Network of European Research Infrastructures for Earthquake Risk Assessment and Mitigation

Final Report

Seventh Framework Programme
EC project number: 262330

Executive summary

The overall aim of NERA was to achieve an improvement and a long-term impact in the assessment and reduction of the vulnerability of constructions and citizens to earthquakes.

To accomplish this, NERA integrated the key research infrastructures in Europe to monitor earthquakes (ORFEUS, EMSC) and to assess their hazard and risk (EFEHR), and combined expertise in observational and strong-motion seismology, modelling, geotechnical and earthquake engineering to develop activities to improve the use of the above infrastructures and facilitate the access to data.

NERA ensured the sustainable provision of high-quality data and transparent services, including rapid access to earthquake data and parameters and to hazard and risk products and tools. NERA coordinated with other EC projects (SHARE, SYNER-G) a comprehensive dissemination effort. NERA contributed to the OECD GEM program and to the EPOS ESFRI infrastructure.

NERA created a sustainable portal (www.seismicportal.eu) for all users of information related to earthquakes risk. It covers the entire subject from seismology to earthquake engineering and civil protection.

The NERA consortium consisted of 28 participants (European universities and research centres) executing 22 different activities: 1 Management Activity, 9 Networking Activities, 5 Joint Research Activities, 4 activities providing grants for Transnational Access and 3 specialised Service Access activities. A total of 75 project scientific reports was produced and at least 34 peer reviewed papers were published in scientific journals. NERA offered grants for Transnational Access to 43 researchers that resulted in 61 scientific results.

Summary description of the project context and main objectives

NERA (2010–2014) integrated key research infrastructures in Europe for monitoring earthquakes and assessing associated hazard and risk. The project aim was to achieve an integration that significantly facilitates cross discipline assessment of hazard and risk assessment and reduce vulnerability of constructions and citizens to earthquakes.

NERA's long-term objective was to integrate seismic and engineering infrastructures and thus establish an effective integrated network of European research infrastructures for earthquake risk assessment and mitigation.

NERA's strategy was to combine expertise in observational and strong ground motion seismology, modelling, geotechnical and earthquake engineering and information technology. Within NERA they developed multidisciplinary advanced infrastructures facilitating integrated data and product access and use of the data to a broad scientific public.

NERA activities took optimal advantage of developments within other relevant EC-projects and European and global initiatives, contributing among others to the ESFRI EPOS infrastructure and the OECD GEM program.

NERA was organised along a number of working packages/activities:
- Cooperative actions (Networking Activities),
- RTD actions (Joint Research Activities),
- Transnational Access to highly specialised research facilities

NERA integrates and facilitates the use of these infrastructures and access to data for research, provides services and access to earthquake data and parameters, and hazard and risk products and tools.

Description of main S & T results/foregrounds

The NERA project aimed at a measurable improvement and long-term impact in the assessment and reduction of the vulnerability of constructions and citizens in Europe to earthquakes. To accomplish this, NERA has a) integrated key research infrastructures monitoring earthquakes and accessing their hazard and risk, and b) improved the use of these integrated facilities and their data, by developing multidisciplinary tools and applications in observational and strong-motion seismology, modeling, geotechnical and earthquake engineering. NERA also provided and promoted access to high quality services providing earthquake data and parameters, hazard and risk products, and research grants for visiting and using specialized seismological and engineering research facilities.

The NERA consortium consisted of 28 participants, consisting of European universities and research centres. The 22 different activities comprises1 Management Activity, 9 Networking Activities, 5 Joint Research Activities, 4 activities providing grants for Transnational Access and 3 specialised Service Access activities. The scientific and technological work that was performed during the different activities is described in detail in 75 scientific reports (Deliverables) which are open for access: http://www.orfeus-eu.org/organization/projects/NERA

The main Scientific and Technology results are summarized below:

▪ European Integrated waveform Data Archive: EIDA

Access to seismic waveform data in the Euro-Med region has been expanded significantly through the establishment of EIDA within ORFEUS. This distributed but federated network of data archives in Europe integrates data archiving and access from permanent and temporary networks recording broad-band seismic data in the larger Euro-Mediterranean region, and expands the collection and storage of and access to data for the whole region. This also implies improving the data quality for research, optimizing technical interoperability, standardizing data collection, format and archive procedures, and quality control standards. Currently data from about 4800 seismic stations are openly available for the seismological and engineering communities through a common portal (www.orfeus-eu.org/eida; Figure 1).

Deliverables:

- *D2.1: Data archival for Europe and its surroundings: inventory, organization and implementation*
- *D2.2: Strategy document on EuroArray deployment*
- *D2.3: Automatic data QC and distribution statistics routines for data providers*
- *D2.4: Data quality improvement statistics*

Figure 1 – geographical distribution of seismic stations in and around Europe from which data is openly available through the distributed, federated data archive (EIDA; www.orfeus-eu.org/eida). Green triangles are permanent seismic stations, orange triangles are temporary stations and blue squares are the connected data archives.

▪ Rapid Raw Strong Motion (RRSM) and Engineering Strong Motion (ESM) databases

The collection and processing of acceleration data in the vicinity of an earthquake provides crucial information to the engineering community. NERA has been very successful in building a system to collect, process and distribute strong motion data from across Europe based on the existing infrastructure within ORFEUS EIDA. The key products are the RRSM (Rapid Raw Strong Motion) and the ESM (Engineering Strong Motion).

RRSM (http://www.orfeus-eu.org/rrsm; Figure 2) is an automatically produced strong motion database that takes advantage of the state-of-the-art in seismic network processing (EIDA) to provide rapid access to any openly available strong motion data and engineering parameters immediate after a significant earthquake in Europe. ESM is the high quality component of the European strong motion database consisting of high-quality (reviewed) strong motion data from both present and historical strong motion waveforms.

