STARTPAGE

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PART B

AUTOMATED REAL-TIME ANALYSIS OF BROADBAND SEISMIC DATA IN THE AZORES-GIBRALTAR REGION

"ART-SEIS"

Table of Contents

B1 SCIENTIFIC AND TECHNOLOGICAL QUALITY

B 1.1. Scientific and technological quality, including any interdisciplinary and multidisciplinary aspects of the proposal

Project ART-SEIS has four objectives:

Objective 1 – To develop a seismic system that will allow rapid response (RR) to earthquake disasters in Portugal by rapidly computing the earthquake location, magnitude, style of faulting and maps of ground shaking (shakemaps).

Objective 2 – To implement a set of algorithms for high-quality estimate of earthquake parameters (hypocenter, magnitude and centroid moment tensor (CMT)) taking into account the specific geographic situation of Portugal.

Objective 3 – To investigate and implement procedures that reduce the operational costs of the seismic networks using the available technologies (cheap and effective data transmission, automation of routines, etc.) in order to render its operation sustainable in time.

Objective 4 – To advocate and promote the implementation of the solutions identified and developed in the project by the national authorities, in the scope of the recently created National Geophysical Network (RNG).

The overall rationale of the project is to contribute to the mitigation of seismic risk through effective and sustainable seismic monitoring, allowing for near-real-time earthquake-information after an earthquake, to assist rapid response in case of disaster. The project will take advantage of the new research infrastructures of the National Geophysical Network of Portugal (Rede Nacional de Geofisica – RNG).

On short time-scales, earthquake damage mitigation relies on post-earthquake-nucleation strategies. Two types of strategies are nowadays actively pursued: early warning (EW) and rapid response (RR). EW systems aim at detecting earthquakes in an early stage and providing alerts to regions before they are hit by strong and damaging shaking. In opposition, RR systems do not provide alerts, but rather aid in the rapid and efficient recovery from the catastrophe state that follows a big earthquake. RR systems quickly compute the earthquake's parameters (e.g., epicenter, magnitude, style of faulting, map of ground-shaking) after the earthquake is over and disseminate the results to relevant agencies. The information provided by RR systems is vital for the quick recovery of lifelines, to determine the expected location of aftershocks, and to help emergency teams, governments, private institutions and Earth scientists, among others, define their strategies.

Our first goal is to develop a seismic system that allows for RR to take place in the Portuguese territory. Several European groups currently report on earthquakes that occur in the Euro-Mediterranean region (EMSC, ETH Zurich and GFZ Potsdam) (van Eck et al., 2004). However, these groups take several tenths of minutes to compute earthquake parameters for events that occur outside their regional networks, as they need to collect data from a number of institutions (e.g., ETH Zurich reports on earthquakes approximately 90 minutes after their occurrence (Bernardi et al., 2004)). Also, the quality of the results that these groups obtain for earthquakes in Portugal and offshore Atlantic is limited, given that their data coverage is not ideal. An effective RR system in Portugal must rely on the regional Portuguese seismic network. Regional networks can be connected in very efficient ways, thus allowing for a rapid determination of the earthquakes' parameters (typically less than 15 minutes). Also, regional networks have a density of instruments appropriate for the detection of moderate and small events. Regional RR systems have been in place around the world for almost two decades. However, no such system is yet implemented in Portugal and surrounding seas. The seismic system we propose to develop will rapidly determine earthquake locations, magnitude and style of faulting (centroid moment tensor – CMT), and produce maps of

ground-motion (shakemaps). In addition, the system will contribute near-real-time information on offshore earthquakes to NEACMTWS (Tsunami Early Warning and Mitigation Systems for the North-Eastern Atlantic, the Mediterranean and Connected Seas, led by the Intergovernmental Oceanographic Commission of UNESCO). This project will interact significantly with the on-going European projects NERIES (Network of Research Infrastructures for European Seismology, FP6, http://www.neries-eu.org) and SAFER (Seismic Early Warning for Europe, FP6, http://www.saferproject.net/index.htm). It should be underlined that we do not intend to build a rapid response system to issue alerts, solely to develop the necessary technology that the competent authorities/institutions may use.

Our second goal is to develop a more elaborate set of automatic algorithms for high-quality earthquake locations and CMT solutions. Earthquakes in mainland Portugal are typically moderate to large. Offshore earthquakes have the potential to be very large due to the Eurasia-Africa plate boundary, which lies about 100 km away from southern Portugal (Serpelloni et al, 2007). The reliable characterization of offshore seismicity is an important but challenging task given the geographic limitations (location and shape of the country) and the sparsity of the seismic network (even though the Portuguese network has just been extended, it is still sparse. Within the scope of the Comprehensive (Nuclear) Test Ban Treaty (CTBT) a number of methods were recently developed to optimise earthquake locations with sparse networks. In particular, some of these methods are aimed at locating earthquakes that occur outside the limits of the sparse network. Dreger et al. (1998) studied earthquakes in California and concluded that sparse networks can accurately determine locations and CMT solutions for events with M>3.5-3.7 that take place 250–500 km outside the network. Meyers and Schultz (2000) applied Bayesian kriging to teleseimically constrained calibration events to improve earthquake locations with a sparse network. Ubiquitous sources of error in earthquake locations are uncertainties in the material structure (and consequently in the Green functions). Non-linear algorithms have the ability to handle those uncertainties in a probabilistic manner (Lomax et al., 2000). Husen et al. (2003) recently applied probabilistic earthquake locations to improve a map of seismicity for the Alps. We will consider these approaches to improve the results of our network.

The third goal of this project is to render the seismic network sustainable in time by reducing its cost of operation. The automation of most procedures (related to the first goal) will contribute significantly to a cost-efficient network. Data telemetry (VSAT) will be based on state-of-the-art technology that makes use of "cheap" and robust satellite links. This technology will be developed at the host institution (IST), under the scope of FP7-ENV-2007-1 Project MIA-VITA (Grant Agreement 211393, starting Summer of 2008).

This project will provide the basic science rationale for a seismic rapid response system in Portugal; however, the implementation of such system itself is out of the scope of the project. Our last goal is to promote the strategies and solutions found by this project near the responsible institutions (Instituto de Meterologia – IM and Laboratorio Nacional de Engenharia Civil – LNEC). Throughout the duration of the project the results will be transmitted to IM and LNEC as soon as available.

B 1.2. Research methodology

The Portuguese government recently invested in the upgrade and augmentation of the Portuguese seismic network (section B3.1.), with the deployment of two very broadband (VBB) networks (operated by IM and by the host institution IST, FCT contract REDE/1523/RNG/2007) and one strong-motion network (operated by the host institution IST, FCT contract REDE/1524/RNG/2007). We will take advantage of the newly available data to characterize the

seismicity in Portugal and offshore Atlantic. Specifically, we will use for this pilot study the VBB network NAVIGATORS and the strong-motion network SEISNETg (section B3.1.). NAVIGATORS comprises six stations, located in the north (Porto), center (Coimbra) and south (Lisboa) of the country, in the Terceira Island (Azores), in the Island of Madeira, and in the south of Morocco.

B 1.2.1. Rapid determination of earthquake parameters

Celerity lies at the heart of any real-time seismic system: earthquakes must be quickly detected; data must be immediately transferred to an analysis centre; the operating algorithms and host computer(s) must be fast.

