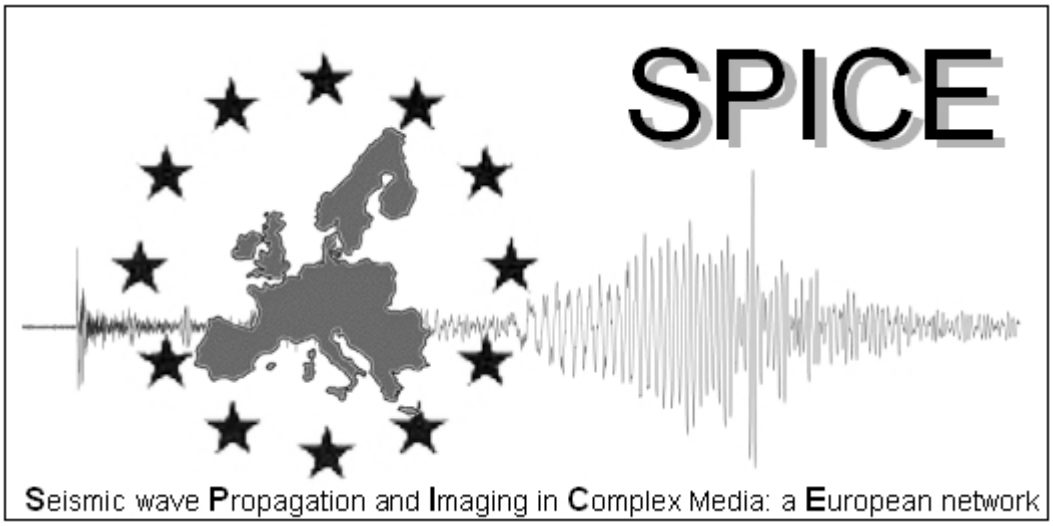
“SPICE”

SEISMIC WAVE **P**ROPAGATION AND **I**MAGING IN **C**OMPLEX MEDIA: A **E**UROPEAN NETWORK

Description of work



PART A: CONTRACT DETAILS AND OBJECTIVES

1: **Full Title:** Seismic wave propagation and imaging in complex media: a European network

Short Title (i.e. Project Acronym): SPICE

2: **Proposal Number:** 504267

Contract Number:

3: **Duration of the project:** 48 Months

4: **Contractors and Place(s) of Implementing the Project**

The Co-ordinator and other Contractors listed below shall be collectively responsible for execution of work defined in this Annex:

The Co-ordinator
1. Ludwig-Maximilians-University Munich [LMU] established in Germany

Other Contractors
2. Institute de Physique du Globe Paris [IPG] established in France;
3. Istituto Nazionale di Geofisica e Vulcanologia [INGV] established in Italy;
4. University of Oxford [Uox] established in United Kingdom;
5. University of Utrecht [UU] established in the Netherlands;
6. Swiss Federal Institute of Technology Zurich [ETH] established in Switzerland;
7. Ecole Normale Superieure [ENS] established in France;
8. Istituto Nazionale di Oceanografia e di Geofisica Sperimentale [OGS] in Italy;
9. University of Naples "Federico II" [UoN] established in Italy;
10. Comenius University [FMPI] established in Slovak Republic;
11. Universitetet I Oslo [UiO] established in Norway;
12. Universität Hamburg [UHH] established in Germany;
13. National University of Ireland, Dublin [NUID / UCD] established in Ireland;
14. Charles University, Prague [CUP] established in Czech Republic.

The Co-ordinator and other Contractors are referred to jointly as "the Consortium".

5. Project Overview

5.1 Overall Objectives

The theory and applications of acoustic (elastic, seismic) wave propagation are entering a new era in fields such as seismology, oceanography, meteorology, acoustics, engineering, material sciences, medical sciences and others. In the past ten years the methodologies used in those fields have dramatically converged due to the massive use of numerical methods. Modern computational techniques in combination with parallel computer architectures allow the simulation of the complete three-dimensional phenomena of wave propagation for realistic complex structures with unprecedented detail. This suggests that the reverse processes (e.g. imaging of the Earth's internal structure, physical description of hydrocarbon reservoirs, monitoring of zones of weakness in constructions, characterization of earthquake rupture processes, etc.) will experience a quantum jump in resolution and accuracy over the next decade.