Deliverables:

- *D3.1: Exchange protocol for (near) real time parametric data*
- *D3.2: Guidelines for station and instrument response database integration, station metadata update tool*
- *D3.3: Dedicated acceleration network integration meeting*
- *D3.4: Methodology and open-source software for strong-motion data processing and estimation of ground-motion parameters*
- *D3.5: Station book compilation*
- *D3.6: Dedicated acceleration network integration meeting*

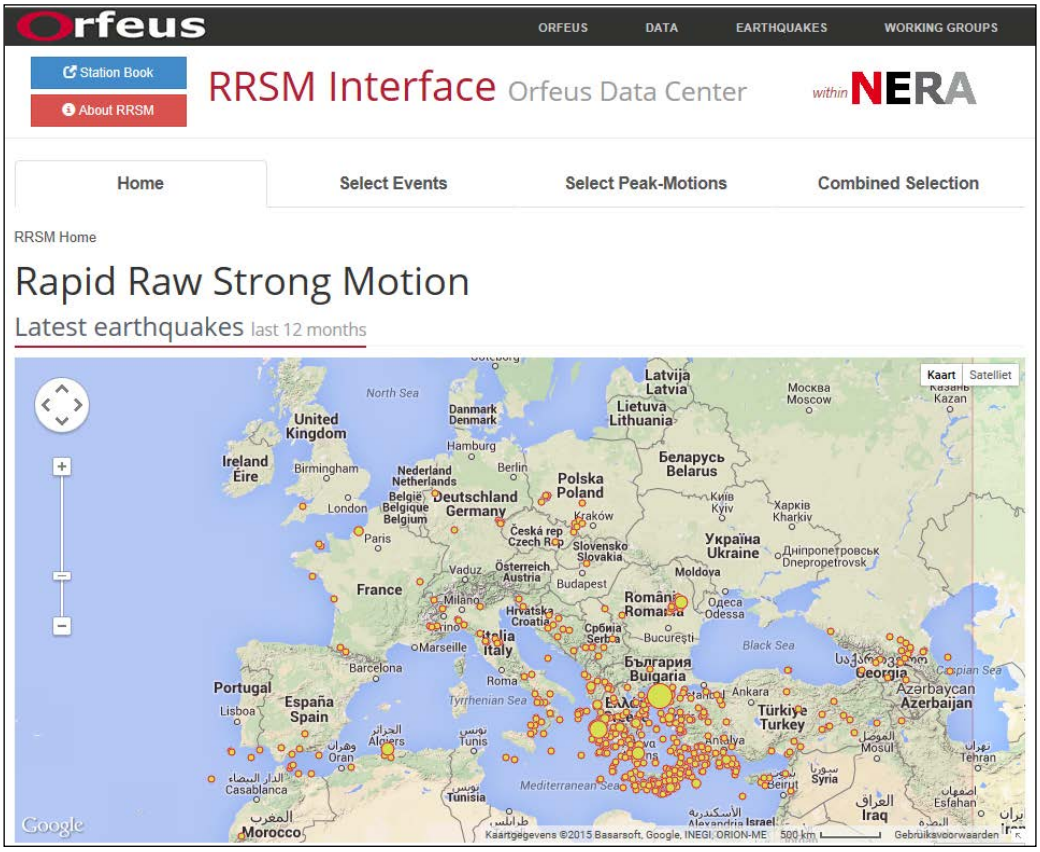

Figure 2 – Web-interface to the Rapid Raw Strong Motion database. The database contains engineering parameters (PGA, PGV, spectral values, ShakeMap XML input files)and is filled automatically after an earthquake alert by the EMSC by collecting waveform data (through EIDA) from relevant seismic stations nearby the earthquake location. The underlying software to fill the database is based on SeisComP3 and the waveform processing module 'scwfparam' to automatically retrieve the engineering parameters.

▪ Waveform data quality monitoring system

Quantification of waveform data quality is an emerging, important challenge for the seismological community. The rapid growth of data archives, the distributed system of data archives throughout Europe and the demanding requirements by users willing to explore the huge amount of data in Europe by novel processing techniques require a smart system to discover data based on a variety of quality measurements. Within NERA a system was developed and implemented for parameterizing waveform data by a set of quality parameters which can be used a) for real-time interaction with network operators to optimize overall data quality and b) by scientific researchers to discover and harvest high quality data. The new system is based on webservices (http://www.orfeus-eu.org/man/odcws_wfmetadataselect.html) and offers the user a tool for searching and downloading high quality data based on dynamic (user specific) requirements.

Deliverables:

- *D2.3: Automatic data QC and distribution statistics routines for data providers*

▪ **Common European strategies for temporary deployments**

Within NERA a common European strategy for temporary deployments has been developed for large scale, complex, cross border temporary experiments incorporating permanent stations, OBS and mobile land-based equipment. A strategy plan for the AlpArray was prepared and well embedded. Also a common implementation policy was developed for rapid network deployments after an earthquake, consisting of a core group forming the European Rapid Response network (ERN; http://nera-ern.gfz-potsdam.de). To facilitate this core group an ERRN portal was developed to guide the rapid deployments. Data from different, successfully organized, swarm and aftershock sequence missions have been added to EIDA.

Deliverables:

- *D4.1: ERRN implementation policy and deployment*
- *D4.2: Guiding tool for deployment of joint rapid response networks*
- *D4.3: Metadata and data availability report*
- *D4.4: Report on ERRN deployments during the project*

▪ **Near-Fault Observatories Network (NFO)**

The seismic hazard generated by fault zones slipping in large earthquakes and the need for mitigating risk to population and structures drive the pursuit to understand the physics of faulting and the near-surface response to shaking. To facilitate research into the faulting process and its effects, near-fault observatories (NFO) comprised of dense, multidisciplinary geophysical networks have been constructed in many European fault zones. These NFOs have collected a wealth of data and represent an infrastructure of great importance for research into the faulting process and near-fault site effects.

In NERA, six European NFOs have been networked. The fault zones represented by the observatories are in different tectonic regimes: The South Iceland Seismic Zone (SISZ) in Iceland, the Marmara Sea in Turkey and the Corinth Rift in Greece are at plate boundaries, with strike-slip faulting characterizing the SISZ and the Marmara Sea, while normal faulting dominates in the Corinth Rift; the Alto Tiberina and Irpinia faults, dominated by low- and medium-angle normal faulting, respectively are in the Apennine mountain range in Italy; the Valais Region, characterized by both strike-slip and normal faulting is located in the Swiss Alps. The fault structures range from well-developed long faults, such as in the Marmara Sea, to more complex networks of smaller, book-shelf faults such as in the SISZ. All the fault zones can generate large earthquakes ($M \geq 6$) posing substantial earthquake hazard and two of them, Marmara and SISZ have experienced earthquakes of $M > 7$. Two of the zones, Marmara Sea and Corinth, are under an ocean causing additional tsunami hazard and steep slopes and sediment-filled valleys in the Valais give rise to hazards from landslides and liquefaction. Induced seismicity has repeatedly occurred in connection with geothermal drilling and water injection in the SISZ. The active volcanoes flanking the SISZ also bring the added dimension of volcano-tectonic interaction.