All the stations of the NAVIGATORS network will transmit data in real-time to the lab via satellite (VSAT technology). This new technology allows for robust data transfer independent of land issues that may occur in case of large and damaging earthquakes (e.g., disrupted phone lines or internet connections). VSAT telemetry is also ideal to provide network redundancy. The telemetry strategy includes selecting adequate technology, optimising the network architecture, and bandwidth sharing. This high-performance telemetry technology will be developed at IST under the scope of FP7-ENV-2007-1 Project MIA-VITA (Grant Agreement 211393, starting Summer of 2008).

The NAVIGATORS network is presently being deployed with SeisComP2.5 software (developed by GEOFON/GFZ Potsdam and ORFEUS, Hanka et al, 2000). The task of SeisComP is six-fold: 1) data acquisition; 2) data recording; 3) monitoring and controlling; 4) real-time communication; 5) user access and 6) automatic (near-real-time) data processing (quality control, event detection and location). SeisComP will provide a first set of near-real-time analysis tools.

In a second stage we will improve the real-time seismic analysis by taking into account the specifics of the Portuguese network (time of arrival of data at the lab, geometry of the network, uncertainties in velocity structure, etc). In order to improve the real-time tools we will take advantage of insights gained from the experience with non-real-time, more reliable algorithms for location of earthquakes and CMT solutions (section B.1.2.2). The final version of the real-time tools will include the periodic re-computation of the earthquake's parameters as more data comes in from "friend networks" (i.e., other neighbour networks that share their data in real-time).

We will also implement software that quickly produces shakemaps, i.e., maps of ground shaking. For this purpose we will use the data collected by the strong-motion array managed by IST (section B.3.1.). All the new strong-motion accelerographs (SEISNETg network) will transmit to IST in real-time via ADSL internet connections. The FP6 project NERIES is currently working on the development of shakemaps for Europe; we plan to interact closely with NERIES.

Contacts are underway with the British Geological Survey to include the results of project ART-SEIS in a future (under discussion) regional tsunami warning center for the North Atlantic (Luckett et al., 2008). Similar availability will apply if the center is based elesewhere.

B 1.2.2. Accurate (non-real-time) determination of earthquake parameters

We will implement non-real-time algorithms that generate high-quality earthquake locations and CMT solutions. The goal of using advanced and reliable algorithms is two-fold: 1) to obtain accurate earthquake locations and CMT solutions that will serve research purposes (e.g. better understanding of the regional tectonics, seismic processes, etc.); and 2) to gain insight into the best procedures specific to the NAVIGATORS network and the regional Portuguese network. One of the methods that we will examine is the use of Bayesian kriging to teleseismically-constrained events to calibrate the location algorithm (Myers and Schultz, 2000). This method has proved to ameliorate locations performed by sparse networks. We will also study the effect of uncertainties in

the velocity structure using non-linear approaches (e.g., Lomax et al., 2000; Husen et al., 2003). We will study the impact of using different norms, multi-phase picks, etc. We will also conduct studies on the optimal locations for the deployment of new seismic instruments that may be critical to improve the performance of the Portuguese seismic network itself. These high-quality studies should help us define which features on the earthquake characterization methods are most important given the specifics of the NAVIGATORS network. When feasible, those features will be imported into the real-time procedures. Thus, this optimisation study feeds-back into the real-time processing (section B.1.2.1.).

One of main goals of ART-SEIS is to reliably characterize earthquakes that occur offshore, which have limited data coverage. In order to validate our results we will crosscheck our results with those obtained by other agencies (e.g., IM, ING, IAG). In particular we will compare the locations and CMT solutions for earthquakes that occur outside the NAVIGATORS network but which are well covered by other networks. In those cases, we will take the locations obtained by other networks as ground-truth to estimate the error of our results. We will also crosscheck the results obtained by our two sets of algorithms (real-time and non-real-time).

B 1.2.3. Reduction of operation costs

The main strategies to follow envisioning cost-reduction are the automation of analysis procedures (section B.1.2.1) and the adoption of VSAT telemetry for data transfer. The technology for "cheap" and robust VSAT telemetry is currently being developed at IST (FP7-ENV-2007-1 Project MIA-VITA (Grant Agreement 211393, starting Summer of 2008) and strongly relies on bandwidth sharing. VSAT telemetry will also ensure network redundancy.

B 1.2.4. Integration of the solutions at a national scale

Lastly, we will encourage the competent national institutions, namely the Instituto de Meteorologia (IM) and the Laboratorio Nacional de Engenharia Civil (LNEC), to take advantage of the products generated by this project to improve the performance of the Portuguese seismic network, as well as to improve preparedness and rapid response to earthquake disasters. Contacts with IM and LNEC are already underway.

B 1.3. Originality and innovative nature of the project, and relationship to the 'state of the art' of research in the field

At the present time there is no automated real-time procedure in place for the detection, location and characterization of earthquakes in Portugal and offshore Atlantic. We propose to implement such a system for a pilot set of stations (NAVIGATORS network).

SeisComP3.0 software is presently being developed at GFZ, Potsdam, to address the challenges posed by the new Indian Ocean tsunami monitoring network (project GITEWS, www.gitews.org, Kraft et al., 2007). SeisComp3.0 is likely to become a new standard for seismic data retrieval and analysis, and it is due to be released during 2008. This updated version of the SeisComP software includes more real-time analysis tools than the previous version 2.5. We plan on installing SeisComp3.0 in the NAVIGATORS network as soon as it becomes available. We will work closely with the developers of SeisComP to improve both the performance of the NAVIGATORS network and that of the software itself.

In parallel with the implementation of real-time seismic analysis, we will develop tools for more reliable (but slower) characterization of seismic events. We will use state-of-the-art inversion methods to accurately characterize earthquakes that occur in the Portuguese territory. In particular, we will focus on the accurate characterization of earthquakes that occur on the Eurasia-Africa plate boundary. These tools will have to be adequate for sparse networks with non-ideal geometry. They

must also be able to adequately deal with poorly known material structure. These are problems traditionally faced by less developed countries (many of which must cope with high seismic and volcanic risks) and by regions characterized by slow tectonic deformation rates, where the seismic hazard is low but the seismic risk is high (earthquake unpreparedness in regions of low seismic hazard commonly leads to a high seismic risk). The tools we will develop can be used for the advantage of such populations.

For data telemetry we will look at new ways to reduce the cost of commercial satellite links. Data telemetry via satellite is a field that just began to be explored, and we plan to make use of the most recent technology being developed at IST under FP7 Project MIA-VITA (BRGM coordination) to achieve the goals of this project (see section B3.1). VSAT telemetry is a robust technology and is ideal to ensure network redundancy (given that the stations transmit data to a satellite, the satellite can then easily send the data to more than one receiver). We will find optimum choices for mirror sites that will receive data from NAVIGATORS.

ART-SEIS is planned in perfect harmony with European state-of-the-art research. We have received emphatic support for this project from ORFEUS, who coordinates I3 EC-Infrastructure NERIES (see section 4.4), and also from the Euro-Mediterranean Seismological Centre (EMSC), another leading partner in NERIES (see section 4.4). In addition, ART-SEIS has the support from the British Geological Survey (BGS) regarding the improvement of seismic monitoring through the development of algorithms for automated earthquake processing and reduction in operational costs (see section 4.4)..