The SPICE Consortium aims at integrating institutions with specialisations in physical, mathematical, geological, and computational aspects of wave propagation. The goal is to develop, verify and apply computational tools for wave propagation and imaging problems on all scales. With the novel computational algorithms we expect breakthroughs in (1) the determination of global Earth structure; (2) the quantitative estimation of shaking hazard; (3) the characterization and monitoring of reservoirs; (4) understanding the structure and processes inside volcanoes; (5) simulating the physical processes of earthquake rupture; and (6) characterizing the small-scale properties of rocks.

Computational methodologies play an increasingly important role in Earth Sciences. However, the curricula are not able to provide the required teaching to equip young scientists with the necessary background in mathematical and computational aspects of a rapidly expanding field. The goal of the proposed network is to compensate for this and to provide open training facilities for the next generation of researchers in the field of computational wave propagation. This shall be achieved by regular training courses involving the network team and leading scientists in the associated fields of research.

5.2 Overall Approach and Methodology

The Consortium will employ a wide range of computational techniques for wave propagation ranging from normal-mode techniques to entirely numerical approaches. In the following a list of the methodologies that will be developed, extended, verified and applied is given and their domains of application in the various fields illustrated

- **Finite differences (FD):** Applications in earthquake scenario simulations, dynamic rupture simulations, volcano seismology, global wave propagation and exploration seismology.
- **Pseudo-spectral methods (PS):** Applications in earthquake scenario simulations and exploration seismology.
- **Finite (spectral) elements (F(S)E):** Applications in earthquake scenario simulations, dynamic rupture simulations, global wave propagation.
- **Boundary elements (BE):** Applications in dynamic rupture and crack propagation.
- **Parallel computing:** All large scale simulation algorithms will be parallelized using common standards (e.g. message passing interface).
- **Particle approaches:** Applications to wave propagation in strongly heterogeneous media and porous media, reservoir wave propagation. Hydro-mechanical coupling.

- **Unstructured grids**: Development of unstructured grid methods for media with complex shapes (free or internal surfaces).
- **Ray-theoretical methods**: High-frequency approximations supporting calculations for long-distance wave propagation in the domains of tomography, exploration seismology and earthquake scenario simulations.
- **Normal-mode methods:** Quasi-analytical solutions for spherically symmetric media (benchmarks), approximate perturbation solutions for global 3D structures.
- **Non-linear inverse problems**: Incorporation of numerical wave propagation and fully non-linear inversion methods into the imaging process with applications on all scales.

Continuous code development requires careful verification which can only be carried out using quasi-analytic methods (e.g. normal mode methods for spherically symmetric media) and comparative studies with different algorithms. This will be a key element of the SPICE collaboration with the aim of developing an accessible www-based archive of verified and documented computational algorithms with models and solutions.

The methodologies listed above will be employed to further our understanding of wave propagation on multiple scales such as:

- **Planetary and continental scale (>1000km):** Global wave propagation and imaging of the Earth's interior; interpretation of the internal structure in relation to the Earth's dynamic behaviour (e.g. mantle convection, geo-dynamo, plate tectonics). Seismic signature of mantle convection; development of regional reference models (e.g. Europe); Scattering at the core-mantle boundary.
- **Local scale (10-1000km):** Understanding of shaking hazard for specific and multiple earthquake scenarios; simulations and inversion of dynamic rupture phenomena; phenomenological studies of 3D wave effects of lateral heterogeneities in the Earth (e.g. subduction zones, hot spots); phenomenology of rupture processes.
- **Small scale (<10km):** Simulation of wave propagation in reservoirs; waves in porous media; imaging the interior of volcanoes. Scattering from topography, shaking hazard in mountainous regions. Wave fields on a laboratory scale (e.g. fracture experiments).

Large-scale computer simulations – which will play an increasingly important role in all branches where elastic waves are analysed – is at the heart of the Consortium's tasks. These simulations are now playing a similar role as observations, yet no standards for archiving, interactive handling and dissemination exist to date. Therefore, the Consortium aims at developing standards for large-volume data handling in computational seismology using www-based interfaces, that will be linked to the training modules.