Within NERA the foundation was made for the establishment of standards within a multidisciplinary NFO. Real time data flow into EIDA from at least one NFO has started.

Deliverables:

- *D5.1: Inventory of operational near-fault observatory networks and data*
- *D5.2: Near fault observation systems networking and communication protocols*
- *D5.3: Near fault observatory collaboration, integration and implementation*

▪ **Networking Field Testing Infrastructures**

In structural engineering 'field testing' indicates a large class of activities with the aim of improving the knowledge of existing structures and evaluating their actual conditions. This improved knowledge is the basis for an actual real-time assessment of either the remaining life time of structures or the seismic vulnerability of these structures. Field testing procedures in vibration monitoring techniques are crucial to collect this knowledge. Within NERA guidelines were made for optimal design of force vibration methods to facilitate building vulnerability assessment, with consensus on the application of state-of-the-art field monitoring technologies. These guidelines are directed to the engineering community with the aim of increasing the number of dynamic tests on structures to improve their seismic vulnerability assessment.

The guidelines introduce the problem of soil-foundation-structure interaction and propose the optimal design to investigate that interaction. Finally, the guidelines are completed by 18 different case studies to help the engineers to understand on how to implement the described methods. One pilot experiment (Figure 3) was done for an area (8th district) in Vienna to identify critical structures in that region and rank the buildings according to assessment priority for seismic vulnerability.

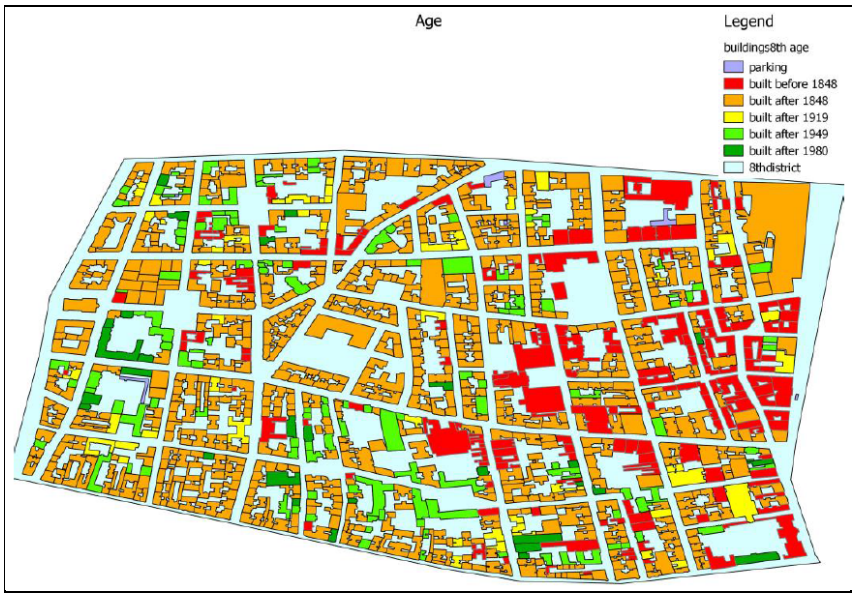

Figure 3: View of the classification of buildings in the 8th district of Vienna, with respect to the construction.

Deliverables

- *D6.1: Current status inventory of field testing infrastructures and existing approaches*
- *D6.2: Guidelines for designing optimal dynamic monitoring strategies*
- *D6.3: Guidelines for optimal design of force vibration method*

▪ **European Building Inventory Database**

Within NERA a database was implemented that describes the number and area of different European building typologies (e.g. unreinforced masonry bearing wall, non-ductile reinforced concrete moment resisting frame etc.) within each cell of a grid, with a resolution of at least 30 arc seconds (which is approximately 1 km square at the equator) for use in the seismic risk assessment of European buildings. The database structure of the Global Exposure Database, an initiative of the Global Earthquake Model (GEM), is being used to store the European building data following the European Building Classification and contains now data covering 45 European countries.

Building inventory data is available at different levels of resolution and characterisation across Europe (Figure 4). Thus one of the aims of the database is to produce both homogeneous levels of building exposure data as well as provide a place where detailed, high resolution data can be stored. For this reason, the Global Exposure Database has been designed with a number of different levels, which are split between three different databases. To enable new data collection techniques (e.g. crowd collection) the European building inventory data base matches GEM's Android Inventory Data Capture Tools schema.

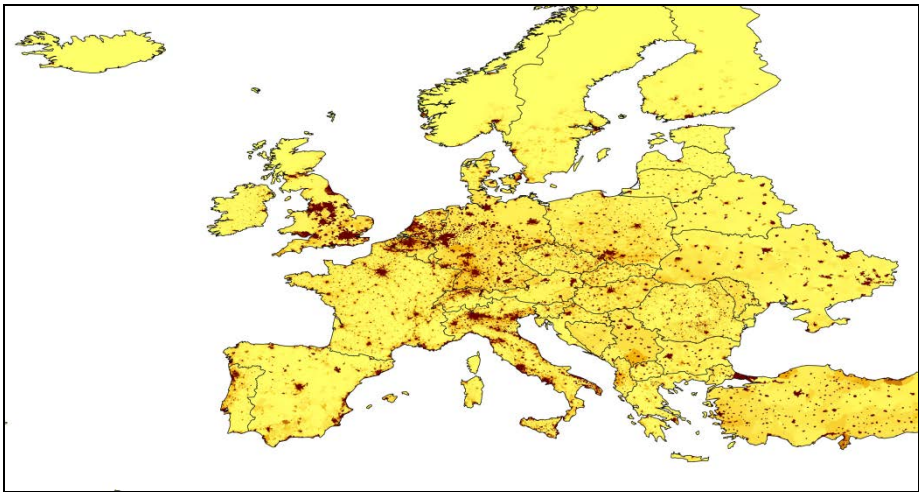

Figure 4: Map showing available building data inventory for 45 European countries to allow a 30-arc second grid of building count.

