceptual base giving common tools for the design of civil works and construction products. Beyond its particular characteristics of seismic protection, Eurocode 8 must be regarded as one of the components promoting competitiveness in Europe, as a contractual base allowing calls for tenders and as a single framework for the development of new products designed to meet the needs of citizens.

Eurocode 8 thus fits with the professional engineering tasks for the design of civil works, and as support for the choice of construction products and for the constitution of the call for tenders of contractors, by offering "deemed to satisfy" procedures

Research and Development of the Eurocodes

As for every technical Standard, Eurocode 8 offers rules and procedures representing the state of the art of design at the time of their publication as recognised by the professional Community. A Standard does not necessarily take into consideration the latest scientific discoveries; neither does it hinder in any way their development: Standards should never be an impediment to innovation. When passing from the experimental ENV to the present EN versions of the Eurocodes, Eurocode8 has benefited from important discoveries due mainly to research programmes that took place just before and during the conversion period. It is certain that research programmes presently underway in Europe or elsewhere will lead in the future to the updating of existing or to the drafting of new versions (i.e. pre-normative research) of the Eurocodes, thus allowing to improve the safety of construction works.

Research programmes should be oriented towards a better knowledge of the behaviour of structures during an earthquake. The development of a norm should always strive to obtain high efficiency in terms of safety and cost. Naturally, to be efficient from a social point of view, aseismic protection should be attained at a minimum cost: the less expensive the cost the easier it will be for it to be accepted and implemented. Therefore, research work should always be carried out taking into account economic aspects

A better Coverage of the Field of Protection

The reduction of earthquake risk in Europe depends mainly on the assessment and retrofit of existing structures. This in itself presents very challenging technical and socio-economic problems.

Even though Eurocode 8 has, in Part 3, innovated by proposing original assessing procedures and has set up limit states for existing buildings, the procedures put forward could neither have the feed-back experience nor the same reliability as for the design of new structures. There exists therefore a wide field of potential research Eurocode concerning the assessment and retrofit of existing structures. Also, the majority of existing buildings in European urban areas, dating back to the mid-XX century and earlier, cannot be treated as individual buildings as they constitute entire blocks of constructions where the different buildings are interdependent. For these buildings, which are often of great historical value and undergo preservation works, it is important to set up appropriate assessment and design methods and rules.

The economic damage caused by strong earthquakes has increased dramatically during the XX century in developed countries. A great part of the economic losses is caused by damage to industrial installations and lifelines. A large part of the equipment and industrial installations in European countries were not designed, built and installed with the concern of providing seismic resistance. This situation is due to the fact that when the first modern structural codes started to be developed, at the end of the first half of the XX century, (i) the attention focused almost exclusively on the safeguard of the human life, therefore on civil engineering constructions (mainly buildings and bridges) and (ii) the lifelines did not have the importance for the support of the life of the populations and the economy they have today in developed countries. In several domains there is still a lack of codes or technical recommendations for the design, fabrication and installation of mechanical, electrical and other equipment. It is therefore proposed:

to identify the areas in which there may a shortcoming of codes or technical recommendations for the seismic design, fabrication and installation of equipment of the lifelines or industry.

to develop the necessary codes or technical recommendations.

Recognizing that each community has only limited means, it is clear that assessment and retrofitting cannot be implemented on a wide scale unless the methods used are efficient and offer the best safety measures at low cost. That implies not only having the appropriate norms, but also to implement political choices in terms of priority of actions, the level of safety to be attained and planning.

There are many European construction companies and engineering/consultancy firms that compete for international projects in regions with very high seismicity: in China, Taiwan, Indonesia, Iran, the Caucasus area, and Central and South America. European engineering will be at a disadvantage in those parts of the world, unless it enjoys a world reputation for seismic expertise and leadership in earthquake engineering. Moreover, high seismicity regions are located in those parts of Europe that more badly need development of civil infrastructures and that receive European cohesion support for it. Such regions include Bulgaria, Greece, the South of Italy, Portugal, Romania, Slovenia, and - most likely in future - Western Balkan countries and Turkey. European know-how and expertise in earthquake engineering is essential if European construction industry is to play its intended role in these regions, to the benefit of their economies and for the safety of their citizens and for the economic progress in Europe as a whole. The "increase of competitiveness of the European civil engineering firms, contractors, designers and product manufacturers in their world-wide activities" is emphasized in Document CONSTRUCT 01/483 "Guidance Paper L - Application and use of Eurocodes" of the European Union's Standing Commission on Construction, as one of the intended benefits of the Eurocodes

4.4 The Role of Civil Protection

While it is agreed that post-event actions, such as those carried out by Civil Protection in the aftermath of a disaster, are not the most efficient way of avoiding damage or reducing the number of victims of earthquakes, these activities are nevertheless very important because an adequate response can reduce damage and the number of victims very significantly. Therefore, search and rescue operations, as well as putting down fires, are additional contributions to reduce the number of victims and the extent of damage. Civil Protection actions are very important to the recovery of the populations and the economy of the affected zones, namely by providing support to the survivors that may need temporary shelter and other forms of support to survive. Civil Protection also identifies the usability of buildings and facilities and performs other important tasks to bring the affected zones to normality.