B 1.4. Timeliness and relevance of the project

The tectonic deformation rates in and around Portugal are rather slow (in the order of 5 mm/year, Serpelloni et al, 2007), which results in long time intervals (recurrence times) between consecutive seismic events. Because earthquakes do not happen often, the Portuguese society in general is not aware of the adequate procedures to mitigate the dangers posed by earthquakes. Nevertheless, Portugal has been hit by destructive events in the past (e.g., the great 1755 Lisbon earthquake). Given the general unawareness of the Portuguese population about earthquakes, widespread havoc will probably mark the post-earthquake period when the next large earthquake hits Portugal. Portugal is a country with many old villages, towns and cities: pervasive narrow roads and old buildings will make it very hard for emergency teams to successfully reach everyone in need. In case a calamity state becomes installed after an earthquake, it will be key for governmental and private institutions to have access to fast earthquake parameters (e.g., earthquake location, magnitude, style of faulting and maps of ground-shaking). Fast earthquake information will allow for more rapid and efficient emergency services and recovery.

We will develop and install a set of algorithms for monitoring seismic activity at a time when the Portuguese geophysics network is being renovated and expanded. In particular, the host institution (IST) will be responsible for the deployment and management of a sub-network of very broadband (VBB) seismographs (NAVIGATORS network) and strong-motion accelerographs (SEISNETg network) (section B.3.1). In order to take the most out of the new data we will follow the boost in seismic instrumentation with the necessary development and implementation of analysis software.

This project is planned at a time when new broadband stations are being deployed all around Europe. In particular, the new VBB stations operated by IST will be part of the European Virtual Broadband Seismic Network (EVBSN), an initiative of ORFEUS (van Eck et al., 2004). Significant advances have recently been made in the near-real-time and fully automated seismic analysis in the central Mediterranean (Braunmiller et al., 2002; Pondrelli et al., 2002; Bernardi et al., 2004). We

will complement these initiatives by implementing fast tools for automatic seismic monitoring in the westernmost part of Europe. Small sub-networks can provide fast results in terms of real-time monitoring (e.g., Wu and Teng, 2002); hence the importance of implementing regional monitoring systems.

ART-SEIS complements two on-going FP6 seismology projects: NERIES and SAFER. The real-time exchange of seismic data and the production of shakemaps are issues that NERIES addresses. SAFER concentrates on real-time seismic analysis procedures. ART-SEIS will be undertaken in close connection with NERIES and SAFER. ART-SEIS has support from several European seismological institutions, namely ORFEUS, EMSC and the BGS (section B.4.4).

B2 QUALITY OF THE RESEARCHER

Due to maternity leave, the researcher, Dr. Susana Custódio (SC), was not working full-time from June 2007 through January 2008. For this reason, we will present relevant information in the subsequent sections for the previous 3 1/2 years (September 2004 – March 2008), rather than for the previous 3 years mentioned in the proposal guidelines.

SC maintains a professional webpage: http://www.crustal.ucsb.edu/~susana.

B 2.1. Research experience

SC was a research trainee at the Institute for Structure Engineering, Territory and Building Technologies (ICIST) of Instituto Superior Técnico (IST), Lisbon, from November 2001 through June 2003. During this time she participated in the VIGIL and TAGUSnet projects, both under the supervision of Dr João Fonseca. In the VIGIL project she participated in the seismic study of the active Fogo volcano, Cape Verde. In particular she studied the modulation of volcanic tremor in the volcano. Within the VIGIL project SC participated in several field seasons where she got acquainted with different types of geophysical instrumentation: seismometers, tiltmeters, GPS receivers, etc. In TAGUSnet SC participated in the deployment of a seismic network (which included two broadband stations) in the Lower Tagus Valley region. The deployment of TAGUSnet included installation of data telemetry to IST and software installation/preliminary data processing at the lab.

In 2003 SC spent two months at the United States Geological Survey (USGS), Menlo Park, California, working as an invited researcher with Dr. Bernard Chouet on the study of volcanic tremor in the Fogo Island.

From September 2003 to December 2007, SC pursued doctoral studies at the University of California, Santa Barbara (UCSB), under the supervision of Prof. Ralph Archuleta. During her PhD SC studied predominantly the earthquake source. In particular, she worked on finite-fault inversions, integration of different datasets (seismic and GPS), assessment of resolution in inverse problems, non-linear inverse methods, and studies of site effects.

In the summer of 2006 SC mentored a summer research project at UCSB about seismic hazard in the region of Santa Barbara, California.

SC is currently a visiting researcher at the Institute for Crustal Studies (UCSB) where she continues to pursue work on finite-fault inversions.

B 2.2. Scientific and technological quality of previous research

The major achievement of SC in the years 2001–2003 was the study of the tidal modulation

of volcanic tremor in the Fogo volcano, Cape Verde. Tides cause extremely small pressure variation in the solid Earth. Custodio et al. (2003) observed that harmonic tremor, one of the seismic signals in the Fogo volcano, was undoubtedly modulated by tides. This was an important observation: the mechanism responsible for the harmonic tremor had to be extremely sensitive to pressure variations, thus providing a potential means of monitoring volcanic activity.

In the years 2003–2007, SC worked mainly on the 1966 and 2004 M6 earthquakes that took place in Parkfield, California. The M6 Parkfield earthquakes are very important events as they led to the idea of characteristic earthquakes (i.e., the idea that earthquakes occur along fault planes in a characteristic manner: in consecutive events they nucleate at the same hypocenter, rupture the same fault area and in the same direction, thus generating similar ground-motion). SC performed inversions of strong-motion data to obtain finite-fault models for the 1966 and 2004 Parkfield earthquakes (Custodio et al., 2005; Liu et al., 2006; Custodio and Archuleta, 2007). She was able to exclude the hypothesis that the 1966 and 2004 Parkfield earthquakes ruptured the same fault patches (Custodio and Archuleta, 2007). Currently SC is working on the combination of GPS and seismic data in finite-fault inversions, and on the challenging issue of the resolution of finite-fault inversions (Custodio et al. and Page et al., currently under revision).

SC is the author of five papers published in international peer-reviewed journals (and of another two papers currently under revision) and has presented a number of abstracts in international conferences and workshops. In particular, SC presented an invited talk at the 2007 Fall Meeting of the American Geophysical Union (AGU) on the combination of GPS and seismic data in finite-fault inversions.

SC is the recipient of several awards, among which a Young Scientist Research Award (Calouste Gulbenkian Foundation, Lisbon), departmental awards from UCSB, and student presentation awards in international meetings (section B2.6.6.).

B 2.3. Independent thinking and leadership qualities

As an undergraduate SC participated actively in many student-led initiatives. In particular, SC was one of three members of the board of the Physics Student Association (IST, 1998). From 1997 through 2000 SC was the undergraduate Physics representative for her class. In addition, in 2000 she was the undergraduate representative for all Physics students at IST, participating in a number of commissions and committees. As a graduate student SC was the student representative in the departmental faculty meetings for the academic year of 2005/06.