Deliverables:

- *D7.1: Identification of key players in European building inventory data collection*
- *D7.2: State-of-the-art knowledge of building inventory data in Europe*
- *D7.3: European building classification*
- *D7.4: European building inventory database*
- *D7.5: Census data collection and harmonisation for Europe*
- *D7.6: Long-term sustainability plan for the building inventory database*

▪ **Networking School Seismology Programs**

Across Europe scientists and educators have been discovering the power of using earthquakes and seismology as an educational tool to inspire and educate students in a wide range of science and geoscience topics. Within NERA this networking activity has been expanded to promote sharing of best practice and data between interested education groups in Europe, and to develop software for educational seismology.

NERA brought together educational seismology programs from across Europe, while new educational seismology programs started in Romania and Portugal. UNESCO had funded a global educational seismology network through collaborations fostered by the NERA program. A network of schools from UK, France and Italy has created a strategic collaboration within the ERASMUS+ project.

Teachers from across Europe had been invited to attend five-day workshops to learn all about educational seismology and to share their experience with each other. Support for teachers attending was provided by NERA and also the EU COMENIUS funding program.

Deliverables:

- *D8.1: Current school seismology activities*
- *D8.2: Webservice protocols used to transfer data between networks (webservice protocols)*
- *D8.3: Software tools for data exchange and analysis*
- *D8.4: Networking of school seismology groups across Europe*

▪ **Service Activities**

Three Service Activities (SA) were carried out in NERA to facilitate open access to data, models, tools and expertise in the scientific earthquake and engineering communities. Each SA is built on one of the three existing European infrastructures: EMSC, ORFEUS and EFEHR.

▪ Remote access to parametric data and earthquake products (http://www.emsc-csem.org)
This Service Activity, operated by EMSC, provides access to real time earthquake information, parametric data and earthquake products, and ensures coordination of seismological observatories practices at Euro-Med and global scales and serves various communities, academics, network operators and the public for operational and research use. Based on extensive data exchange, the SA activities include strong coordination with seismological observatories and global players such as ISC and NEIC/USGS as well as the definition of standard and policy on issues such as station coding system, nomenclature of seismic event type under the umbrella of the IASPEI.

▪ ORFEUS remote waveform data services (http://www.orfeus-eu.org)
This Service Activity operated by ORFEUS and ORFEUS Data Center provides (1) transparent access to homogeneous, quality controlled waveform data from the Virtual European Broadband Seismograph network (VEBSN) and the networked, distributed European Integrated waveform Data Archive (EIDA) by the scientific community, and (2) offers a broad range of efficient tools through different innovative forms of web services and standard internet services to search for high quality waveform data and related metadata. Within NERA this SA has opened access to data from more than 4800 seismic stations from about 80 permanent networks and 60 temporary networks. ORFEUS, one of the largest seismological organizations in Europe, strongly coordinates its activities with the FDSN (International Federation of Seismograph Networks).

▪ Remote access to earthquake hazard & risk products (http://www.efehr.org)
The European Facility for Earthquake Hazard and Risk (EFEHR), hosted at ETH Zurich, is designed as the sustainable community resource to facilitate access to data, models and tools for the assessment of seismic hazard and risk in Europe. The platform is evolving to a major infrastructure, similar to EMSC and ORFEUS, and is offering services relevant for the scientific and engineering communities as well as for the general public, stakeholders and decision makers. EFEHR is identified as the core of the 'Seismic Hazard and Risk' service pillar in the seismological core service structure of EPOS, and will be fully integrated in the EPOS structure as currently developed. EFEHR is the declared European regional center for the Global Earthquake Model (GEM) and will continue to host and/or provide access to relevant GEM data and tools.

The NERA Consortium has been working closely together with Working Group 1 "Seismological Observatories and Research Infrastructures" of EPOS. The vision on the integration of different infrastructure components and related services has been presented as a four-pillar structure representing the future European Seismological Products and Services. The SA virtual access services above are the first operational versions of three of these EPOS Seismology pillars: 'Waveform Data, 'Earthquake Products' and 'Hazard and Risk'. Within NERA the successful SA services are the outcome of collaboration and coordination by all WPs and have been integrated into the single, integrated seismic portal (next section).

▪ Earthquake Data Portal

One of the main goals within NERA has been the development of a common architecture to provide standard services to the scientific community to improve discoverability, access and usability of seismological, hazard and risk data and products. This has been achieved by the development and implementation of a single, integrated seismic portal (http://www.seismicportal.eu; Figure 5) and associated webservices. This achievement brings together waveform data and products (ORFEUS), earthquake data and products (EMSC) and hazard and risk (EFEHR).

The EDP portal (http://www.seismicportal.eu) and its underlying webservices are now fully operational with huge, demonstrated usage for seismology, seismic hazard and risk, and assessment of structural health of buildings. The EDP provides a single point of access to diverse, distributed European datasets and services, including (a) broadband, seismic waveform data and related metadata from the European Integrated waveform Data Archive (EIDA; www.orfeus-eu.org/eida) in ORFEUS (www.orfeus-eu.org), (b) earthquake parametric data from the EMSC (www.emsc-csem.org), (c) accelerometric data (waveforms and parameters) from European accelerometric networks, (d) waveform simulation and data-intensive e-science services by integrating distributed European public data and computing infrastructures, (e) the European Facility for Earthquake Hazard & Risk (EFEHR; www.efehr.org; Figure 6), (f) the Open Structure Assessment Portlet (OSAP; osap.faw.at), an online service for easy structural assessment of civil buildings and (g) private and historical data from the Archive of Historical Earthquake Data (AHEAD). The use of international standards and open software implies a sustainable framework enabling further expansion of data services.