Civil Protection activities should also comprise, and in many cases do, contributions to prevention and preparedness, for instance by means of information on how the population can and must act before and during earthquakes. Therefore in tackling the earthquake problem, Civil Protection actions must be regarded as an indispensable and important complement of the main preventive policies, and research at a European level should consider means to make pre- and post-event Civil Protection actions more effective

4.5 The role of private initiatives

The popular trend towards private public partnership (PPP) cannot be properly implemented in the earthquake environment. Earthquakes affect economies and societies on all levels. There is no specific industry with the exception of insurance companies that could carry such initiatives. The exception is GEM (global earthquake model) which is mainly supported by the insurance industry, which takes considerable influence on the conception.

In order to achieve the goal of resilient societies it will be necessary to create a strong initiative which is supported by the society itself. It can only be suitability allocated in the framework programs of the European Commission. It is therefore strongly recommended to create such an initiative within Horizon 2020 (2014-2020).

05 VISION and Challenges for 2020 and beyond

5.1 Vision

Resilient and sustainable communities are the overarching long term goal to achieve in earthquake engineering. Significant progress in several directions is needed in earthquake engineering research to reach by 2020 this overreaching goal.

There has been over 3,000 damaging earthquakes globally since 1900, causing either death or injury, and a great number more have caused homelessness or affected the lives of the population. The total number of earthquake-related deaths in all countries since 1900 has been found to be approximately 2.419 million (with an accepted range of 2.291–2.690 million), according to the 1996 fatal earthquakes recorded (*The CATDAT damaging earthquakes database*, J. E. Daniell, B. Khazai, F. Wenzel, and A. Vervaeck). The vision is to both reduce the loss of human life and economic damage to acceptable levels through a range of appropriate and cost effective mitigation measures. It must also be considered the role that Europe has and is auspicable will have also in the future as major donor in international aid. Designing suitable actions will require a massive European research programme that allows a better understanding of the physical and social phenomena involved, to arrive at properly engineered structures, and ultimately to a safer society from the threats of earthquake hazard

5.2 Challenges

There is today a considerable risk of being killed by an earthquake in many of the highly seismic regions of Europe. There is a clear vision of the earthquake engineering community that targeted research work is fundamental to reduce such risk to acceptable levels. The challenge for 2020 would be to put in place a strategy for reducing the vulnerability of European citizens and their economic and cultural activities to a sustainable level.

It is recognized that the vulnerability stretches far beyond the human risk. A disastrous earthquake in a highly developed, but not prepared, European region would result in economic losses at a scale sufficient to threaten the whole European economic system. In particular, the sustainability of vital lifelines and utilities shall be included in the earthquake agenda to ensure the functioning of society after an eventual seismic event

5.3 Target

By taking as refeence the investment in Earthquake Engineering related Research and Development at federal level in the United States and Japan, that amount to 90million € per year, in the European Union an **annual Budget of at least 50 million** € **per year**, **one third of which addressed to experimental activities**, is justified. Several ways on how this figure can be reached are highlighted in the Roadmap

06 Detailed STRATEGIC RESEARCH AGENDA (SRA)

6.1 Earthquake Risk Reduction and Natural Disaster Mitigation in HORIZON 2020

Introduction

This document was originally written in response to the EU Document "Thematic Priorities in FP7", and submitted to the EU on 28.12.04. Its purpose was to propose a Research Theme for FP7 on Natural Disaster Mitigation, with Sub-themes to include:

- Geological hazards – earthquakes, volcanic eruptions, landslides and avalanches.
- Climatic hazards – floods, windstorms, heat-waves and cold weather.
- Wildfires.

The document was drafted by and was supported by the Executive Committees of the European Association for Earthquake Engineering and the European Seismological Commission. Membership of both these bodies extends to countries in the European/Mediterranean area outside the present EU, but each is able to speak for the research community across the EU. Since the document was submitted, the EC has published (COM, 2005, 440 and 441) its proposals for Research Programs during FP7, including a detailed list of themes to be considered on Environment and Climate Change. The EAEE and ESC are pleased to note that the mitigation of natural disasters has a place in many of the research activities proposed; but there remains much to do to bring these rather generally defined aims to the definition of specific research programs and modes of research management. The views of the European earthquake research community expressed in the following pages therefore remain relevant, and we hope they will be considered by DG-RDT in its future task of formulating detailed research programs.

The current version of the earthquake risk agenda (SRA) directly targets horizon 2020 and proposes to establish a large initiative under a joint management scheme of the earthquake research community. Well targeted research is to be expected in a coordinated manor.

6.2 Justification

Natural disasters of all types – earthquakes, floods, windstorms, volcanic eruptions, wildfires in the period 1980 – 2008 have resulted in average annual losses across Europe of around $9bn. In addition they cause significant numbers of human casualties, loss of homes and livelihood: the average of killed people per year is 4,195 and the average of affected population per year is

1,139,022, causing a set-back to economic development wherever they occur (EM-DAT: The OFDA/CRED International Disaster Database, Université catholique de Louvain, Brussels, Bel.).

The EU has supported research on topics related to the mitigation of natural hazards for more than two decades, and much has been achieved during that time, especially in enhancing the understanding of the basic mechanisms involved and in limiting future impacts by better design practices. But much remains to be done in understanding and reducing the vulnerability of the EUs communities and built environment, and in building our capacity to deal with the hazards we face. Research budgets have been neither sufficient in quantity, nor effectively enough targeted, to achieve a real breakthrough. In this respect the EU lags very far behind our industrial competitors in Japan and the United States.