SC was an Erasmus exchange student at the University of Copenhagen, Denmark. As a graduate student SC attended many more than the number of required classes on the Department of Earth Sciences, UCSB (she attended classes both related and unrelated to seismology). In addition, she participated in several extra-curricular field trips.

SC delineated the scientific strategy for a successful NSF proposal ("Resolution, Robustness and Dynamics Based on Inversions of Seismic and Geodetic Data of the 2004 Parkfield Earthquake", UCSB). SC was able to look at the data available from the 2004 Parkfield paper, pose the relevant questions and lay out a feasible scientific plan to pursue. This NSF grant generated four papers already published in international peer-reviewed journals, and another two papers that are currently being revised.

During her stay at UCSB SC was deeply involved in the activities of the Southern California Earthquake Center (SCEC). As a student SC had no access to leadership positions, however she had the opportunity to observe some of the decision-making processes at SCEC. SCEC is an open consortium that invites the participation from all researchers. Many SCEC decisions are made in

open sessions and workshops. As a student SC could participate in these sessions and observe the dynamics of the earthquake centre.

B 2.4. Match between the fellow's profile and project

Throughout her career SC acquired numerous skills that will be invaluable in ART-SEIS. At a technical level SC has field training with geophysical instrumentation and network management (projects VIGIL and TAGUSnet). On a more theoretical level, SC is knowledgeable in inverse problems and resolution issues, earthquake source kinematics and dynamics, and integration of different datasets. SC has further experience in the topics of site effects and seismic hazard. SC has worked with different types of data, such as strong-motion data, broadband data, GPS data, tilt data, etc.

ART-SEIS is a data-driven project; its successful outcome depends on proper data collection and analysis. The previous experience of the applicant with different types of data (seismic – broadband, short-period and strong-motion; geodetic – GPS; etc) signals a good match between her and the project. Many of the problems that ART-SEIS will address are seismic inverse problems (inversion for earthquake locations and CMT solutions). SC has extensive experience with inverse problems. The expertise of SC makes her a perfect fit for this project.

B 2.5. Benefit to the career of the researcher from the period of reintegration

The Portuguese government is currently re-structuring the national research laboratories. In particular, a new seismology research department has been created at the Meteorology Institute (IM), the national institution in charge of seismic monitoring and alert. In addition, a new consortium of national organizations was created – RISCOS – to cope with natural disasters. These reforms create an implicit need for new hires in the field of seismology. The fourth goal of this project implies interaction with the national seismological organizations, and will prompt an easier full reintegration of the applicant into the European science.

B 2.6. Curriculum Vitae

B 2.6.1. Academic achievements

SC concluded her "*Licenciatura*" (5-year degree) in Physics Engineering at Instituto Superior Técnico (IST, Lisbon), with a final average of 17 points in 20. She pursued her "*Licenciatura*" from September 1997 through July 2002.

SC pursued doctoral studies in Geological Sciences at the University of California, Santa Barbara (UCSB, USA) from September 2003 through December 2007 under the supervision of Prof. Ralph Archuleta. The remaining members of her doctoral committee were Prof. Toshiro Tanimoto, Prof. Chen Ji and Dr. Jamison Steidl. Her graduate point average (GPA) for the curricular part of the PhD was 4.0 in 4.0. Her PhD thesis was entitled "Earthquake Rupture and Ground-Motion: The 2004 M6 Parkfield Earthquake".

B 2.6.2. List of research publications

International journals with peer review:

1. Custódio, S., Liu, P. and Archuleta, R.J. (2005). The 2004 Mw6.0 Parkfield, California, earthquake: Inversion of near-source ground motion using multiple data sets. Geophysical Research Letters, vol. 32, L23312, doi:10.1029/2005GL024417.
2. Liu, P., Custódio, S. and Archuleta, R.J. (2006). Kinematic inversion of the 2004 Mw6.0 Parkfield earthquake including an approximation to site effects. Bulletin of the Seismological Society of America, vol. 96, no. 4B, pp. S143-S158, doi:10.1785/0120050826.
3. Custódio, S. and R.J. Archuleta (2007). Parkfield earthquakes: Characteristic or complementary? Journal of Geophysical Research, 112, B05310, doi:10.1029/2006JB004617.
4. Ma, S., Custódio, S., Archuleta, R.J. and Liu, P. (2008). Dynamic modeling of the 2004 Mw6.0 Parkfield, California, earthquake. Journal of Geophysical Research, 113, B02301, doi:10.1029/2007JB005216.
5. Page, M.T., Custódio, S., Archuleta, R.J. and Carlson, J.M. (in revision). Constraining earthquake source inversions with GPS data 1: Resolution based removal of artifacts. Journal of Geophysical Research.
6. Custódio, S., Page, M.T. and Archuleta, R.J. (in revision). Constraining earthquake source inversions with GPS data 2: A two-step approach to combine seismic and geodetic datasets. Journal of Geophysical Research.

Invited talks in international conferences:

1. Custódio, S., Page, M. T. and Archuleta, R. J., 2007. Integrating GPS and Seismic Data in Earthquake Source Inversions. EOS Trans. AGU, 88(52), Fall Meet. Suppl., Abstract G23A-01.

Other presentations:

1. Custódio, S., Page, M. T. and Archuleta, R. J., 2007. A New Approach for Combining GPS and Seismic Data in Kinematic Inversions. EOS Trans. AGU, 88(52), Fall Meet. Suppl., Abstract S53C-05.
2. Page, M. T., Custódio, S., Archuleta, R. J. and Carlson, J.~M., 2007. Using Resolution Information to Remove Artifacts from GPS Inversions. EOS Trans. AGU, 88(52), Fall Meet. Suppl., Abstract S51B-0499.
3. Archuleta, R. J., Liu. P., Custódio, S. and Page, M. T., 2007. Improving on Inversions for Kinematic Parameters of the Earthquake Source. EOS Trans. AGU, 88(52), Fall Meet. Suppl., Abstract S53C-02.
4. Custódio, S., Page, M. T., Larson, K., and Archuleta, R. J., 2007. Combining Different Datasets to Obtain a Rupture Model: the 2004 M6.0 Parkfield, California, Earthquake. Seismological Research Letters, vol. 78(2), pp 305.
5. Page, M. T., Custódio, S., Archuleta, R. J. and Carlson, J. M., 2007. Resolution of GPS Data from the 2004 Mw6.0 Parkfield Earthquake. Seismological Research Letters, vol. 78(2), pp 289.
6. Custódio, S. and Archuleta, R. J., 2006. b-Values as a Proxy for Stress - Inferences for Dynamic Modeling of the 2004 Parkfield Earthquake. EOS Trans. AGU, 87(52), Fall Meet. Suppl., Abstract S23C-0167.