PART B: IMPLEMENTATION

1. Description of the joint Research/Training Project

- **Research**

In this section the project is broken down into tasks which relate to the objectives of the project. The six tasks (T1-6) are further structured into three subgroups: (1) T1+T2: www-interface, archive, dissemination, storage, visualization, etc.; (2) T3: benchmarks for simulation and imaging; and (3) T4-T6: multi-scale wave propagation and imaging. The tasks will be detailed and linked together below. The numbering of the involved Consortium partners refers to those given in Section 4, Part A.

T1: www-interface, e-learning, dissemination, networking (all partners): The project www interface will be the platform to centralize communication and dissemination of results. It shall also develop into an interactive site for (e-)learning in computational seismology. The partners will develop and provide electronic teaching material on their particular expertise in theoretical and practical aspects of computational wave propagation. Teaching modules (e.g. power-point presentations, practicals, test programs) will be developed and published on the central www archive that will be administered by the coordinating institution. Each partner will provide modules on their particular expertise. **18-months-milestone:** www-interface with course material and software archive. **36-month-milestone**: www-based training program (graduate level) for computational seismology; interface to benchmark archives; interface to observational seismology.

T2: Storage, visualization, data contraction, archiving (all partners): The topic of research (computational wave propagation) implies that – in addition to technical developments – large scale computations will play a major part. The involved calculations generate enormous data volumes which may - at least in some cases – be as valuable as observations and need to be stored appropriately. In this task a common format for data contraction and tools for visualization in computational seismology shall be developed. In the initial phase the focus will be on developing common standards for visualization and storage. In the latter phase tools shall be developed to access the data interactively and to involve results and fundamental methodology in teaching modules. **24-months-milestone:** Definition of common formats. **40-months-milestone**: Standards (codes for practice) for long-term interactive data storage in computational seismology. Toolbox for data contraction and visualization.

T3: Benchmarks for multi-scale wave propagation and imaging (1,2,3,4,6,7,8,9,10,13,14): This task will consist of the development of a data archive with test models and seismograms on all scales, and verified computational algorithms. 3D computational methods can only be verified through careful comparative verification exercises. At the first network meeting test models for all scales involved need to be defined. The comparative studies are a fundamental prerequisite to succeed in the imaging stage. To interpret structural images in terms of the associated physical processes (e.g. mantle convection, fluid flow in reservoirs, magma movement inside volcanoes) it is important to understand in a quantitative way the resolving properties of specific algorithms. A definite answer can only come through benchmarking with complete 3D solutions. The Consortium will develop test scenarios with known models and accurate seismograms, an important step to define the domains of application and quality of the imaging process. **24-months-milestone**: Archive with first generation forward modelling algorithms and verified computer programs. **44-months-milestone**: Benchmark seismograms for imaging test. Open access archive with extensively tested programs and benchmark models.

T4: SPICE - Planetary and continental scale (1,2,3,4,5,6,11): Development of simulation algorithms for wave propagation and imaging on a planetary and continental scale. Specific tasks include: grid generation for spherical models; Development, extension,

implementation, parallelization of algorithms for global and continental wave propagation; development of hybrid approaches; applications to simulation and imaging of heterogeneous Earth structures (subduction zones, plumes, global convection models, spreading ridges, mountain roots, continental shelves); and finally the discussion of the implications of the results in the context of geodynamics. **24-months-milestone:** Novel verified algorithms for wave propagation on a planetary and continental scale. **44-months-milestone:** High-resolution images on a global and continental scale.

T5: SPICE - Local scale (1,2,3,6,7,8,9,10,12,13,14) : Development of simulation algorithms for wave propagation and imaging on a local scale. Specific tasks include: Earthquake scenario simulations (regional applications); Dynamic rupture: boundary conditions; rupture problems on curved faults; phenomenological studies; Grid generation for media with strong velocity variations; Incorporation of physical effects such as time-dependent elastic parameters, non-linear elasticity. **12-months-milestone:** Extended, optimised algorithms for Cartesian wave propagation with adaptations for specific areas (e.g. shaking hazard, dynamic rupture). **36-months-milestone:** verified tools for earthquake scenario simulations and dynamic rupture calculations.

T6: SPICE - Small scale (1,3,6,7,8,9,10,12,13,14): Development of simulation algorithms for wave propagation and imaging on a small scale. Specific tasks include: algorithms for media with strong topography (e.g. volcanoes); phenomenological studies on the effects of topography on moment tensor estimations and structural imaging of volcanoes; simulation of seismic signatures due to pyroclastic flows; simulation of wave propagation through cracked, porous media (time-dependent effects). Simulation of media with cavities (e.g. tunnels). **24-months-milestone:** Optimal implementations of topography; methods to include fractures, porosity in wave simulations. **44-months-milestone:** Modelling tools specifically adapted to volcano seismology and reservoir modelling.