The enlargement of the EU is already in place, and that envisaged for the future, will both bring in new Member States with grave natural hazards threats, highly vulnerable infrastructure and recent experience of disastrous events, and at the same time will enlarge the EUs existing pool of research expertise.

The FP8 period 2014-2020 therefore represents an unprecedented opportunity to harness emerging knowledge and technology to bring losses resulting from natural hazards under control throughout the European area, and to improve the safety of its citizens and to safeguard their economic security

6.3 Research achievements (current or closed FP7 most relevant projects)

During the last years important progress has been achieved in Europe in earthquake engineering, seismology, engineering seismology and seismic risk assessment through several national and EC funded research projects. Research infrastructures have been developed and updated and highly specialized human resources are now available (structural and geotechnical engineers, seismologists, geophysisists, geologists, risk engineers) to contribute efficiently to the resilience of the community.

Innovative and comprehensive results have been accomplished, which will constitute the basis for future developments according to the needs of society, research community and industry. The goal now is the resilience of the society and the economy to phase efficiently natural and technological hazards.

A list of the most relevant (FP7) projects is provided:

NERA: Network of European research infrastructures for Earthquake risk assessment and mitigation, www.nera-eu.org

NIKER: New integrated knowledge based approaches to the protection of cultural heritage from earthquake-induced Risk, www.niker.eu

PERPETUATE: Performance-based approach to the earthquake protection of cultural heritage in European and Mediterranean countries, www.perpetuate.eu

SHARE: Seismic hazard harmonization in Europe, www.share-eu.org

SYNER-G: Systemic seismic vulnerability and risk analysis for buildings, lifeline networks and infrastructures safety gain, www.syner-g.eu

SERIES: Seismic engineering research infrastructures for European synergies, www.series.upatras.gr

REAKT: Strategies and tools for real time earthquake risk reduction, www.reaktproject.eu

6.4 Research Approach

Disaster risk mitigation requires enduring solutions for the society at large. The challenge is that risk mitigation is highly complex, requiring an interdisciplinary perspective that mobilizes all actors and stakeholders in engineering, urban planning, natural and social sciences, to develop solutions that work.

Achieving a decisive breakthrough towards natural disaster mitigation will require:

A coordinated program for earthquake engineering research at EU level

A multi-hazard approach

A substantial increase in resources

A multi-disciplinary approach involving scientists, engineers and social scientists

Better collaboration between the research community, government and industry

A managed program

A coordinated program of research on earthquake engineering at EU level is needed:

to create and coordinate a critical mass of research expertise

to maintain and develop the necessary research infrastructure, including large scale research facilities

because the phenomena being studied and their effects are transnational

because national budgets alone are inadequate

The goal of disaster mitigation is consistent with many existing EU policy goals – in environmental protection, in protection of the cultural heritage, in transport, in health, and in social affairs. If the aim of the EU is that citizens throughout Europe should enjoy comparable living standards, this must include comparable levels of protection from natural hazards.

A multi-hazard approach which is integrated across the whole field of disaster mitigation is highly desirable for effective management because:

- a multidisciplinary research approach involving physical and social sciences and engineering is common to all fields
- there is much overlap in methods, approaches, and research facilities
- in the design of facilities, a multi-hazard approach is likely to be cost-effective

- the user-community is the same across different hazards, consisting of designers and builders, urban authorities, estates managers, insurers and civil protection agencies.

A substantial increase in resources is essential because current funding of disaster mitigation research in the EU is at a much lower level than other industrialized nations, such as the USA and Japan. The result is that the development of technologies for scientific monitoring, for improvement in the performance of structures and for experimental and simulation studies is increasingly concentrated in the USA and Japan, including the upcoming of China, leading to a loss of technological leadership and of export markets to disaster-prone countries in Asia and the rest of the world.

Additional resources are needed to provide for:

Much enhanced monitoring networks (including satellite monitoring)

The development of research infrastructure and large scale facilities

Effective use of the complementarities of existing research infrastructures by networking

Providing transnational access to large scale facilities to user groups from Member States with less technologically advanced RTD infrastructures

Creation of a well-focused long-term research program

The formation of networks and centres of excellence on a variety of topics

The mobility of researchers

A multi-disciplinary approach is needed because effective action to reduce disasters requires coordination across several overlapping disciplines. Earthquake risk mitigation for example requires:

Understanding seismic hazards – developing models of earthquakes based on geophysics and observation

Assessing and reducing earthquake impacts – developing tools to simulate the behaviour of buildings and urban systems, and devising technologies to build more earthquake resistant structures and strengthen existing ones

Enhancing public understanding and community resilience – developing the means to communicate effectively about the options available, and to enable communities to devise their own protection strategies

These three areas are traditionally the domain of physical scientists, earthquake engineers and social scientists respectively. But none of these groups can operate effectively or achieve goals of value to society unless they interact closely and understand each other's methods and problems.

Better collaboration between the research community, government and private companies is needed to ensure that the research supported by the EU achieves the highest possible impact on its intended users. Governments stand to benefit enormously from the reduction in future losses; insurers will benefit from a better understanding of risk as well as reduction in losses; and the construction industry will benefit from the exploitation of new techniques. A closer involvement of both government agencies and private companies in the formulation, execution and financing of natural disaster research is then justified. This Strategic Research Agenda has therefore been formulated in collaboration with the European Construction Technology Platform (ECTP), and in coordination with the Natural and Man Made Hazards Working Group in the Quality of Life Focus Area within ECTP.