7. Archuleta, R. J., Custódio, S. and Ma, S., 2006. Effect of Realistic 3D-Velocity Structure on Rupture Dynamics and Ground- Motion. EOS Trans. AGU, 87(52), Fall Meet. Suppl., Abstract S53D-05.
8. Page, M. T., Custódio, S., Archuleta, R. J., and Carlson, J. M., 2006. Resolution of GPS data from the 2004 Mw6.0 Parkfield Earthquake. EOS Trans. AGU, 87(52), Fall Meet. Suppl., Abstract NS31C-1582.
9. Ma, S., Archuleta, R. J., Custódio, S., and Liu, P., 2006. Dynamic Modeling of the 2004 Mw 6.0 Parkfield Earthquake. EOS Trans. AGU, 87(52), Fall Meet. Suppl., Abstract S32A-03.
10. Custódio, S., Ma, S. and Archuleta, R. J., 2006. Modeling Earthquake Dynamic Ruptures in Realistic 3D Heterogeneous Material - Preliminary Results. Annual Meeting of the Southern California Earthquake Center, Palm Springs, California, Sep. 10-13, 2006.
11. Page, M., Custódio, S., Archuleta, R. J., and Carlson, J., 2006. Resolution of GPS data from the 2004 Mw6.0 Parkfield Earthquake. Annual Meeting of the Southern California Earthquake Center, Palm Springs, California, Sep. 10-13, 2006.
12. Custódio, S. and Archuleta, R. J., 2006. The Parkfield Section of the San Andreas Fault, California: Characteristic or Complementary Earthquake Ruptures? International workshop on comparative studies of the North Anatolian Fault and the San Andreas Fault (Southern California), Istanbul Technical University, Turkey, Aug. 14-18, 2006.
13. Page, M., Custódio, S., Archuleta, R. J., and Carlson, J., 2006. Source Inversion Resolution Analysis of the 2004 Mw6.0 Parkfield Earthquake. International workshop on comparative studies of the North Anatolian Fault and the San Andreas Fault (Southern California), Istanbul Technical University, Turkey, Aug. 14-18, 2006.
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B 2.6.3. List of participation in research projects

SC participated in the following research projects:

- VIGIL (IST), funded by FCT, Lisbon. The main purpose of this project was to perform the geophysical monitoring of the active Fogo volcano, Cape Verde. SC participated in the project as a research trainee from 2001 through 2002.
- TAGUSnet (IST), funded by FCT, Lisbon. The main purpose of this project was to deploy a seismic network in the Lower Tagus Valley, Portugal, for seismic monitoring purposes. SC participated in the project as a research trainee from 2002 through 2003.
- Inversion of Seismic and Geodetic Data from the 2004 Parkfield Earthquake (UCSB), funded by SCEC, California. The main purpose of this project was to perform a finite-fault inversion of the 2004 M6 Parkfield, California, earthquake, based on strong-motion and geodetic data. SC participated in the project as a graduate research assistant from 2005 through 2007.
- Resolution, Robustness and Dynamics Based on Inversions of Seismic and Geodetic Data of the 2004 Parkfield Earthquake (UCSB), funded by NSF, USA. The main purposes of this project were to investigate adequate ways of combining GPS and seismic data in finite-fault inversions and to study the source kinematics and dynamics of the 2004 M6 Parkfield, California, earthquake. SC participated in the project as a graduate research assistant from 2005 through 2007, and as a visiting researcher in 2008.

B 2.6.4. List of participation in conferences and workshops

SC participated in the following conferences and workshops in the last 3 ½ years:

- 2004, 2005, 2006 and 2007 annual fall meetings of the American Geophysical Union (AGU);
- 2005, 2006 and 2007 annual meetings of the Seismological Society of America (SSA);
- 2004, 2005 and 2006 annual meetings of the Southern California Earthquake Center (SCEC);
- SAL 2005. International Workshop on Ocean Island Volcanism (Sal Island, Cape Verde Republic, 2005);
- COSMOS workshop 2: site selection, installation and operation of geotechnical strong-motion arrays (San Diego, California, 2006);
- ERI/SCEC workshop (Oxnard, California, 2006);
- International workshop on comparative studies of the North Anatolian Fault and the San Andreas Fault (Southern California) (Istanbul Technical University, Turkey, 2006)

B 2.6.5. List of other professional activities

SC was a teaching assistant for the Department of Earth Science at UCSB for the courses of Seismology (2004 Winter quarter), Natural Disasters (2005 Winter quarter) and Thermodynamics (2006 Winter quarter).

B 2.6.6. Awards and honours

SC was the recipient of the following honours and awards:

- Young scientist research award – Physics and Environment, Calouste Gulbenkian Foundation, Lisbon (2002);
- Graduate scholarship from the Portuguese Foundation for Science and Technology (FCT), Earth Sciences (2003 – 2007);
- Graduate award for Geophysics, Department of Earth Science, UCSB (2005);
- Student presentation award, SSA annual meeting (2006);
- Outstanding student paper award, AGU fall meeting (2006);
- Graduate award for research excellence, Department of Earth Science, UCSB (2007).

B3 IMPLEMENTATION

B 3.1. Quality of host organisation, including adequacy of infrastructures/facilities

The host institution – Instituto Superior Técnico (IST) – is the leading higher education school of engineering in Portugal, and is a member of various European networks of prestigious schools in Engineering, Science and Technology, such as CLUSTER, TIME, and CESAER. Research and services contribute to about half of IST's turnover. IST has a strong research group in earthquake engineering and seismology, which is part of the IST research unit ICIST (Institute for

Structure Engineering, Territory and Building Technologies). IST is a member of the main international seismological organizations, such as the FDSN, IRIS, ORFEUS and the EMSC. Dr Joao Fonseca, from IST, is a member of the Board of Directors of ORFEUS. IST was recently invited to join the "European Plate Observation System" (EPOS) proposal, currently being submitted to ESFRI for inclusion in the European Research Infrastructure Roadmap.

ICIST currently operates a strong-motion network that consists of 44 accelerographs in mainland Portugal and the Azores; a permanent network of 5 broadband instruments in the Lower Tagus Valley region; and a hybrid broadband and short-period network in the Fogo volcano, Cape Verde. IST is currently reinforcing further its research staff in seismology, hiring Dr Mohamed Salah and Dr Silvio de Angelis to investigate the lithospheric structure and the crustal attenuation in SW Iberia. Along with Dr Susana Vilanova, Dr Joao Fonseca and Prof. Carlos Sousa Oliveira, the new members will form a dynamic research team that will stimulate, and benefit from, the contribution of the applicant.

The Portuguese Foundation for Science and Technology (Fundação para a Ciência e Tecnologia – FCT) recently invested in the creation of the National Geophysics Network (Rede Nacional de Geofísica – RNG). One of the goals of the RNG is to increase the amount of geophysical data collected in Portugal and its real-time dissemination. RNG was built around nine projects of geophysical re-equipment approved previously to the National Scientific Re-equipment Programme. Three out of the nine projects are run by ICIST, which makes this research group a key player in seismology at a national level. The above-mentioned three projects are broadband seismology (ICIST is currently deploying six VBB stations in and around the Portuguese territory – the NAVIGATORS network), strong-motion seismology (IST will deploy a new free-field strong-motion network – SEISNETg) and geotechnical Vp/Vs studies.

On-going projects in Seismology at ICIST:

TAGUS2 – Funded by FCT, Lisbon. An investigation of the seismic sources of the Lower Tagus Valley, near Lisbon.

NAVIGATORS – Funded by FCT, Lisbon (National Reequipment Programme). Deployment of a network of very broadband telemetric seismograhic stations in the Azores Gibraltar region.

SEISNETg - Funded by FCT, Lisbon (National Reequipment Programme). Deployment of a network of strong motion seismographs in Mainland Portugal and in the Azores.