The tasks and subtasks are further detailed in **Table 1** (see Appendix). The nature of the tasks in computational seismology in terms of forward (simulation) and inverse (imaging) modelling is such that imaging is only possible when the simulation approaches have been optimised and verified. Therefore in the first two years of the project the emphasis (particularly in the field of global and regional seismology) will be on the simulation (forward modelling) aspects while the latter part of the project will focus on the imaging process (inverse modelling). This does not apply to problems in volcano seismology, earthquake scenario studies or dynamic rupture propagation where the objective is primarily the accurate solution of the forward problem and its applications.

The research-related milestones are complemented by the milestones associated with meetings and documents to be delivered. The complete list of milestones is given in Table 2.

Table 2: Milestones and deliverables summary table (Form A9); Type refers to meetings (M), documents (D), and workshops (W)

Del. Date (months)	Type	Subject	Resp.	Comments
1	M	Kick-Off Meeting	1	Meeting with the scientists-in-charge of all contractors to finalize project schedule
1	D	www - document	1	Project www-page with information on SPICE and advertisements for research positions
5	M	Special session	1,13	Special SPICE session I at EGU Meeting
10	W	Research and training	8,9	Research and Training workshop I
12	D	Periodic activity report	1	Report on network wide activity regarding finances, management, publications and other activities
12	D	www-document	1,10,14	Optimised algorithms for Cartesian wave propagation
15	M	Special session	3,5	Special SPICE Session II at International Meeting (e.g. EGU)

16	D	Proceedings	3,5	Abstract book and posters of Special SPICE session II
18	D	www - document	1	Teaching modules and course material, software archive
20	W	Research and training	10,14	Research and Training workshop II
24	D	Periodic activity report	1	Report on network wide activity regarding finances, management, publications and other activities
24	D	www-document	1,6	Formats for data storage; forward modelling archive
24	D	www-document	1,2,5	Algorithms for wave propagation on a planetary scale
24	D	www-document	10,13	Codes for topography, fractures, porosity
25	M	Mid-Term-Review	1,6	Mid-term-review meeting with scientific presentations and reports on network activities
30	D	www-archive	1,2	Archive with benchmark solutions
30	W	Research and training	4,5	Research and Training workshop III
36	D	www - document	1	Teaching modules and course material on R&T workshops
36	D	www-document	6,7	Tools for earthquake scenario simulations and dynamic rupture propagation
36	D	Periodic activity report	1	Report on network wide activity regarding finances, management, publications and other activities
40	D	www-document	1,6	Toolbox for data storage and visualization
40	M	Special session	11,3	Special SPICE Session III at International Meeting
42	D	Proceedings	11,3	Abstract book and posters of Special SPICE session III
44	D	www-document	2,5	Benchmark seismograms and models for imaging test
44	D	www-document	9,13	Tools for volcano seismology, reservoir modelling
44	D	www-document	2,3,5	High-resolution images, global and continental scale
46	M	Final meeting	1,2	Final meeting with presentation of scientific results and strategy for dissemination
46	D	Proceedings	1	Special issue on scientific results of SPICE, full articles (Deadline for submission month 46 with subsequent publication
48	D	Periodic activity report	1	Report on network wide activity regarding finances, management, publications and other activities

Other research organisations (outside the network) involved in the project: All of the research institutions involved in this network have further international relations outside this network. There is strong involvement with national and international large scale projects such as the IQN Georisk, EarthScope, USArray, Ocean Hemisphere Program, ACES project on earthquake simulation, and others. Specific collaboration is detailed in Table 3. The Consortium will provide at least a total of 15k€ per year (from budget Research/Training/Transfer of Knowledge) to involve scientist (travel to the workshop locations or the contracting institutions) from these institutions into network-wide research and teaching. At least one guest lecturer from outside the network will be involved in each research and training workshop.

Table 3: Other research organisations involved directly in the project through collaborative projects and/or teaching.