A managed program is needed to achieve coordinated outputs and a long-term strategy. Research effectiveness in previous Frameworks has been hampered both by the short time-horizons of each Framework Programme, and by the lack of a coordinated scientific management. An attempt to improve the latter has been the introduction of Integrated Projects in FP6 and FP7, which in spite of having been very successful, have not been able to capitalize on the large efforts made in setting up a management and networking structure that leaves beyond the completion of short term projects.

Considering the limited budget and time frame, FP projects taken individually have given great contribution to Earthquake Engineering Research but without a long term strategy and adequate financing it will not be possible to capitalize and build up upon the successful results obtained in the past.

The Commission has the opportunity, in Horizon 2020, to set up a program with long term goals such as the very effective National Earthquake Hazards Reduction Program (NEHRP) and the Network for Earthquake Engineering Research (NEES) funded by the National Science Foundation (NSF) in the USA.

6.5 Industrial relevance

The European industry is moving towards resource-efficient production and aims at keeping aging infrastructure in service. A roadmap on how to achieve these targets has been elaborated by the IRIS-Project financed by the European Comission. Measures and activities are presented at 4 levels:

- Goals of the European industry
- Technical and management issues
- Research demand
- Enabling technologies

Goals of the European Industry:

European industry needs to rely on uninterrupted support and services from infrastructure and networks (i.e., energy supply, telecommunications, transportation, etc.)

Economic crisis is leading more and more to a reduction of the budget allocated for maintenance plans. This must not induce a reduction of the quality of operation and safety.

The European Union had defined the Grand Challenges (sustainability, energy consumption, environment, use of resources, employment). Nevertheless, due to the strong completion, without any motivation, the industrial sector might have difficulties in pursuing these objectives.

The extension of lifetime is a typical cross-sector issue. Many plants have reached their formal end of life but operators are convinced that capacities have been underestimated at the time of construction. Methods to assess the actual service life are of highest importance.

The issues involved to be addressed by new approaches concern mainly asset management and IT technology.

In the field of asset management there is a constant shrinking of budget, therefore:

A clear definition of aging (degradation laws) based on measurements is required. It would definitively allow a better management of the budget.

Risk paradigms and management are to be renewed and adopted to today's requirements and circumstances.

Asset management processes have to be integrated into existing ones without putting a burden on the normal operation and the methodologies.

Up-to-date decision making tools are to be offered and scenarios are to be created that allow identifying the conditions of a structure and its remaining service life.

Concerning the IT-environment, there is the need for:

A complete system of systems is to be created and a holistic approach used.

A stronger investment on capturing and curation of information. Data driven technologies,.

The research demand resulting out of these issues is explained in the next chapter.

6.6 Earthquake Risk Mitigation Sub-Theme

As an element of an overall Natural Disaster Mitigation Research Theme, the European Association of Earthquake Engineering (EAEE) and the European Seismological Commission (ESC) envisage that it will be essential to address at least the following topics under FP8:

- Better fundamental seismological databases and instrumental networks (regional and local to specific buildings - test sites) for earthquake monitoring
- Improved hazard mapping
- Vulnerability assessment of buildings, lifelines, infrastructures
- Protection of historic buildings and centres
- Common standards of protection for existing public buildings, highways and other infrastructure
- Improved methods for intervention in the existing fabric to increase earthquake resistance
- Better design of the seismic performance of structures and foundations
- Understanding human behaviour in earthquakes and public response to risk
- Building community resilience and response capability

More detail on specific research topics is given below

6.7 Research Topics

1. Earthquake hazard

Even if is not a direct part of the experimental activities, the earthquake hazard represents the threat to be counteracted. Therefore, it cannot be ignored among the research topics that have to be stimulated.

Evaluation of location and probability of occurrence of future large earthquakes

The following themes of research should be encouraged: (a) the modelling of seismic activity; (b) the earthquake cycle on active faults; (c) the relationship between strong or large historical earthquakes and active faults; (d) the mapping of capable and active faults at European scale. Part of these tools is being developed in current FP7 projects such as SHARE. The existing capabilities to monitor earthquakes should be enhanced (see support actions).

Development of a common methodology to evaluate hazard in Europe

Methods for the evaluation and characterization of ground-shaking hazard at regional scale. Selection of the most appropriate return period for design purposes for ultimate and damage-limitation limit states. Evaluation of tsunami hazard in the Mediterranean and Atlantic seas.

Influence of local geology in large cities

Methodologies to understand and map local hazards including the influence of local geology and subsoil, active faults and zones with potential for landslides, subsidence and liquefaction, with application to large urban centres.

Real time observation and warning systems for earthquakes and related hazards

Monitoring and real-time reporting and impact analysis and systems for automatic response to earthquake warnings. Development of Tsunami warning systems.

2. Seismic risk assessment and mitigation for existing buildings and infrastructure

Simplified probabilistic methods for seismic risk analysis

Development of probabilistic methods suitable for European building typologies. Definition of a unified approach for seismic risk evaluation using GIS tools. Mapping tools for proposed interventions on existing buildings.