Dynamic and Cyclic Soil Characterization - Funded by FCT, Lisbon (National Reequipment Programme). Laboratory for the measurement of seismic wave velocities in soil samples.

NERIES – Funded by the EU (FP6). An Integrated Infrastructure Initiative networking the main research institutions of European seismology.

MIA-VITA – Funded by the EU (FP7 – Environment). A Specific International Cooperation Action addressing the mitigation of volcanic risk. ICIST leads the workpackage on real-time data retrieval.

SHARE – Submitted to the EU (FP7 – Environment). The goal is the harmonization of seismic hazard assessment throughout Europe with a view to the implementation of Eurocode 8. ICIST will coordinate the identification and characterization of seismic sources in Iberia and its offshore region.

The list of relevant papers published by the host institution includes Vilanova and Fonseca (2007), Fonseca (2005), Vilanova and Fonseca (2004), Vilanova et al. (2003) and Fonseca et al. (2000).

B 3.2. Practical arrangements for the implementation and management of the project

For the duration of the project, the applicant will hold a contract of assistant researcher with IST, who will provide adequate office space and computational resources. Project funds will be managed centrally through IST's Project Management Office, under the supervision of the representative of the host institution (Dr J. Fonseca). Yearly progress reports will be prepared by the applicant. Financial reporting will be prepared centrally by IST's Reporting Office. The applicant will have full access to the facilities and resources of the Seismological Laboratory at IST, and further computational and laboratorial facilities of IST, and will be involved in the international activities of the current research projects (seminars, workshops). The applicant will present regularly her results at international conferences, and publish them in peer-reviewed journals.

B 3.3. Feasibility and credibility of the project, including work plan

The work plan is presented next in terms of tasks (T), deliverables (D) and months after kick-off (M). A chronogram is provided, as well as a PERT diagram. The budget is shown in a table.

Task 1 (M1 to M3) – Inspection (remotely and in situ) of the deployment of the NAVIGATORS VBB stations
D1.1 – Report on the network status, with recommendations of solutions for any remaining problems. Due: M3

Task 2 (M1 to M9)- Assessment of regional specificities and respective impact on data analysis
D2.1 – Report on regional specificities and respective impact on data analysis. Due: M6
D2.2 – Recommendations for the optimum approach to data analysis. Due: M9.

Task 3 (M1 to M9) – Implementation of the SeisComp3.0 software at IST Seismological lab.
D3.1 – Report on the implementation of the software package. Due: M9
D3.2 – Report of bugs and other shortcomings to the developers (GFZ). Due: M9

Task 4 (M10 to M18) – Testing and comparative analysis of available tools for automated real time seismic analysis (ARTS)
D4.1 – Progress report on the comparative analysis of ARTS tools. Due: M18

Task 5 (M10 to M18) – Testing and comparative analysis of available tools for accurate focal parameter estimation (AFPE). This Task takes place concomitantly with T4, because the two tasks interact.
D5.1 – Progress report on the comparative analysis of AFPE tools. Due: M18

Task 6 (M19 to M21) – Implementation of the selected tools for ARTS
D6.1 – Operational set of applications. Due: M21
D6.2 – Report on the ARTS implementation. Due: M21

Task 7 (M23 to M24) – Implementation of the selected tools for AFPE.
D7.1 – Operational set of applications. Due: M24
D7.2 – Report on the implementation of AFPE tools. Due: M24

Task 8 (M7 to M24) – Investigation of optimum procedures for cost reduction and sustainability, with emphasis on VSAT bandwidth sharing.
D8.1 – Progress report on cost reduction and sustainability. Due: M12
D8.2 – Report on cost reduction and sustainability. Due: M24

Task 9 (M13 to M36) – Integration of the NAVIGATORS data and ARTS procedures into regional tsunami warning (TW) for the North Atlantic (jointly with BGS)

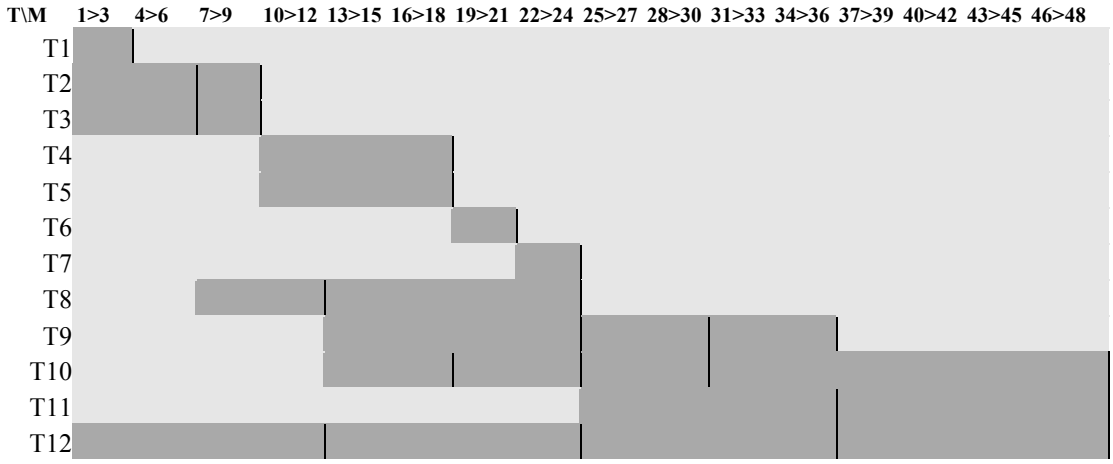
D9.1 – Progress report on data integration. Due: M24
D9.2 – Progress report on the integration of ARTS procedures. Due: M30
D9.3 – Report on integration of data and ARTS procedures. Due: M36.

Task 10 (M13 to M48) – Implementation of ShakeMap for mainland Portugal and Azores
D10.1 – Report on real-time strong motion availability and recommendations for improvement. Due: M18
D10.2 – Operational software application, with report. Due: M24
D10.3 – Report on the performance of ShakeMap in Portugal and Azores, with recommendations for further improvement. Due: M48