Partners	University/Institution	Country	Topics
All	ORFEUS	Holland	Regional and global seismic observations, data archiving, data contraction. To be involved in development of data archive.
1,8,13	BP Institute, University	UK	Reservoir modelling, Waves in porous

	of Cambridge		media. To be involved in research and teaching of exploration aspects.
1,3,6,7	University of Southern California, Los Angeles	USA	Dynamic rupture, code verification, earthquake scenario simulations. To be involved in research and teaching of earthquake dynamics
3,4,6,7	Harvard University	USA	Global seismic tomography, dynamic rupture. To be involved in research in imaging global structure.
1,2,4,6,7, 10	University of California, Santa Barbara	USA	Dynamic rupture propagation, rotational motions in seismology, tomography. To be involved in research in earthquake dynamics.
1,5	Arizona State University, Tempe	USA	Global earth structure, scattering in the Earth, observational global seismology. To be involved in research and teaching in global seismic imaging.
1,2,3,4,5, 11	MIT	USA	Global earth structure, seismic tomography. To be involved in research and teaching of global imaging and the organisation of one workshop.
1	University of Potsdam	Germany	Mathematical foundations of numerical methods. To be involved in research and teaching in numerical methods
1,6,10	University of Tokyo	Japan	Optimal FD operators, waveform inversion
1,2,3,4	Australian National University, Canberra	Australia	Theoretical seismology, seismic tomography. To be involved in research and teaching in seismic tomography.
1,2,6	University of Pau	France	Spectral element methods. To be involved in research and teaching in spectral element methods.

- **Training and Transfer of Knowledge (ToK)**

The following number of person months are allocated to the network (Swiss person-months are given in brackets)

Early Stage Researchers (ESR)	Experienced Researchers (ER)	Total
504 (36)	336 (22)	840
58%	42%	100%

The network as a whole undertakes to provide a minimum of 840 person-months (of which 58 will be provided by the Swiss partner) of Early Stage and Experienced Researchers whose appointment will be financed by the contract. Quantitative progress on this, with reference to the table contained in Part C and in conformance with relevant contractual provisions, will be regularly monitored at the consortium level.

ESR and ER: The scientific topics that are being carried out in the project – computational wave propagation on all scales – necessitate profound expertise in various fields such as mathematics, physics, computer science and earth science. Depending on their particular background, doctoral students tend to take a substantial amount of time to be able to perform at the forefront of science in this particular field. One of the main goals of this network is to develop interactive course material and offer courses through which this time can be

considerably shortened in the future. Experience with other similar networks has shown that experienced researchers must be part of the local research groups to successfully combine local training with network-wide training, and to achieve the ambitious scientific objectives and disseminate the results. Therefore, approximately two-years of experienced researchers are allocated to each partner, who will – in the early stages of the project – overlap with the early-stage researchers.

In general, the focus of the training contents on a local and network-wide level for the **early-stage researchers** is the technical side of computational wave propagation (e.g. mathematical tools, numerical methods, parallel algorithms, inverse theory) while the focus of the training of the **experienced researchers** is on the specific applications of the computational tools on specific scientific problems (imaging the earth's interior, calculation of earthquake scenarios for specific regions, understanding earthquakes). The ERs will be expected to have some experience in computational wave propagation or related subjects to be employed by the consortium.

In the following table, the specific training contents are listed for each contractor distinguishing between more methodological issues (more relevant for ESRs) and their applications (more relevant for ERs).

Table 4: Contents of local training per contractor on methodologies and applications

Partner	Methodology	Applications
1	Numerical methods – unstructured grids – probabilistic inverse problems – parallel computing	Earthquake scenario simulations – seismic signature of mantle convection – wave propagation in volcanoes – dynamic rupture
2	Surface wave propagation – Global wave propagation – spectral elements – seismic imaging	Imaging the Earth's deep interior – imaging crust and upper mantle – dynamic rupture
3	Observational seismology – surface wave imaging – regional tomography	Structure of the Earth's crust and upper mantle – Development of reference models – strong motion seismology
4	Seismic tomography – normal-mode methods source imaging – large-scale inverse problems	Global synthetic waveform modelling – inversion of earthquake source parameters – global waveform data archive
5	Seismic inverse problem – non-linear inverse methods – ray theory	Ray-theoretical imaging of the Earth's interior – implications of images for the composition of the Earth's interior
6	Seismic networks – empirical Green's functions	Shaking hazard estimation – dynamic rupture propagation - strong motion seismology
7	Finite-difference methods – deformation modelling – source imaging	Dynamic rupture propagation – stress transfer before, during, and after earthquakes
8	Spectral methods – large-scale modelling	Wave propagation in reservoirs - regional wave propagation - waves in porous media – seismic anisotropy
9	Earthquake rupture processes - finite-difference methods	Wave propagation in volcanoes – Structural imaging of volcanoes
10	Finite differences – finite elements – Boundary conditions	Earthquake ground motion – dynamic rupture processes – earthquake scenario simulations
11	Mode coupling – surface waves – multiple scattering	Nonlinear tomography of complete waveforms – anisotropy in the Earth's mantle
12	Boundary elements – spectral methods	Crack growth, crack propagation – reservoir wave propagation - volcanology