Development of a unified approach to rapid screening

Common definition of rapid screening approaches to assess vulnerability of single buildings or groups of buildings. Rapid screening procedures for bridges.

Methods for evaluation of the vulnerability of the existing built environment

Defining vulnerability relationships for European building typologies/materials, notably for masonry structures, lifelines, industrial plants and equipment, and for monuments and historical buildings.

Evaluation of non-structural and economic losses and human casualties. Emphasis on evaluation techniques for public buildings, especially schools and hospitals. Development of inventory databases; monitoring of the dynamic response of existing structures; post-event damage surveys and data-gathering.

Evaluation of Risk Protection Measures

Improvements in understanding the public perception of earthquake risk; evaluation and case-studies of risk-reduction and risk-transfer measures, including non-structural actions; cost-benefit studies for risk-reduction measures.

3. Design of new facilities and strengthening of existing facilities

Innovative approaches for the design of rational earthquake-resistant structures

Analytical and experimental studies on new materials and building typologies and techniques as seismic design objective; new and more efficient energy dissipation systems and base isolation methods; non-continuous frames stabilized by relative rocking of structural components.

Development of strengthening techniques for existing buildings and infrastructure

Strengthening techniques for existing buildings and low ductility reinforced concrete buildings, with emphasis on low-cost techniques for large scale interventions; emphasis on schools, hospitals and multi-storey multi-occupancy buildings; development of low intrusive strengthening techniques for application in monuments, historical buildings and other structures; seismic design and upgrading of mechanical, electric and other types of equipment used in lifelines and industry; cost-benefit studies..

4. Support actions

Strategic Research Agenda which shall be coordinated with all other natural hazard sectors.

Support for networks to monitor earthquakes

Development of Europe-wide networks for seismic monitoring, including sea-floor monitoring, with emphasis on seismically-active but poorly instrumented areas in South and South-Eastern Europe.

Support for existing large earthquake research infrastructures

Facilities at both JRC and other national laboratories will need continued support to enable them to be available to carry out necessary experimental studies (see chapter 7).

Support for international meetings and exchanges

Support for meetings, exchanges and collaborative projects to facilitate transfer of knowledge and experience with researchers from non-EU countries with a highly developed earthquake protection culture, notably USA, but also Japan and New Zealand. Support for knowledge transfer to and data acquisition from developing countries in high-risk zones.

Support for training workshops for young scientists and engineers

Support, under Marie Curie funding, for international workshops to transfer research results and good practice to young scientists and design practitioners, with emphasis on accession countries.

Development of educational tools

Dissemination of research outcomes, suitable for design practitioners and the general public.

6.8 Fit with the EUs Criteria for identifying Thematic Domains

Contribution to European Policy Objectives.

The proposed Research Agenda will make a vital contribution to Europe's aim of achieving sustainable economic growth. Societies which are constantly coping and struggling with the consequences of natural disasters do not achieve sustained growth. This has been shown by the impact of storms and floods in the EU countries in 2000. The present Research Agenda will contribute to policy objectives in many areas – in environmental protection, in protection of the cultural heritage, in transport, in health, and in social affairs. The creation of a uniform level of protection of the citizen from natural disasters is clearly consistent with EU policy objectives.

European Research Potential

The proposed Research Agenda has a potential both for the creation of research excellence and for converting the results from research into social and economic benefits. At scientific and technical level, natural hazards research in Europe leads the world in many areas. This has been achieved partly through previous EU funding, and future funding at an increased level is needed to maintain that status in the advent of growing international competition. The potential now exists to convert this research into social and economic benefits to a much greater extent than has been achieved so far, and this is the challenge that must drive the research activity in FP8.

6.9 Enabling Technologies

Various enabling technologies are to be developed in order to achieve the vision of a safe and resilient infrastructure. The technologies to be addressed are:

- Integrated online vulnerability assessment techniques: allowing the evaluation of the condition of the structure and providing support for interventions
- Infrastructure inventory techniques: understanding the existing inventory and its current state is needed for quantifying resilience and for prioritizing maintenance efforts
- Early warning systems: real time measurements are essential to support prediction and to inform owners of infrastructure in case of emergency
- New smart sensing and communication technologies: real-time data acquisition and risk assessment is needed to improve situation awareness of operators for structural response prediction and assessment, and to acquire data to improve models and infrastructure inventory systems

- Innovative data collection, processing and aggregation systems: large amounts of data will be acquired with redundant sensing requiring advancing our capabilities regarding data aggregation, collection and management
- Advanced non-linear modeling capabilities: simulation of realistic damage and collapse in structural systems for assimilation of real-time data and evaluation of the integrity of a structure
- Multi-scale and multi-physics modeling techniques: to consider the complex behavior of new materials and structural systems and to consider the performance over their life-cycle
- Life-cycle engineering including aging management: definition of standardized degradation models and quantification of possible uncertainties. A methodology to introduce this process into current infrastructure management systems is to be developed
- Advanced decision support tools: for prioritizing risk mitigation measures, aiding first responders, and conducting informal renewal of the built environment
- High performance computing: larger, faster simulation capacities that can consider the needs for performance based design as well as of multi-scale, multi-physics and cyber-physical social models needed for the simulation of systems of systems
- Sustainable model of systems of systems: creation of a general global infrastructure model overarching all disciplines and sectors holding all necessary information
- Communication tools: for optimal management and mitigation steps as well as for assessing the impact of the above mentioned actions
- Research on improving technology transfer: needed to ensure that knowledge associated with the most critical physical and social components for developing resilient and sustainable infrastructure is acted upon in a timely manner

Ongoing research and needs for research:

Many of the above mentioned technologies have been addressed in a fragmented way in previous Framework Programs. Risk based assessment leading towards risk based design has been addressed in the RIMAP (Risk Based Inspection and Maintenance Procedures for European Industry) - project and is currently further developed in the iNTeg-risk (Early Recognition, Monitoring and Integrated Management of Emerging, New Technology related Risks) and IRIS (Integrated European Industrial Risk Reduction System) initiatives. These projects have identified future research needs that address the content of this roadmap.