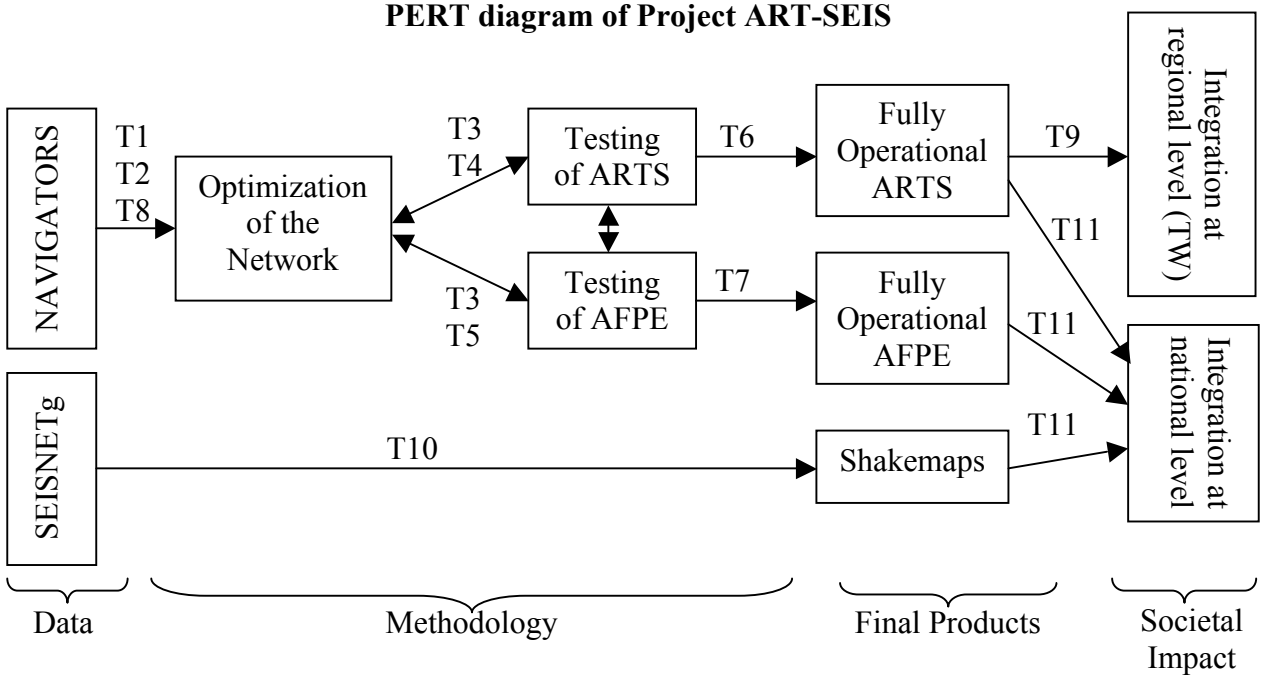
Task 11 (M25 to M48) – Dissemination
D11.1 – Progress report on dissemination activities. Due: M36
D11.2 – Final report on dissemination activities. Due: M48

Task 12 (M1 to M48) – Management
D12.1 to D12.4 – Financial reports at the end of each year.

Chronogram of Project ART-SEIS. Black traces show deliverables.



PERT diagram of Project ART-SEIS



COST OF THE PROJECT: Total (T) and EU Contribution (EU)

Budget (euro)	Year 1		Year 2		Year 3		Year 4		Total	
	T	EU	T	EU	T	EU	T	EU	T	EU
Applicant's salary	22800	16800	22800	16800	22800	16800	22800	16800	91200	67200
Travel	3000	3000	3000	3000	3000	3000	3000	3000	12000	12000
Consumables and other direct costs	677	677	677	677	427	427	427	427	2208	2208
Services	1500	1500	1500	1500	500	0	500	0	4000	3000
Publication costs	0	0	0	0	1750	1750	1750	1750	3500	3500
Management	750	750	750	750	750	750	750	750	3000	3000
Total direct	28727	22727	28727	22727	29227	22727	29227	22727	115908	90908
Indirect costs	2273	2273	2273	2273	2273	2273	2273	2273	2273	9091
Total	**31000**	**25000**	**31000**	**25000**	**31000**	**25000**	**31000**	**25000**	**125900**	**100000**

B4 IMPACT

B 4.1. Potential of transferring knowledge to host

The applicant will work directly with a team of seismologists, civil engineers and geophysicists at ICIST, ranking from Full Professors to undergraduate research trainees. All the team will benefit not only from the state-of-the-art knowledge of seismology brought by the applicant, but also from her experience and advocacy of new collaborative schemes between colleagues and between institutions. The applicant has shown already (during her previous engagements at ICIST) to be an excellent team member, motivating other team members and keen to disseminate her knowledge among the research group and further. The applicant will have a positive impact in the recruitment of new graduate students to this scientific area, and we will try to integrate undergraduate research trainees in the project.

Portugal lacks basic data to characterize its seismic hazard, much to the contrary of what happens in South California. The training of the applicant at Santa Barbara, namely in the context of SCEC, will make her an excellent support for the definition of strategies for data acquisition and analysis towards a more effective seismic hazard assessment, the leading priority of the Earthquake Engineering and Seismology Group at ICIST.

Through the National Geophysical Network (RNG), the applicant may also contribute to a more effective performance of the national seismological community and its institutions.

Under the San Fernando Memorandum of Understanding, subscribed by the host institution within the scope of FP6 EERWEM Project, the applicant will assist in the data and know-how exchange with countries from the Maghreb region.

B 4.2. Capacity to develop lasting co-operation with the third country

During her stay in California, the applicant participated actively in a number of workshops, fieldtrips and meetings where she became familiar US researchers and their work. Future collaborations with some of those researchers stand as a possibility. In particular, co-operation with

the seismological group at UCSB is very likely.

The applicant's PhD main advisor (Prof. Ralph Archuleta) was the director of the Southern California Earthquake Center (SCEC) during most of the time that the applicant spent in California. Naturally, Dr. Susana Custódio became acquainted with SCEC's dynamics. SCEC is an umbrella institution that welcomes the participation of groups from around the world. The applicant would be a natural bridge between European institutions and SCEC.

B 4.3. Contribution to scientific excellence by attracting a first class researcher; or in the exceptional case where the researcher has already gained an employment position in Europe by producing a significant improvement in his/her employment condition or career prospects.

Seismology in Portugal raises many important and interesting issues, due to the combination of intraplate and interplate scenarios, potential for very large offshore earthquakes and associated tsunamis, lack of knowledge of the causative faults of these large earthquakes, etc. However, Portuguese Earth Sciences, and Geophysics in particular, are in general poorly represented in European organizations and projects. This reflects a lack of "young blood researchers" based in Portugal and willing to participate actively in European research initiatives. The CV of the applicant shows that she has all the right qualities to act as an "ambassador" of Portuguese seismology, stimulating formal and informal collaborations and contributing to the creation of conditions to use Portugal as a natural laboratory for the relevant type of research. This will bring a positive development both to Portuguese seismology and to European seismology.

B 4.4. Contribution to European excellence and European competitiveness

Despite significant progress over the last decade, seismological research in the Euro-Mediterranean region is still damped by lack of open collaboration and sharing of data and techniques. In Portugal, important steps towards generalized sharing of seismological data in real time are now being taken under the scope of the RNG initiative. This shift in scientific culture can only be taken by clearly demonstrating its benefits to individuals, institutions and society. It can only have a positive impact to integrate a researcher who is at the same time a "show-case", an advocate and a champion of this new scientific culture. The contribution of project ART-SEIS to European excellence is recognized by the leading European seismological organizations – the ORFEUS Consortium and the EMSC – and also by the British Geological Survey and the Portuguese National Laboratory for Civil Engineering (LNEC), as documented by the following value statements:

"ORFEUS strongly supports the Marie-Curie action proposal ART-SEIS. This project is an excellent complementary action to the large and unique EC-funded seismological infrastructure project NERIES (Network of Research Infrastructures for Earthquake Seismology; www.neries-eu.org) … The submitted ART-SEIS proposal provides an excellent opportunity to get involved in both the implementation and research related to the European data exchange infrastructure as developed and coordinated through NERIES. This timely proposal and subsequent approval would enable close interaction with the networking activities of NERIES. … Consequently, ORFEUS strongly recommends this project and will seek a strong coordination with NERIES and other European relevant projects once the proposal has been approved. Particularly, the applicant will be encouraged to actively partake in the relevant NERIES activities." – Dr Torild van Eck, Secretary General, ORFEUS, Project Manager, NERIES.