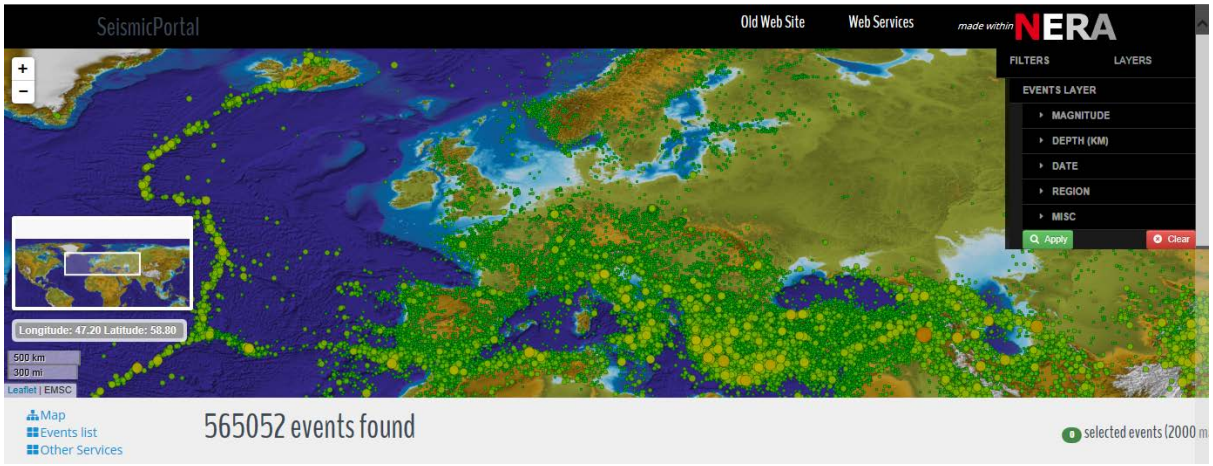

Figure 5: Earthquake Data Portal

Deliverables:

- *D9.1: Initial implementation and integration strategy report*
- *D9.2: Architecture specification for data workbench*
- *D9.3: User interaction specifications*
- *D9.4: Global coordination in portal and web services development*
- *D9.5: Integrated portal and services*

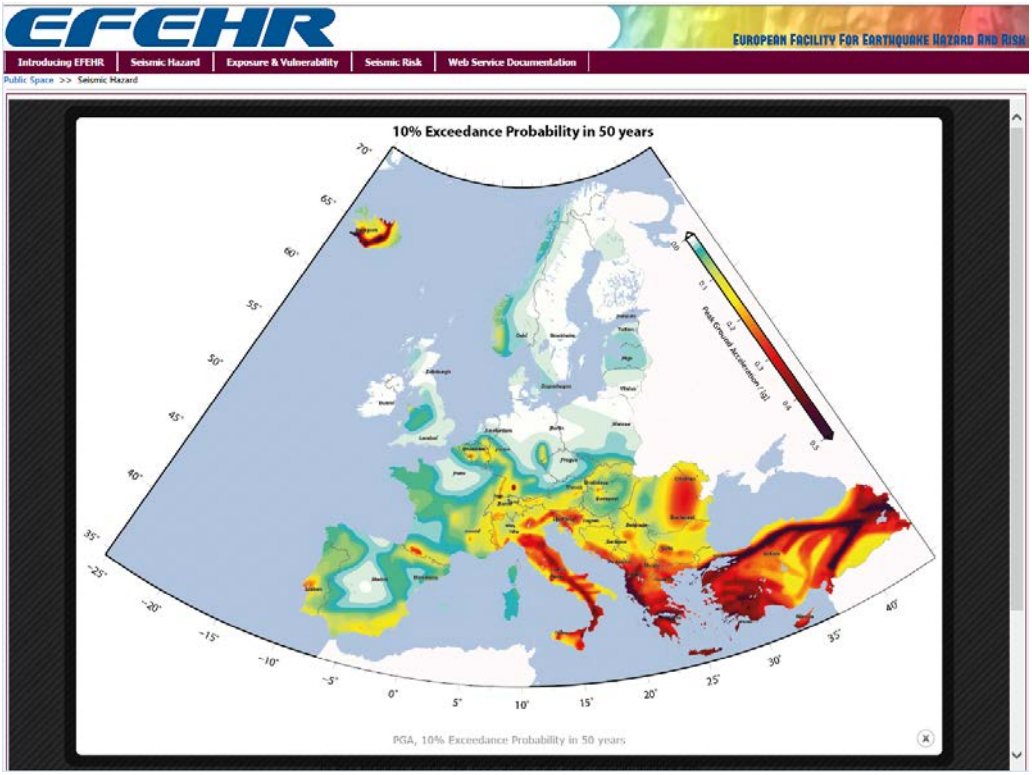

Figure 6: EFEHR portal - the European Facility for Earthquake Hazard & Risk

▪ Research on waveform modelling and site coefficients for basin response and topography

The effects of surface and subsurface geometry on seismic ground motion have been recognized for a long time, and have been the topic of many instrumental and numerical investigations over the last decades. Yet, their complexity, combined with the imitations of geophysical investigation techniques and numerical simulation as well, made it impossible till now to include such effects in earthquake mitigation and risk reduction policies: the vast majority of building codes do not include any provision for basin and surface topography effects. Within NERA, researchers build on recent advances and results from instrumental seismology, geophysical exploration and numerical simulation to propose physically sound, economically acceptable and relatively simple models to include proper accounting for the effects of surface and subsurface geometry in building codes.

Specific research was performed in NERA on quantifying the effects of (sub)surface geometry on seismic ground motion. Also, surface topography effects were studied by detailed geophysical investigations on two Italian sites (Narni Hills and Mt Ocre), both affected by the L'Aquila seismic sequence. Research on basin effects was done by analysis of temporary deployed, dense networks (Argostoli, Fucino basin). Finally, numerical simulations were done to calculate the effect of 2D geometry on a number of engineering parameters. .

Deliverables:

- *D11.1: Existing data sets meeting the JRA1 goals: conversion into common format*
- *D11.2: Review of recent data on surface topography effects*
- *D11.3: Geophysical surveys on a few sites: report and findings*
- *D11.4: Array measurements*
- *D11.5: Code cross-check, computed models and list of available results*
- *D11.6: Comparison between data and numerical models*
- *D11.7: Implementation plan*

▪ Tools for real-time seismology, acquisition and mining

Current advances of communication technology together with the advent of new and rapid ways to communicate at global scale affect the way seismological information is disseminated. This represents an important challenge to institutions and agencies in charge of seismic monitoring at a global, regional or national level. There is both a need for shortening the time delay between earthquake occurrence and the release of information, and in improving the accuracy of the analysis and thus the quality of the information being provided. The overall goal is to provide accurate and immediate information to respond to government agencies and the public and, similarly, to provide accurate earthquake parameter estimates to the seismologists. This whole process requires the implementation of innovative procedures that were developed for research purposes. Many of these additional procedures can add substantial information about the on-going phenomena and therefore improve our knowledge of the earthquake process and its effects.