07 ROADMAP for Implementation of the SRA Priorities

7.1 Strategy for Implementation

A sustained support from the European Commission, according to the directions presented in the previous sections, constitutes the platform out of which various national and international initiatives can achieve the vision specified in this document.

In the following the strategic principles are recommended:

The selection and recommendation of research topics, instruments and budgets shall be done in coordination between stakeholders and the European Commission.

- The implementation of a European hazard reduction program is recommended.
- The large European testing facilities are an integral part of earthquake engineering research and shall be supported. The activities of these research infrastructures shall be closely coordinated with the intended research work.
- It is recognized that valuable earthquake engineering research work is carried out globally and collaboration is recommended and necessary. Such collaboration therefore shall be promoted and supported.

It is intended to update this strategic research agenda according to the development and identified needs of society and the research community.

7.2 Implementation Concept

To allow a systematic approach to the implementation of the Strategic Research Agenda, a hierarchical concept is proposed consisting of:

→ Goals
→ Objectives
→ Topics
→ Projects

The **Goals** are subsequently defined and remain valid throughout the program.

The **Objectives** are described under chapter 4 and will undergo an annual reevaluation and improvement.

The **Specific Research Topics** will be specified and individually negotiated with the stakeholders groups and the European Commission.

Relevant **Research Projects** should ensure a good response on the calls for proposals.

The **Goals** that the earthquake engineering community aims achieving within Horizon 2020 are:

A	Improvement of the understanding of the effect of earthquakes
B	Improvement of seismic hazard assessment
C	Improvement of knowledge, methodologies and techniques to assess risks and to reduce seismic vulnerability of the existing built environment, facilities and systems
D	Improvement of knowledge, methods and techniques to improve the earthquake-resistant design of new facilities
E	Development of effective policies, practices and technologies for sustainable earthquake loss reduction
F	Utilization, maintenance and improvement of large testing facilities and related normative works for European integration and enabling synergies
G	Improvement of the global competitiveness of European suppliers of products and services related to earthquake risk reduction.
H	To contribute to earthquake risk reduction worldwide

7.3 Detailed ROADMAP for Implementation in HORIZON 2020 and beyond

A conception how the vision can be achieved is given in Table 2. It shows an indicative split of the necessary budget for the individual programs. Out of this information the planning for the topics and instruments for each year of Horizon 2020 can be elaborated.

The set of Research Priorities is oriented towards existing Research Programs and schedules.

The proposal consists of a major number of small to medium targeted research projects and a few large collaborative projects. The core group is of the opinion that progress will be better achieved by small and medium size projects rather than large activities. Nevertheless the community is aware of the need of programs like NMP, Energy, Security or Transport to organize large collaborative projects, which could be structured like an umbrella which combines 5 or 6 of targeted small and medium projects under one coordination frame.

The following topics are considered to be addressed in the next calls as top priority:

- Building response and resistance against earthquakes and following events (in particular aftershocks).
- Integration of Environmental Sustainability with Seismic Safety.
- Vulnerability of lifelines and critical infrastructure.

- Complex geo-structures and site effects including microzonation.
- Protection of the cultural heritage against earthquake effects.
- Combination of natural hazards with man made hazards.

Table 6. Allocation of Research Topic Budgets to respective Programmes and Calls.

DETAILED ROADMAP (Allocation of Strategic Research Priorities to Programs and Calls)								
Program	**Budget (Million €)**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**
ICT	9.110	Work Program finished		5		5		5
NMP Construction	3.500		12			10		
NMP Industrial Safety				10			10	
Energy	2.300				12			10
ENVIRONMENT Hazard related	1.900		4	4	4	4	4	4
ENVIRONMENT Mitigation related			5	5	5	5	5	5
ENVIRONMENT Cultural Heritage				2		2		2
ENVIRONMENT Supporting Activities			1			1		
ENVIRONMENT International Collaboration				1			2	
Transport	4.180			10			12	
Security	1.350			8		5		10
Specific Program: Ideas	7.460		1	1	1	1	1	1
Capacities: Research Infrastructure	1.850		24			16		
Capacities: SME's	1.336			1	5	1	5	5
Capacities: International Cooperation	185		4			4		
DG ENT and other DGs				5	15			8
ESF			1	1	1	1	1	1
Cohesion Funds (ISPA, PHARE, …)					15		15	
Total Annual Budget for EE			**52**	**53**	**58**	**55**	**55**	**51**

7.4 Further Recommendations

In order to enhance the process of risk mitigation in Europe the following actions should be considered, involving interactions between the European Commission, Member States and the scientific community:

