Table 1.3 d1: Work package description for Management, Networking activity or Joint research activity

Work package number	JRA1	Start date or starting event:		Month 1		
Work package title	Waveform modelling and site coefficients for basin response and topography					
Activity Type[1]	RTD					
Participant number	22	8	2	7	25	17
Participant short name	LGIT	INGV	ETHZ	GFZ	ITSAK	AUTH
Person-months per participant[2]:	70	64				

Objectives

The effects of surface (topography) and subsurface (valley, basin, lateral discontinuity) 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 four decades. Yet, their complexity, combined with the limitations of both geophysical investigation techniques and numerical simulation, made it impossible till now to include such effects in earthquake hazard assessment and risk mitigation policies: the vast majority of building codes do not include any provision for basin and surface topography effects.

However, a series of recent advances and accomplishments allow to consider that the topic is now mature to propose some practical, simple tools to the engineering community:

a. Numerical simulation tools and computing capacities have greatly improved, allowing 2D simulations over the whole frequency range of interest in earthquake engineering (up to 10 Hz) and 3D simulations up to frequencies of obvious engineering usefulness (2-4 Hz). Several benchmarking exercises (SCEC, ESG, Cashima) allowed to develop simple models and tools for careful checks of the agreement between very different numerical schemes (FDEM, FEM, SEM, DG, see Chaljub et al., 2010)
b. Numerous instrumental recordings have been obtained in various valley and mountainous areas (especially Italy, Greece, Switzerland, France), with mobile as well as permanent instrumentations, while developments in data processing techniques now allow to recover experimental site transfer functions even without local reference stations. Special attention was dedicated also to dense array measurements and processing techniques giving rise to a detailed analysis of the wavefield (fk techniques, polarization techniques) and its evolution with time during an earthquake signal
c. Geophysical investigation techniques (tomography, surface wave techniques, noise correlation) now allow to obtain quantitative images of the subsurface either with improved resolution or at lower cost
d. This scientific maturity matches the raising awareness in the engineering community, convinced by the observed damage distribution in Kobe, together with the new format of ground motion prediction equations and/or site amplification factors that could accommodate simple additional, simple basin or topography factors.

As a consequence, the ultimate objective of this work package is to establish some scientifically solid and practically acceptable – thus simple enough – propositions to incorporate basin and surface topography effects in seismic design (building codes, microzonation studies, critical facilities). This in turn implies a series of intermediate, more specific objectives to be reached within several tasks: data gathering and literature review, numerical simulation and parametric studies, cross-checks between well constrained observations and numerical predictions, development and calibration of simple engineering-oriented correlations or models.

[1] Please indicate one activity per work package:
MGT = Management of the consortium; COORD = Networking activity; RTD = Joint research activity.
[2] except human effort already included in the calculation of the access costs.

Description of work (possibly broken down into tasks), and role of participants

Based on these objectives, we propose the following work plan, separated into several tasks, which are related but do not necessarily need to be completed sequentially.

Task 1. *Literature review and data gathering* (**ITSAK**, LGIT, INGV, GFZ, ETHZ, AUTH).
This initial work is to be conducted within the first year of the project. It consists in three main components

- a thorough literature review to gather all the existing propositions to include an "aggravation" factor (for surface or subsurface geometry) in building codes or microzonation studies, or site specific studies for critical facilities.
- gathering all the already existing instrumental data within the NERA consortium, from past temporary experiments, or from permanent networks, for which high quality recordings are available together with high quality mechanical / dynamic and geometrical metadata. These data sets are needed to test the validity of numerical simulations and to of the end proposals. These data sets will be organized in a unique data base, and disseminated within the consortium for further analysis.
- identify sites that would deserve complementary geophysical surveys (surface topography effects, Task 4), or complementary seismological campaigns (array techniques, Task 2) to enrich the existing data set.

Deliverables :

D1 : Report on existing data sets meeting the JRA1 goals, and conversion into a common format

D2 : short report on proposed aggravation factors (Month 12 18)

It would be very helpful to establish some kind of formal link with ongoing similar studies in Far-east (Japan, Taiwan) and North America (SCEC, UNAM Mexico); this could imply to allocate some money for a specific workshop at the beginning of the project – or to propose a specific session in a conference (for instance ESG2011 in Santa Barbara), where selected representatives from these institutions would be invited to present their latest results and vision.
Milestone 1 : Initial workshop