"I would like to support the ART-SEIS project to be submitted as a Marie Curie IRG project The topic is particularly timely at a time when Europe is evaluating the possibility to establish a tsunami warning system which will, by definition, heavily rely on automatic real time data

processing. This project will help covering an area which has been the affected by one of the most devastating tsunami in 1755. This project will be the occasion to attract a young scientist Dr. Susana Custodio back to Europe after several years in the US. Our research sector in Europe is already facing a decline in the number of students, postdocs and young scientists and I personally believe that every step which could help attracting scientists should be encouraged. In conclusion, I strongly support ART-SEIS project." – Dr Rémy Bossu, Secretary-General, EMSC.

"With reference to your 'Marie Curie Reintegration Grants' proposal titled 'Automated real-time analysis of broadband seismic data in the Azores-Gibraltar region' we note similarities to the seismic monitoring projects at the British Geological Survey (BGS). (…) We would appreciate the possibility to collaborate with you on these topics. (…) The BGS is also carrying out a project to detect earthquakes on a regional scale that could generate tsunamis affecting the UK (…) One of the regions that could produce tsunamis affecting the UK is off the coast of Portugal as was the case in 1755. (…) As both Portugal and the UK could be affected by the same tsunami, we would appreciate the possibility to work with you on the topic of tsunami monitoring." – Dr Lars Ottemoller, BGS, Project Leader UK Tsunami Monitoring

"The Earthquake Engineering Research Centre (NESDE) is a LNEC division devoted to the research of several topics of earthquake engineering (...) A real time operating system together with the production of maps of measured ground motion obtained from seismic networks (shake maps) will help local and regional authorities providing a decision support for the establishment of rational emergency management and planning. LNEC-NESDE scientific researchers give full support to the ART-SEIS project and believe that the project will benefit from the experience of Dr. Susana Custódio, who is highly qualified and fulfill all the requirements for the project to come to a good end." - Dr Ema Coelho, Head of Division, Earthquake Engineering Research Centre, LNEC

B 4.5. Potential and quality of lasting professional integration (expected length of work contract, expected career development)

For the duration of the ART-SEIS project (four years) the applicant will be integrated at IST with a contract of assistant researcher. For the longer term, the current situation in Portugal offers interesting prospects of integration for a researcher with the profile of the applicant, be it at the host institution as a senior researcher or in one of the national laboratories or universities that are active in this rapidly developing area. The Portuguese Government decided in 2007 to restructure the Institute of Meteorology (IM), the national laboratory in charge of seismic monitoring, in order to introduce a research department in what was until now an operational institute. New research staff will have to be recruited for that purpose. The National Laboratory for Civil Engineering (LNEC) is also recruiting seismologists to join their Earthquake Engineering Department, and this trend can be expected to continue. The RISCOS Consortium, created recently by the Portuguese Government to unite the Institute of Meteorology, the National Laboratory of Civil Engineering and several universities and research laboratories, is another indication that research related to natural risks will gain a higher profile and require qualified researchers. The excellent profile of the applicant makes her a natural favourite for recruitment at any of the involved institutions, host institution included.

B5 ETHICAL ISSUES

ETHICAL ISSUES TABLE

	YES	PAGE
Informed Consent		
• Does the proposal involve children?		
• Does the proposal involve patients or persons not able to give consent?		
• Does the proposal involve adult healthy volunteers?		
• Does the proposal involve Human Genetic Material?		
• Does the proposal involve Human biological samples?		
• Does the proposal involve Human data collection?		
Research on Human embryo/foetus		
• Does the proposal involve Human Embryos?		
• Does the proposal involve Human Foetal Tissue / Cells?		
• Does the proposal involve Human Embryonic Stem Cells?		
Privacy		
• Does the proposal involve processing of genetic information or personal data (eg. health, sexual lifestyle, ethnicity, political opinion, religious or philosophical conviction)		
• Does the proposal involve tracking the location or observation of people?		
Research on Animals		
• Does the proposal involve research on animals?		
• Are those animals transgenic small laboratory animals?		
• Are those animals transgenic farm animals?		
• Are those animals cloning farm animals?		
• Are those animals non-human primates?		
Research Involving Developing Countries		
• Use of local resources (genetic, animal, plant etc)		
• Benefit to local community (capacity building, i.e. access to healthcare, education etc)		
Dual Use		
• Research having potential military / terrorist application		
I CONFIRM THAT NONE OF THE ABOVE ISSUES APPLY TO MY PROPOSAL		**X**

ANNEX 1 – List of Acronyms

ARTS – Automated Real-Time Seismic Analysis
AFPE – Accurate Focal Mechanism Parameter Estimation
BB – Broadband
BGS – British Geological Survey
BRGM – Bureau de Recherches Géologiques et Minières, France
CESAER – Conference of European Schools for Advanced Engineering Education and Research, Europe
CLUSTER – Consortium Linking Universities of Science and Technology for Education and Research, Europe
CMT – Centroid Moment Tensor
EERWEM – Earthquake Monitoring and Earthquake Risk in Western Mediterranean
EPOS – European Plate Observation System

ESFRI – European Strategy Forum on Research Infrastructures
ETH Zurich – Eidgenössische Technische Hochschule Zürich, Switzerland
EVBSN – European Virtual Broadband Seismic Network
EW – Early Warning
FCT – Fundação para a Ciência e Tecnologia
FDSN – International Federation of Digital Seismograph Networks
FP – Framework Program
GFZ Potsdam – GeoForschungsZentrum Potsdam, Germany
GITEWS – German Idonesian Tsunami Early Warning System
GPS – Global Positioning System
IAG – Instituto Andaluz de Geofisica, Spain
IM – Instituto de Meteorologia, Portugal
ING – Instituto Geografico Nacional, Spain
ICIST – Instituto de Engenharia de Estruturas, Território e Construção, Portugal
IOC – Intergovernmental Oceanographic Commission, UNESCO
IRIS – Incorporated Research Institution for Seismology
IST – Instituto Superior Técnico, Portugal (host institution)
MIA-VITA – Mitigate and Assess Risk from Volcanic Impact on Terrain and Human Activities, FP7
NEACMTWS – Northeast Atlantic and Mediterranean Tsunami Warning System
NERIES – Network of Research Infrastructures for European Seismology, FP6
NSF – National Science Foundation, USA
ORFEUS – Observatories and Research Facilities for European Seismology
RNG – Rede Nacional de Geofisica, Portugal
RR – Rapid Response
SAFER – Seismic Early Warning for Europe, FP6
SC – Susana Custódio (applicant researcher)
SCEC – Southern California Earthquake Centre
SeisComP – Seismological Communication Processor
SSA – Seismological Society of America
TIME – Top Industrial Managers in Europe
TW – Tsunami Warning
UCSB – University of California, Santa Barbara
US/USA – United States of America
USGS – United States Geological Survey
VBB – Very Broadband
VSAT – Very Small Aperture Terminal

ANNEX 2 – NEFERENCES

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PART B

AUTOMATED REAL-TIME ANALYSIS OF BROADBAND SEISMIC DATA
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