13	Hydromechanical coupling – particle-based methods – parallel algorithms	Wave propagation in fractures, fluid-saturated rocks – volcanology – rock deformation
14	Ray theory – finite differences – finite elements	Earthquake scenario simulations - dynamic rupture propagation

Integrated training: The network will organise three open network-wide research schools with lecture series and computer practicals as well as three special sessions at international meetings. The researchers employed by the consortium will meet at least twice yearly. The network-wide training will also be fostered through the development of online course material and practicals. Each researcher funded through the project is expected to spend 2-3 months per year at other participating institutions. The local training courses that will be offered by the partners **in addition** to the network-wide workshops will be open to all researchers involved in SPICE (an others). The local training facilities will be advertised through the coordinating institution on the project www pages. Some local supercomputing centers (e.g. at Munich) offer specific training courses in the parallelisation of computing algorithms (e.g. message passing). These training courses will be advertised network-wide.

One of the key ingredients of the ESR training of SPICE is the **joint supervision** of Ph.D. projects. Each Ph.D. project to be completed in SPICE will be carried out under the formal supervision of at least two of the leading scientists of the Consortium. Each ESR will undergo a **first-year-check** through which progress can be further monitored. This check must be attended by the involved supervisors.

At the kick-off meeting the consortium will define specific **working sub-groups** (e.g. following the task description above). Within these subgroups there will be further interaction through research visits and specific open training by the contractors on their expertise (see Table 4). These activities will specifically concern the code verification exercises (Task 4), where direct collaboration (and visits to other institutions) is essential.

In addition to the network-wide training workshops, **three special sessions** at international meetings are scheduled where the researchers employed by the network are expected to present their results. At each of these meetings there will be a **network meeting** where all network-relevant issues shall be discussed.

Training and ToK elements and their relation to the overall schedule: The training program builds up logically starting with the fundamentals of numerical wave propagation (research and training workshop R+TI), followed by training in large-scale simulations (R+T II) and applications to the inverse problem (R+T III). The contributions by the contractors are listed below:

Table 5: Contents and schedule of SPICE network-wide training

Contractor	Training material content	Schedule	Milestones & Deliverables
1	Simulation in spherical geometry Unstructured grid methods	R+T II	Course material and practicals for R+T workshop II
2	Hybrid methods in global seismology	R+T II	Course material and practicals for R+T workshop II
3	Methods in regional tomography	R+T III	Course material and practicals for R+T workshop III
4	Normal-mode approaches in global seismology	R+T III	Course material and practicals for R+T workshop III
5	Inverse problems in global seismology	R+T III	Course material and practicals for R+T workshop III
6	Strong-motion simulations	R+T II	Course material and practicals for R+T workshop II
7	Dynamic rupture simulation	R+T II	Course material and practicals for R+T workshop II
8	Spectral techniques	R+T I	Course material and practicals for R+T workshop I
9	Seismic imaging of volcanoes	R+T III	Course material and practicals for R+T workshop III

10	Finite-difference modelling	R+T I	Course material and practicals for R+T workshop I
11	Surface-wave tomography	R+T III	Course material and practicals for R+T workshop III
12	Boundary-element methods or pseudo-spectral methods	R+T I	Course material and practicals for R+T workshop I
13	Particle-based methods	R+T I	Course material and practicals for R+T workshop I
14	Hybrid methods for source, path and site effect simulations	R+T I	Course material and practicals for R+T workshop I

1.1. The R+T workshops will consist of at least 50% practical training. The experienced researchers will play a major role in preparing and supervising the practical part of the workshops. Mid Term Review - as well as presentations of results - will include an overall assessment of the implementation of the Description of Work, progress with recruitment and training activities and budgetary review including all indicators of progress and performance. The network administrator will gather the relevant information prior to the meeting. A summary of the meetings scheduled within the SPICE project is given in Table 6. The **final project meeting** will specifically focus on dissemination to researchers outside Earth Science.