A number of software tools was developed for this purpose to serve real-time data analysis and to facilitate data access within the NERA infrastructure: (1) Early-Est (Figure 7), a rapid real-time earthquake monitoring system with tsunami alert functionality, (2)MWFMNEAR, a tool for fast determination of magnitude and focal mechanism at local and regional scale, (3) SCARDEC, a tool for earthquake source parameter determination, (4) pyDTMT, a tool for time domain moment tensor determination and (5) msstatqc, a tool to determine quality parameters from raw waveforms.

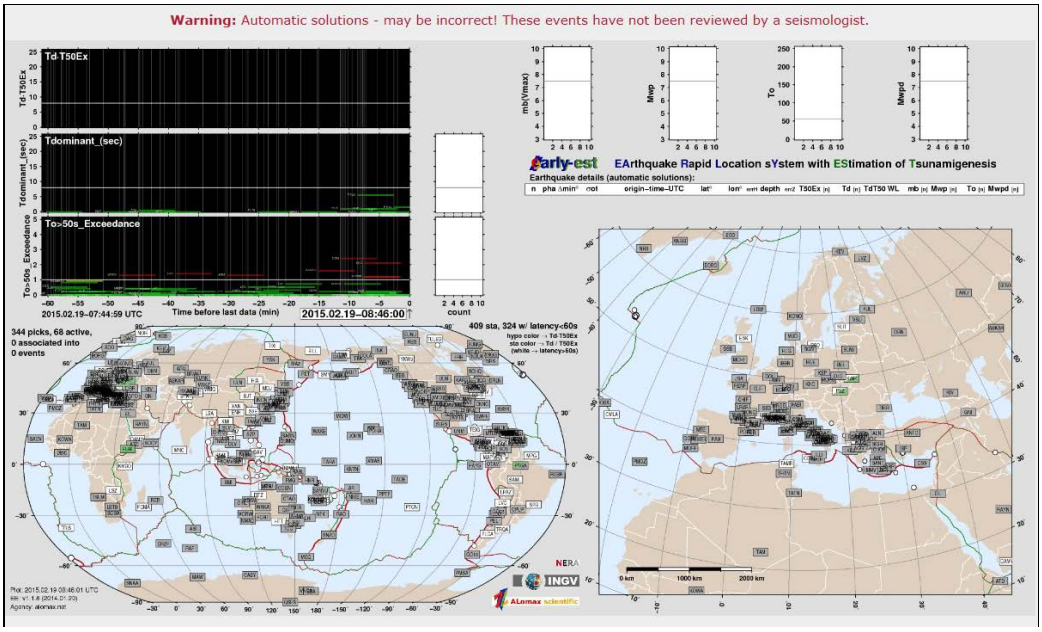

Figure 7: Early-Est - a rapid real-time earthquake monitoring system with tsunami alert functionality

Deliverables:

- *D12.1: Toolbox definition*
- *D12.2: Toolbox 2: seismic moment and earthquake size determinations*
- *D12.3: Toolbox 1: absolute and relative high-resolution relative earthquake locations*
- *D12.4: Toolbox 3: fast finite fault determination*
- *D12.5: Toolbox 4: shakemap*
- *D12.6: Toolbox 5: data quality control, pre-processing and integration*
- *D12.7: Implementation*

▪ Research on the coherence of near-fault ground motion spatial distribution and ground strain

Physics-based Ground Motion Prediction Equations (GMPE) provide a means of predicting the ground shaking at any given site or location, based on an earthquake magnitude, source-to-site distance, local soil conditions, fault mechanism, etc. GMPEs are required to estimate ground motions for use in seismic hazard analyses. Within NERA research have been directed to (1) numerical modeling of waveform propagation and frictional sliding to simulate the complexity of earthquake source (kinematically and dynamically) and near-source broadband ground motion (deterministic and stochastic), (2) the derivation of dynamic source parameters from real earthquakes and their scaling relations, (3) the investigation of the upper frequency limit of deterministic ground motion simulations. All with the final goal to quantify statistical properties of ground-motion variability and to propose physics-based Ground Motion Prediction Equations (GMPE) for engineering needs. The development of physics based ground motion models significantly improved through ground motion simulations with refined source and site models, assessment of nonlinear dynamic building response to simulated ground motion and experimental studies on short distance spatial variability of seismic ground motion. Studies of source complexity effects and oversaturation of ground motion very near the source are on-going.

Deliverables:

- *D13.1: Review on studies related to spatial variability of ground motion in the near field*
- *D13.2: Sub-set of near-source earthquakes records*
- *D13.3: New simulation schemes (high frequencies, moderate earthquakes, near-field)*
- *D13.4: Analysis of relative contribution of source, scattering and local site effects to ground motion..*
- *D13.5: Implementation report*

▪ Real-time seismic risk assessment and decision support

A tool to estimate real-time seismic risk assessment is available (Figure 8) and assessment of the progressive damage of buildings during a seismic sequence is implemented via a vulnerability model. This includes additional attenuation relations for hazard computations. During NERA two case studies were performed. A WebGIS application has been developed for users to perform and visualize damage scenarios for progressive damage during an earthquake sequence.

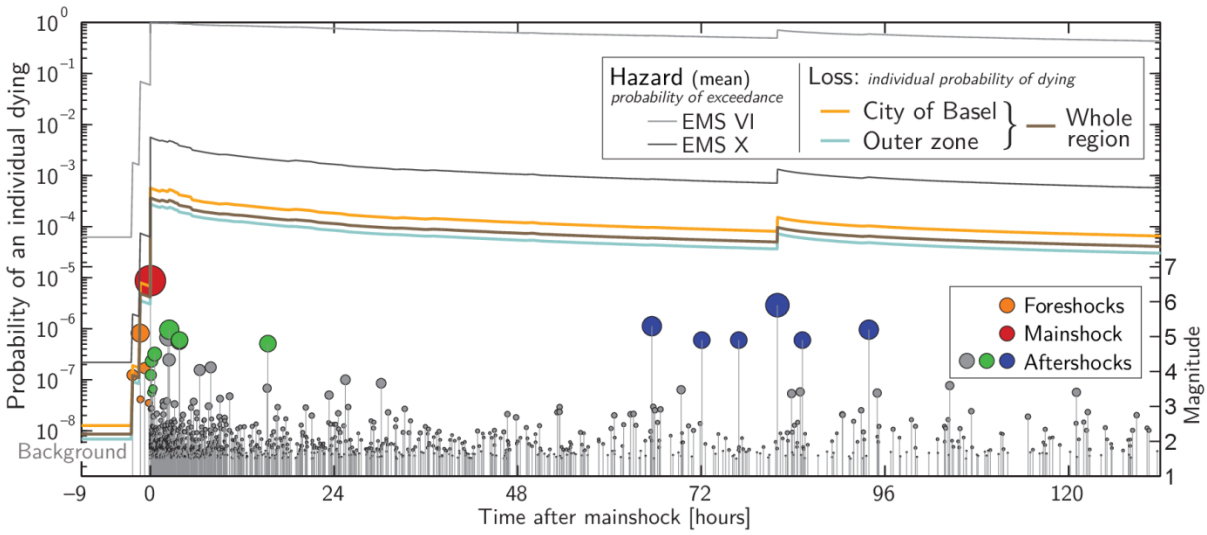

Figure 8: Example of time-varying probability of hazard and loss before and after an M6.6 event using information available at that time (retrospective).