- An initiative towards the European Parliament to increase funding for earthquake engineering research
- A review of the Role of DG-RTD to create a new longer-term support structure for European Research, with associated changes in funding mechanisms, relationship between EU-funded and nationally-funded research activities, and administrative arrangements.
- An enhanced research programme at a European level covering aspects of earthquake hazard, better construction and communication of seismic risks to the general public and within the construction industry, and means to reduce the earthquake risk in existing buildings and infrastructure, coupled with mechanisms for improved collaboration with countries outside Europe.
- Enhanced activity by DG-ENV to support the ability of Civil Protection agencies in Member States to respond after a major earthquake, and to ensure that land-use planning and urban development for sustainability incorporates provision for minimising seismic risks, alongside those from other natural hazards
- Further support to the development of Eurocode 8 by DG-ENTR, in order to bring the fruits of new research into practice, to improve its applicability by the construction industry, and to strengthen its effectiveness for use in retrofit strengthening programmes.
- Use of European Regional Development Funds (ERDF) (i.e. Interreg Program), to support essential strengthening and upgrading of key infrastructure and public buildings such as schools and hospitals in areas of high seismicity. Ensuring construction to satisfactory antiseismic standards wherever ERDF or the Cohesion Funds (CF) are used.
- Use of the European Social Fund (ESF) to support training and public awareness campaigns for earthquake-preparedness of populations at risk
- To examine the scope for new mechanisms of funding to support actions to preserve historical monuments and buildings and artefacts of cultural importance from future earthquake damage
- Strengthening of the European Integration through ERANET+

08 Realization of the Vision

8.1 Role of DG-RTD in a European Earthquake Risk Reduction Program

Problems in Earthquake Risk Reduction and motivation for EU funded research.

Each country in the European Union possesses entities which, under various covers, deal with natural hazards. They are:

- Institutions in charge of land management and urbanism
- Research Institutions dealing with various natural hazards, in particular earthquakes.

In many countries there is no organized chain of responsibility in charge of the components of seismic risk: seismology, geology, evaluation of buildings vulnerability, evaluation of risk to buildings, evaluation of risk to people, retrofitting of existing buildings, earthquake disaster management, and seismic design aspects in new construction technology.

There can be additional problems:

- An insufficient background in seismic risk evaluation
- A poor implementation of seismic design codes
- A lack of retrofitting measures
- Repairs after earthquake made without following seismic design principles
- In low seismicity regions, unawareness of the hazard posed by earthquakes at the political or professional level, due to the “rare event” character of earthquakes and to poor communication between various competencies.

In all countries in Europe there is:

- A need for better communication between the various national entities in charge of the evaluation and the reduction of earthquake risk.
- A need for standardised procedures in seismic risk evaluation & mitigation.
- A need for research cooperation in seismic risk mitigation.

From the explanation above, it can be concluded that an effective mitigation of earthquake risks requires a dedicated European Research Structure.

8.2 European Research Structure

The structure proposed here is similar to the one used in the development of Eurocodes, in particular Eurocode 8, which has recently concluded its work with success. It involves two research levels, with one connection:

- One European Network of Expertise
- In each country, one national "mirror" Network of Expertise
- One "liaison" person between the European and the national Networks

The European Network of Expertise would be in charge of:

- leading research
- making scientific breakthroughs in all aspects of earthquake risk mitigation
- proposing European scientific procedures needed in earthquake risk evaluation
- creating and maintaining a website dedicated to the deliverables of research work

The European Network of Expertise would be led by a "Top Lead Unit" composed of 2 persons: one Chairman, one vice chairman. The European Network of Expertise would be composed on the basis of the scientific-research excellence proved through international qualification criteria (publications, available man-power etc). The same applies to research infrastructures: for the efficiency of the research activity, research infrastructures of experimental and numerical-analytical natures are of prior importance. They should be part of the aforementioned evaluation of a research group. Groups would be formed to cover focused topics such as: seismology, evaluation of buildings vulnerability, new design, etc. Each research group would be driven by one lead person or "coordinator". The partners in the group would be members from EU top research units working on the focused subject. In a research project, periodic meetings with 1 "liaison" representative for each nation would be organized.

For dissemination purposes, each project would have to produce as deliverables two books. One book would be a "Guide for Application"; it would describe the practical output. The second book would be a background document which reflected in an extensive way the details of the research work and the options taken to define the content of the Guide for Application.

The research activity at the European Network of Expertise level would be funded by the EC's DG-RTD in long duration projects of at least 6 years, with negotiation and competition for renewal before the end of projects so as to ensure continuity. This would avoid the present "stop and go" situation, in which lead researchers have to seek for funding, with periods of one and a half to two years of inactivity between the end and the start of a new project, often with very different goals and objectives. The "Top Lead Unit" would be funded for the general management of research and would overview all the projects in the European Network of Expertise.

National "mirror" Networks of Expertise would be in charge of national implementation of European research output and European agreed procedures in earthquake risk evaluation. It is proposed that they would be collaborative units joining public research institutions (Universities and research institutions), industry (designers, construction companies) and Public Authorities. The existence of these national “mirror” Networks is justified by the fact that several research aspects of earthquake mitigation require calibration taking into account national characteristics: seismic action, sites effects, peculiarities of building practice (materials, composition of walls, etc…). This activity can best be achieved at a national level. It has a feature of “application” of research and corresponds to less sophisticated developments than those made at the European Network level, but the activity remains research, due to its very specialized content. National Authorities would be required to set up those “mirror” groups so that the various national entities do cooperate in order to realize the “chain” of competencies at a national level, which is often missing.