Table 6: Meeting schedule

Year	Time	Duration	Resp. partner	Possible Locations / Comments / Participants
1	01/04	3 days	1	Spitzingsee, Germany / Kick-off Meeting / Leading scientists of SPICE and administrator
	05/04	Not applic.	1	Nice, France / EGU special SPICE session on *computational seismology* / SPICE and other researchers
	09/04	One week	8	Near Trieste, Italy / Open "Introductory school" Research and training workshop on *Fundamentals of numerical methods applied to wave propagation* / All SPICE researchers, invited speakers, invited students, other participants.
2	03/05	N.A.	3	Nice, France / EGU special SPICE session on *Multi-scale computational seismology* / SPICE and other researchers
	09/05	One week	10	Smolenice Castle, SK / Second Open Research and training workshop on *Large-scale simulations and computational aspects* / All SPICE researchers, invited speakers, invited students, other participants.
3	01/06	3-5 days	6	Davos, Switzerland / Mid-Term-Review Meeting / Leading scientists of SPICE, SPICE researchers, referees
	08/06	One week	5	Holland / Third Open Research and training workshop in *Inverse Problems in computational seismology* / All SPICE researchers, invited speakers, invited students, other participants.
4	04/07	N.A.	11	N.N. / EGU-EAGE special session. Scientific results of SPICE / SPICE and other researchers
	10/07	One week	2	Cargese, Corsica / Final, Multidisciplinary Meeting. Wrap-up and schedule for dissemination of results (e.g. PAGEOPH special issue, final WWW data base, etc.) / Leading scientists of SPICE, SPICE researchers, researchers from other disciplines.

Further elements of the SPICE network training: The network will combine and exploit the complementary expertise of network members by the combination of local open training courses that are advertised throughout the network and network wide training for all involved researchers. The Consortium will also involve scientists from outside the network (industry and academia) in the research and training planning and encourages placements in companies. Table 7 summarizes specific partnerships with industry. This partnership will include the invitation of industrial researchers to the workshop meetings or the participating institutions. This funding will be provided through the 15k€ allocated to the involvement of

outside researchers mentioned on page 6. Several of the graduated seismologists from the consortium are employed in these companies. The ability of the industrial partners to provide career opportunities strongly depends on economic indicators (e.g. oil prize).

Table 7: Industrial partners

Partners	Company(ies)	Country	Topics
1,6	MunichRe	Germany	Seismic hazard and risk. To be involved in research and teaching
1,4,5	Schlumberger Research	UK	Seismic anisotropy, borehole seismology, 3D surveys, ray theory. To be involved in research and training.
8	AGIP	Italy	Seismic well drilling, modelling and inversion, joint research projects.
8	ENEL	Italy	Seismic inversion and tomography for geothermal resources, joint research.
8	Norsk Hydro	Norway	Reservoir geophysics and characterization, joint research.
4	Atomic weapons establishment (AWE)	UK	Discrimination of nuclear sources and earthquakes, joint research projects.
4	Royal Dutch Shell	Holland	Exploration seismology. Potential employer.
14	Shell, Chevron, Elf, Aramco, Japan National Oil, Amerada Hess, Petrobras	Global	CUP runs an industrial consortium SW3D (seismic wave in complex 3D structures) with excellent contacts to the involved companies. Joint research and training.

The network will ensure **effective integration and mentoring/tutoring** of the appointed ESR and ER through the scientific personnel at the contracting institutions and the network-wide communication means (e.g. e-mail, www pages, etc.). Each contractor will appoint one member of their senior scientific staff to assist each researcher engaged by their institution with practical matters related to their installation. Each researcher will meet their mentor at the start of their appointment to decide on a career development plan and regularly thereafter to discuss their progress. The contractors will inform them of their contractual rights and obligations and will particularly invite them to contribute to the network-wide activities. In addition the local mentors will

- advise researchers on visa issues
- provide help in finding accommodation prior to arrival
- provide funds for language courses (2k€ per contractor).
- provide help in local administrative issues
- integrate them into their institutional life (seminars, etc.)