Deliverables:

- *D14.1: State of art and user needs in real-time risk assessment and decision support*
- *D14.2: Updating of fragility functions of buildings after earthquakes*
- *D14.3: Guidelines for implementing real-time risk assessment during earthquake emergencies*
- *D14.4: Implementation*

▪ **Vulnerability assessment from field monitoring**

Because of missing information about the structural systems of historic buildings the vulnerability can be hardly assessed by traditional methods such as an inspection. Also the question of material parameters leads to problems. A combined numerical – experimental analysis is the most promising approach to assess these objects. Therefore in situ measurements (Figure 9) of brick-masonry buildings in Vienna, Istanbul and Bucharest were executed. Accelerometers placed on every storey on top of each other were recording the impact of ambient and transient excitation. Evaluation of the recorded vibration response renders the dynamic parameters such as natural frequencies and mode shapes. With these data the computer simulation was updated and the differences between the model and reality could be minimized.

A harmonized method for fragility assessment using field monitoring data was worked out and made ready for application. Tools for deriving fragility functions using field monitoring data have been developed, are available, and have been tested for several cases. A framework for seismic risk assessment and application to Europe is available which is a major step in harmonization and progress in this community.

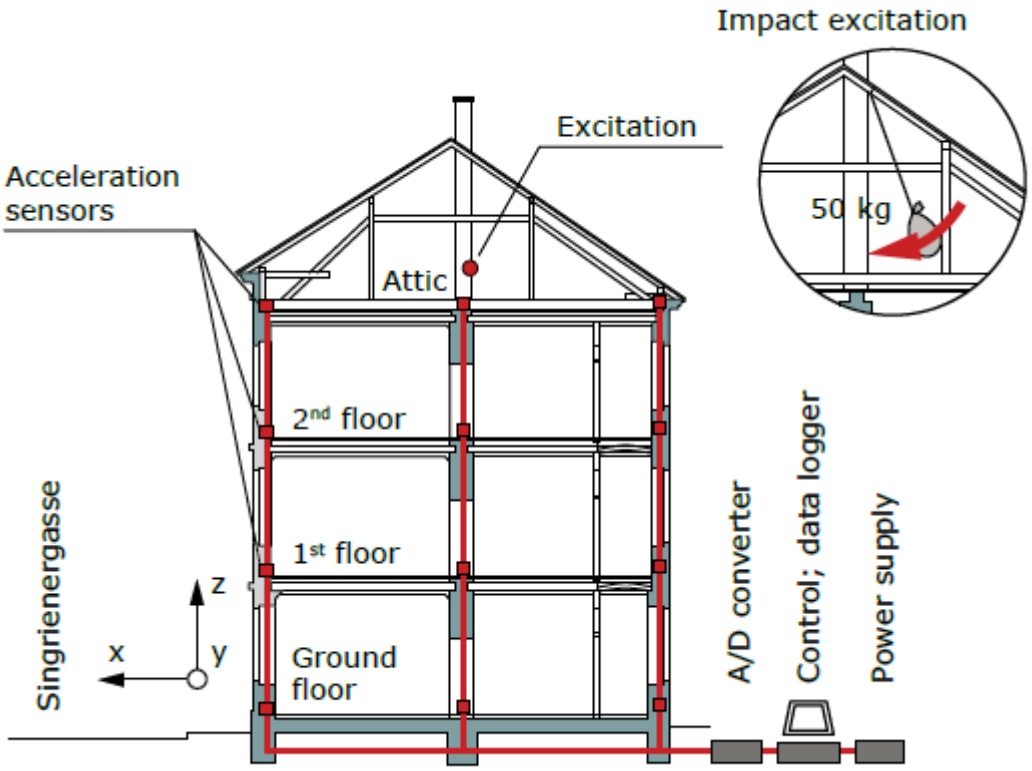

Figure 9: schematic view of in-situ monitoring configuration to record the impact on the building structure of ambient and transient excitation

Deliverables:

- *D15.1: Developed integrated field monitoring technologies*
- *D15.2: Data collected for common European building typologies using field monitoring technologies*
- *D15.3: Socio-economic vulnerability relationship formulation*
- *D15.4: Structural fragility assessment using field monitoring data*
- *D15.5: Implementation*

Transnational Access

The Transnational Access (TA) to research infrastructures is a major component of NERA, giving participating visitors unique opportunities to widen their professional skills. In addition, it familiarizes researchers with working environments at different scientific institutions in Europe; it improves networking between European scientists and creates a base for a future cooperation in seismology.

The NERA Transnational Access Facilities (TAs) offer access to four selected infrastructures (Figure 10), which allow users from the scientific and technical communities inside and outside the NERA consortium to become familiar with technologies and innovative network operations, which are likely to become future standards; these include large structural monitoring (Bosporus bridge, KOERI), rapid response systems (Istanbul, KOERI), early warning networks (Bucharest, BREWS and Irpinia, ISNet) and seismic arrays (NORSAR).

The TA to the infrastructures was managed through a TA-User Selection Panel, composed by the four TA-activity leaders, the NERA Project Manager and two external specialists, in order to guarantee the best interaction/integration between the different proposed user projects and common quality of selection criteria during the whole project period. Major attention is given to new users at the different activities to support research networking and knowledge distribution within Europe; a critical evaluation criterion is the adherence to the NERA spirit and activities.