Task 2. *Complementary measurements on basin effects* (**GFZ,** INGV, LGIT, ETHZ, ITSAK, AUTH).
The basin site(s) identified within Task 1 as deserving additional, denser measurements will be instrumented with a temporary array network in order to obtain instrumental measurements of differential motion and ground strains. This experiment shall be long enough (around 6 months) . This task will be performed in close link with activity JRA3. The goals are threefold

- to investigate the link between ground motion spatial variability, strains, seismic wavefield (both can be estimated with specific array processing techniques) and subsurface properties
- to compare numerical estimates of ground strain (Tasks 3 and 5) with actual measurements
- to investigate also the capability of estimating ground strains from noise correlation studies

Deliverable D3 : Report on array measurements (M24)

Task 3. *Modeling of basin effects* (**LGIT** + UBA**,** ETHZ, ITSAK, INGV, AUTH).
The goal here is to perform extensive numerical simulations on 2D and 3D basin models with varying mechanical (sediment-bedrock impedance contrast, sediment velocity and damping profile), geometrical characteristics, and incoming wavefields (point sources with different distance and depth, plane waves with different azimuth and incidence angles). This parameter study will be shared amongst the various teams, after a verification on a set of common cases. The basin characteristics will be discussed and selected during the first year, together with the verification, and the computations will be performed in monthes 12-30 in order to leave enough time for the post processing. Special focus will be put on the coupling of NL effects and geometrical effects for 2D/ (and 3D if possible) geometries, in order to better describe how linear elastic results are modified for high strains in such cases; the corresponding parameter study will however be of limited extension because of computational limitations.
This task will take advantage from tight connections and synergies with other projects: QUEST(funded), VERCE(submitted).
Different numerical codes are available and used within the consortium (SEM – Spectral Element Method – Chaljub et al., 2010, FDM – Finite Difference Method – Moczo et al., 2007: Olsen et al., 2009 , Generalized finite difference – Ely et al., 2008; DG – discontinuous Galerkin finite element method – Käser & Dumbser,

2008). Most of them are codes developed for research purposes; considering the applied goals, a special attention will be given also to the use of "commercial" software in order to compare their results and user friendliness (FLAC, ABAQUS, for which AUTH has the appropriate licences and experience).
Deliverables and Milestones
D4 : (M30) Report on code cross-check, computed models and list of available results

Task 4. *Controlled experiments on surface topography effects* (**INGV,** LGIT, ETHZ, GFZ, ITSAK).
Previous investigations on this topic point out a wide scattering of observations (from weak to very large amplifications), while models predict only weak to moderate amplifications. The priority here is thus to perform a careful, meaningful comparison between data and numerical results of a few set of representative sites. This requires

a) the selection of a few, already instrumented with temporary or permanent installations, representative sites, with some exhibiting moderate amplification and some large amplification. Such sites do exist in France (Castillon, Rognes, Piène), Greece (Grevena, Aigion, Athens), Italy (L'Aquila, Nocera Umbra, Sicily) and Switzerland (Matter-Valley in the Valais with the Grächen site, a moving large soft sediment slope, and Randa site an instable rock slope).
b) to perform a ***detailed geophysical survey*** at these few selected sites (few means from 2 to 5, depending on the size and amount of work needed to image the internal structure of the topography
c) to carry out numerical simulations on those well constrained few sites, to be compared with actual measured effects

Deliverables :
D5 : Review of recent data on surface topography effects (M12)
D6 : Geophysical surveys on a few sites : reports and findings (M24)
D7 : Comparison between data and numerical models (M36)

Task 5. *Development and calibration of simple, engineering-oriented correlations* (LGIT, INGV, ETHZ, AUTH, ITSAK).
5.1 *Specific data processing (real recordings + synthetics)* (INGV, LGIT, ETHZ, GFZ, ITSAK).
The whole data set gathered during previous tasks, including real earthquake recordings and synthetics from numerical simulation, will be first processed in a similar way in order to derive several parameters of engineering interest :

- transfer functions (Fourier domain) and amplification factors (response spectra) with respect to a reference site
- H/V spectral ratios
- duration increase (with different techniques: sonogram, group delay, band-pass filtering)
- ground strains (mainly from synthetics, but also from array recordings whenever possible

5.2 *Correlation with mechanical and geometrical parameters* (INGV, ITSAK, LGIT, AUTH).
Considering the complexity of the problem and the multiplicity of parameters, several techniques will be used in parallel in order to derive such correlations (and also to simply detect in the data the existence of 2D or 3D site effects):