The research activity at that level would be funded on a national basis in the framework of a EU-Member State Cooperative Research Agreement, by which a country commits itself to bring the “mirror money” necessary for the implementation of European agreed evaluation procedures related to the mitigation of earthquakes risks. Funding at national level would thus run in parallel to EU funding in long duration projects of at least 6 years.

8.3 Definition of the Research Agenda

A distinction must be made between problems related to the existing building stock and problems related to new constructions. For seismic risk mitigation related to new constructions, a close cooperation with the industry (i.e. ECTP) is necessary from the scientific and R&D point of view. The role of each part must be specified. Fundamental research should not be marginalized. Applied engineering oriented R&D and fundamental research should be well balanced. Development of innovative techniques and methods to improve the seismic performance of buildings, infrastructures (and their components) and integrated approaches in a city or/and network scale are of prior importance.

For seismic risk mitigation related to the existing building stock, cooperation with public authorities of Member States should be conducted in order to define expectations and goals. This is necessary:

- to check that a seismic risk reduction is really intended in a given country
- because the funding scheme explained above involves national contributions, which requires a national motivation
- because the implementation of any type of measures in a country will necessarily go through national channels.

A tentative list of subjects needing further research at a European level is shown in the roadmap of Chapter 7. For earthquake risk reduction studies, the priority should be established considering, among other things, the expected reduction in uncertainties brought by a specific research development, in comparison with present state of the art; subjects bringing the highest reduction in uncertainty being given priority.

8.4 Administrative Management

In comparison to FP6 and FP7, the administrative work of research projects should be reduced, in order to maintain conditions of "manageability". EU funded projects should respect the following requirements:

- the maximum number of partners in a project (= research group) should be 6.
- 1 technical report/year/partner is required; it should be sent to the project coordinator.
- 1 activity report/year is required; it should be prepared by the project coordinator and sent to the EU Officer and to the "Top Lead Unit"; it should be presented by the project coordinator to an evaluation committee; national "liaison" persons and "Top Leaders" would attend that meeting to be informed of work progress and to discuss issues.
- 1 cost statement/year would be established by each partner and sent to the project coordinator, who would gather them and send them to the EU Officer.
- The planning of a project would be defined at the submission stage. There would be no requirement to revise each year the original planning. A revision of the planning revision might be asked by the coordinator, with justifications.
- Deliverables of the project would be defined at the submission stage (content + delivery date); no milestone definition and no yearly compulsory updating of deliverables would be required.
- The final report of the Project would be constituted by the deliverables. It may be approved or not approved by the evaluation committee. Justifications and requirements for improved versions would have to be explicit. The improved documents would have to be delivered within 6 months from the evaluation committee meeting.

8.5 Project Results Dissemination

Each Project would have to produce as deliverables, at least:

- Two books/EU funded projects. One book would describe the practical output, the way to use the results in practical application; it would be a "Guide for application". The second book would be a background document which reflected in an extensive way the details of the research work and the options taken to define the content of the Guide for application.
- One report on nationally funded projects

These books & Reports will be accessible on the "European Network of Expertise" website for free download, and as books edited in official and unified presentation with EU funding support.

Besides these channels, access to information should take place in conference and journal papers. To increase dissemination, DG-RTD could support the promotion of education in earthquake engineering by pushing the development of an agreed European curriculum at the "Master" level (using the Bologna system). Thereby a wide dissemination will be achieved by Universities, Schools of Architecture and professional Associations in charge of higher and continued education. Success at exams in the curriculum will result in a "European Seismic Certificate" which should be made compulsory for designers making projects in seismic zones.

8.6 Enhancement of Cooperation with the International Research Community

- It is essential to develop good links with top research teams at international level:
- to inform European research about developments in countries with high levels of advancement in earthquake engineering research
- to avoid duplication efforts
- to find better routes to the application of research results
- Cooperation with the international research community will be enhanced:
- By allowing the use of part of the projects funds for participation in International Forums, Conferences and Workshops bearing on specific topics directly related with the research project.
- By funding grants to allow EU researchers to work in foreign Institutions (e.g. Japan, US, New Zealand) where research of international excellence is carried out

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IRIS, Integrated European Industrial Risk Reduction System

NERA, Network of European Research Infrastructures for Earthquake Risk Assessment and Mitigation

SERIES, Seismic Engineering Research Infrastructures for European Synergies

SHARE, Seismic Hazard Harmonization in Europe

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Abstract

The present deliverable contains the Exploitation Plan of the project, which is represented by the European Strategic Research Agenda on Earthquake Risk: Vision and a Strategic Research Agenda, a roadmap for implementation.

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As the Commission's in-house science service, the Joint Research Centre's mission is to provide EU policies with independent, evidence-based scientific and technical support throughout the whole policy cycle.

Working in close cooperation with policy Directorates-General, the JRC addresses key societal challenges while stimulating innovation through developing new standards, methods and tools, and sharing and transferring its know-how to the Member States and international community.

Key policy areas include: environment and climate change; energy and transport; agriculture and food security; health and consumer protection; information society and digital agenda; safety and security including nuclear; all supported through a cross-cutting and multi-disciplinary approach.

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