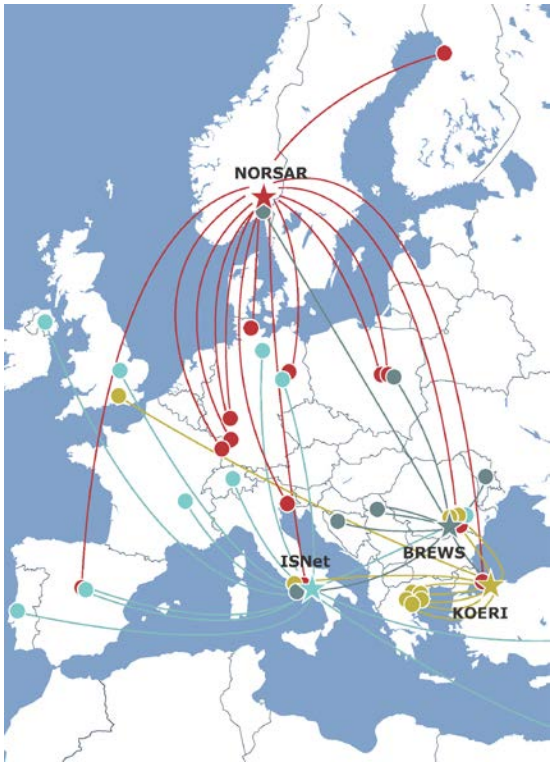

Figure 10: Geographical map showing the location of the four TA facilities and the affiliations of the TA visitors.

The TA grant opportunities have been broadly advertised in Europe, and 43 persons have taken advantage of the offered grants (15 female, 28 male). All TAs realised more than the proposed access, achieving altogether more than 65 visiting months (instead of the 63 proposed ones). To our knowledge until now, the scientific results of these visits have been or will be published in at least 15 scientific publications, 8 MSc theses, 2 PhD theses and 36 oral/poster presentations at national and international conferences, workshops and invited talks.

Description of the potential impact (including the socio-economic impact and the wider societal implications of the project) and the main dissemination activities and the exploitation of results

NERA delivers measurable, long-term impact beyond the present state-of-the-art in all steps leading to a correct assessment of seismic risk – in the definition of engineering requirements, in collection of input data, in their analysis, in procedures for hazard assessment, and in engineering applications – as well as long-lasting structural impact in areas of crucial societal and economic relevance. Focusing on the long-term impacts in random order:

A. Integration of key research infrastructures in Europe to monitor, assess and prevent earthquake hazards
NERA will have a profound long-term effect on the infrastructure panorama in Europe, bringing together the main classes of infrastructures covering different aspects of earthquake monitoring and hazard and risk assessment under a single program, as well as expanding the access to and collection of data. On the basis of the NERIES successful implementation, the NERA efforts expand the coverage to a wider range of infrastructures beyond the initial set chosen by NERIES, and to bridge between seismology and earthquake engineering.

B. Establishing one key element of the EPOS (European Plate Observing System) RI infrastructure
NERA contributes with two important elements to EPOS:
- Constructing a coordinated and broadly oriented seismological observational infrastructure, by integrating a wide diversity of seismological networks and data centers with ORFEUS as coordinating organization.
- Coordinating and implementing a seismological and earthquake engineering data service facility involving a distributed, but integrated, set of data archives, including innovative and standardized service facilities for the research community.

C. Reduction of vulnerability of European citizens and constructions to earthquakes
All the NERA activities are designed to contribute important tassels to the key long-term aim to reduce the vulnerability of European citizens and constructions to earthquakes. NERA produced the first complete building taxonomy and inventory for buildings of the whole Euro-Med region, established the methodology to better assess the corresponding vulnerabilities with field testing and to implement the collected data in risk assessment. NERA's strategic, wide-geographical coverage resulted in harmonization of procedures for monitoring and hazard and risk assessment and ultimately in a safer building-construction practice in the whole Euro-Mediterranean region. NERA has also issued some practical recommendations for changes in the definition of hazard in current EC8 provisions, and also gathered new, high quality, open, observational data and comprehensive sets of numerical simulations that open new directions for site-specific hazard assessment studies.

D. Capacity of civil protection authorities and society to react during an earthquake and in the post-earthquake and recovery period
NERA covers uniformly the critical phases in the earthquake cycle: long-term preparation, event (including short-time event preparation and post-event emergency) and recovery. All these aspects pose important challenges for our society and for the response of the authorities to an earthquake. We recognize that the physical prediction of earthquakes is not a target that can be explicitly pursued in

the immediate future and within the restricted implementation period of NERA, and that possibly we will never be able to reach. Nonetheless, the combination of approaches and the selection of near-fault observatories offer the most concrete possibility in Europe to date to initiate future coordinated efforts to collect new data and develop new knowledge that in the long-term might enable a better understanding of the physical processes leading to the earthquake initiation.

E. Harmonization of hazard and risk input, output, and assessment methodologies NERA built a framework for integration across disciplines, by involving participants, competences and experts spanning all fields from seismology to geotechnical engineering to earthquake engineering, and for integration across national borders, to compile earthquake data and assess seismic hazard and risk without the burden of political constraints and administrative boundaries. Authoritative community models began to be assembled, the tracks for a modern assessment of seismic risk to become the common European standard have been established, a long-lasting level of harmonization on a European scale instead of only national level. Among the highlights:

- a standardized approach to field installation, data collection, storage and distribution, and quality control was extended to all the sectors of observational seismology.
- a unified taxonomy and inventory for European building
- cross-border proposals for changes in the EC8 provisions and guidelines for site-specific hazard assessment procedures
- overall progress in waveform modeling and parameter extraction by developing codes and applications found immediate application in all seismological agencies and serve as basis for future projects.

F. European participation in the Global Earthquake Model program initiated by the OECD
Important elements of NERA are integral components of GEM, the most comprehensive program in global risk assessment ever proposed. Specifically:
- The European hazard component of GEM, covered by the SHARE project, is being integrated within the common infrastructure portal.
- The assessment of system vulnerability and associated risk, covered by the SYNER-G project, is being integrated within the common infrastructure portal.
- The first comprehensive classification and inventory of European buildings to be accomplished in NERA, is in full alignment with the global inventory initiated by GEM in 2010, but will maintain the granularity and specificities appropriate for Europe.
- The NERA-EFEHR Service Activity, is the European component of the GEM Global Model Facility delivering harmonized assessment of seismic hazard and risk.