- usual (least-square) correlations using predefined functional forms consistent with the usual case where geometrical effects are not accounted for. The variance reduction will be carefully analyzed to quantify the actual improvement brought by the accounting of sub-surface geometry
- using a standard multivariate statistical analysis, namely, factor analysis and canonical correlation, for which no a priori functional form is needed
- using a neural network approach considering several tests with different learning data set (synthetics and /or instrumental observations

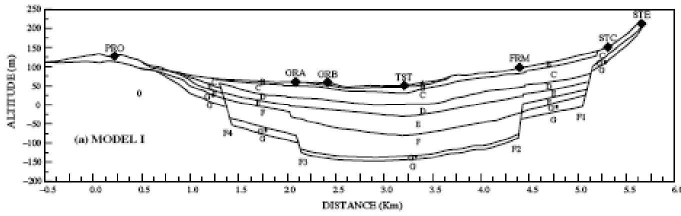
Deliverables :
D8 : Report on correlation studies

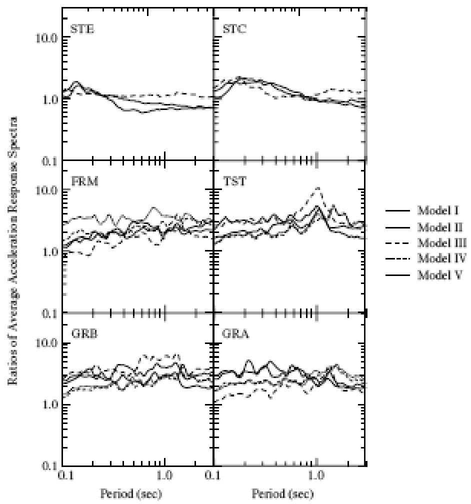
Task 6. *Final propositions for specific building code provisions (***AUTH** + all, + discussion with other NERA engineering partners)
The results obtained in Task 6 will then be synthesized and discussed within a workshop open to other engineering partners within and as much as possible outside the NERA consortium, in order to come out with practical propositions concerning

- Frequency dependent basin "aggravation factors" to be applied in building codes
- Frequency dependent surface topography aggravation factor
- Recommendations as to the way to detect the existence of such geometrical / topography effects

Deliverables :

- D9 : Report on final propositions for building codes





Example aggravation factors (right), defined as the ratio between the response spectra obtained with different 2D approximate models and the local 1D soil column, for the Volvi - Euroseistest valley (top) – From Makra et al., 2004.

Deliverables and time table

Task	Year 1				Year 2				Year 3							
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
1																
2																
3																
4																
5																
6																

Budget

LGIT : 200, ETHZ : 80 ; INGV : 80 ; GFZ : 80 ; ITSAK : 80; AUTH : 80

References

Chaljub, E., P. Moczo, S. Tsuno, P.-Y. Bard, J. Kristek, M. Käser, M. Stupazzini and M. Kristekova, 2010. Quantitative Comparison of Four Numerical Predictions of 3D Ground Motion in the Grenoble Valley, France, Bull. Seism. Soc. Am., in press.

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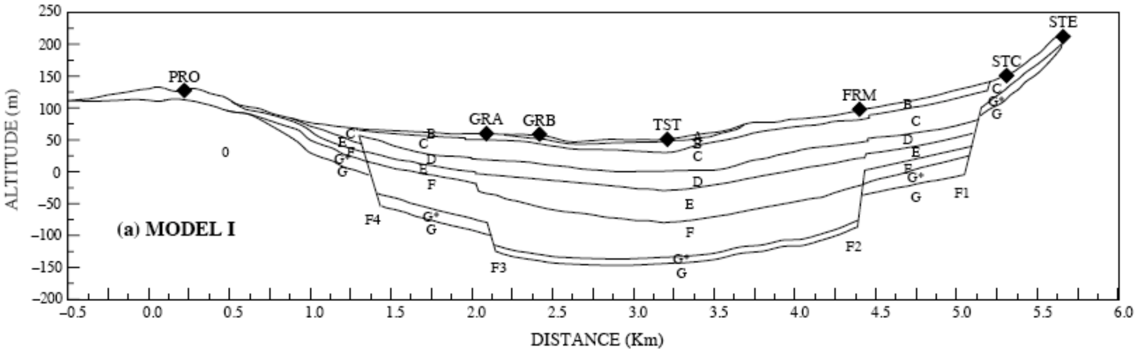
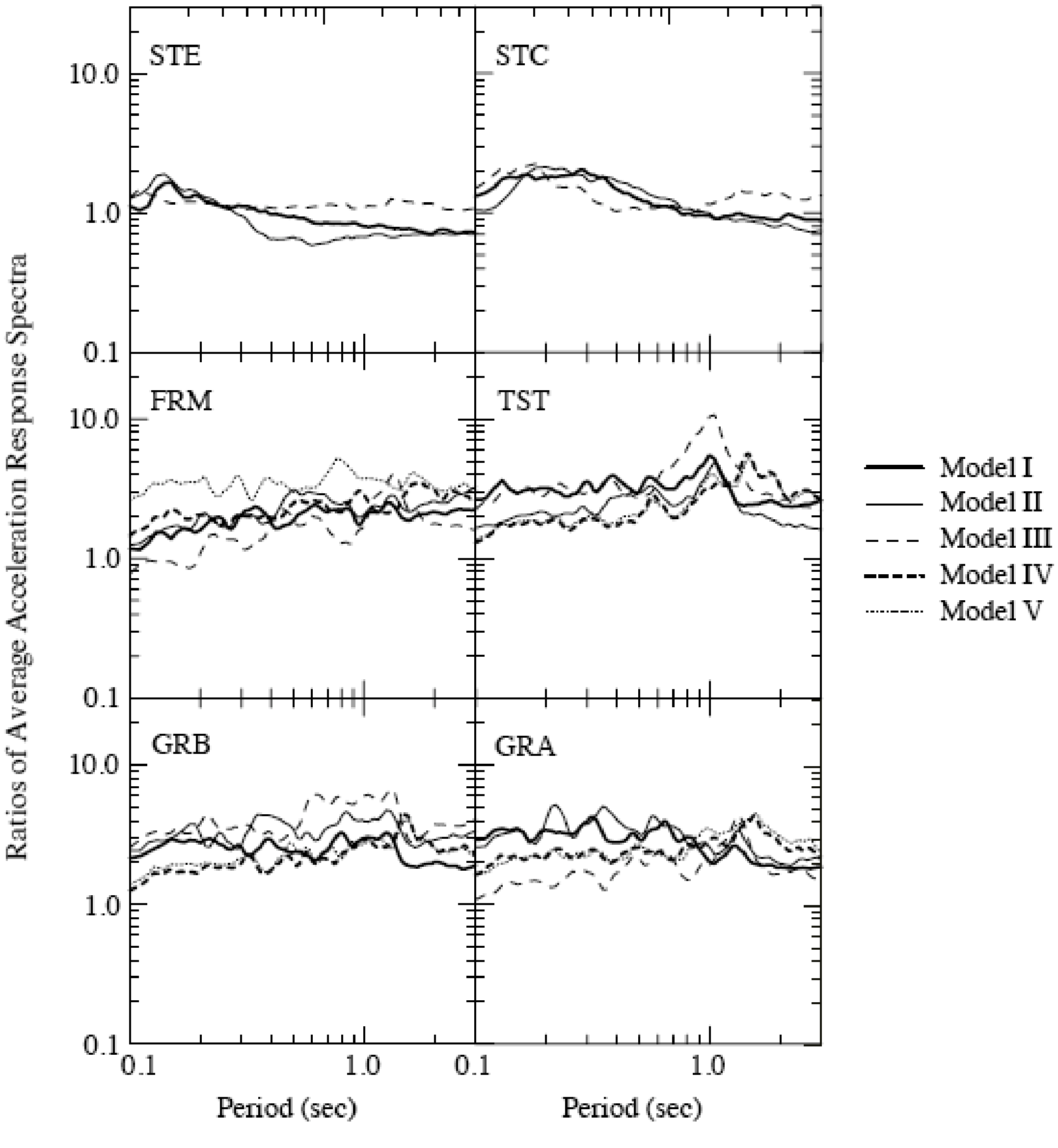
Olsen, K., S.M. Day, L.A. Dalguer, J. Mayhew, Y. Cui, J. Zhu, V.M. Cruz-Atienza, D. Roten, P. Maechling, T.H. Jordan, D. Okaya and A. Chourasia (2009) ShakeOut-D: Ground motion estimates using an ensemble of large earthquakes on the southern San Andreas fault with spontaneous rupture propagation, Geophys. Res. Lett., 36, L04303, doi:10.1029/2008GL036832.

Figures



(a) MODEL I
PRO
GRA
GRB
TST
FRM
STC
STE
ALTITUDE (m)
DISTANCE (Km)
F1
F2
F3
F4



STE
STC
FRM
TST
GRB
GRA
Ratios of Average Acceleration Response Spectra
Period (sec)
Period (sec)
Model I
Model II
Model III
Model IV
Model V