In addition to the specific scientific training, the following **complementary skills** shall be trained:

- the ability to give oral scientific presentations
- the preparation of presentation material (Powerpoint, Animations, Graphics)
- teaching (involvement in courses, practicals)
- management (e.g. seminar or workshop organisation)
- scientific writing (abstracts, articles)
- scientific proposal writing (national, international funding possibilities)

These skills shall be trained primarily on a local basis. However, SPICE researchers will get feedback on some of these skills through their performance at the network-wide research and training workshops and special sessions.

The Consortium nominates two network mentors from the leading scientists of SPICE who will ensure the production of **career development plans** (for academia or industry) and provide network-wide information on upcoming positions. The mentors will keep track of the

timing of the positions of all involved young researchers and will notify scientists at appropriate times on open positions in academia and industry. This will require setting up automated links to data bases where such information is available.

The network will provide extra funding for several **workshop-scholarships** for non-SPICE students (e.g. from less favoured regions) who will be funded to participate in the research schools based on scientific excellence. Each workshop will be advertised with an invitation to students to apply for five scholarships for each school. A minimum of 5k€ per workshop will be spend on these scholarship (Research and Transfer of Knowledge).

At the beginning of the project information on SPICE will be sent by e-mail to all institutions who might be interested in the topic also in Less Favoured Regions, Associated States and Candidate Countries. In addition, an article on SPICE describing the goals and the upcoming possibilities is scheduled to be published in EOS, the globally most widely read weekly journal in Earth Science published by the American Geophysical Union. Furthermore, knowledge transfer will be enabled through the open www-archive and **e-learning facilities** that are going to be developed within SPICE (see Task 1). This **www-archive** will be used by all the teams for subsequent training, also after termination of the RTN, and it will be available to the whole scientific community. It will also host research material, such as the benchmarks and validation datasets that will be developed as part of the program.

2. Management

At the project kick-off meeting the Consortium creates a **management panel** that will meet twice a year to coordinate network-wide activities. The **financial management** duties will be distributed among all the partners, following recommendations and common policies set by the management panel, and under the supervision of the network co-ordinator. The instruments we chose to implement to guarantee coordination (management panel, biannual meetings) will ensure proper integration.

The following chart summarizes the tasks of the management panel, and of partners, at the two levels:

Management panel	Scientific organization of Training Workshops Set recruitment strategies and standards Monitor global progress and identify weaknesses Propose collaborative research tasks Decide on updates of www archive Career development administration Annual budgetary review
Partners	Local organization of Training Workshops Actual recruitment of researchers Local training through research Financial administration Carry out collaborative research tasks Contribute to the www archive Budget monitoring and forecasting

The Community financial contribution toward **management-related expenses** will be used to pay the salary of a **network administrator** who will work in contact with the co-ordinator. The network administrator will be the permanent liaison among all the members, will ensure the general organization, collect and distribute any material, monitor respect of deadlines, particularly the timely preparation of the periodical reports on financial and other matters, advises the partners on eligible expenses. The network administrator will gather the network-wide indicators of progress and success (section 3). The network administrator also functions as a **public relations (PR)-manager** who will be coordinating the adaption of material on SPICE research for the general public. Each other partner will use the allowed overhead to arrange for local accounting assistance within at his/her institution.

The publication of vacancies and appointments of ERS and ER will be undertaken at appropriate times for the whole network by the coordinating institution with further support by the partners. The consortium will promote equal opportunities (e.g. for male and female researchers) in the appointments. The **recruitment** will be decided on a local level. However, before final appointment, the partners submit the relevant application documents for approval to the Management panel. The Management panel will check eligibility and whether the recruitment strategies and standards have been applied. To avoid difficulties in recruitment, information on SPICE and recruiting options will be published (e.g. in EOS) immediately upon contract completion. In addition, at the first special scientific SPICE session (EGU, Nice, April 2004), specific actions will be taken (e.g. posters, flyers) that will publicize the opportunities.

Each **training workshop** will be organized by a partner. The organizing partner will bear all the administrative duties connected to this action.

Joint publications will be fostered through the collaborative research projects as well as the joint supervision of Ph.D. projects. Adequate publication activity is the responsibility of the contractor's leading scientists. The management panel provides recommendations in which international journals SPICE results should be published. Each publication must be sent in electronic form to the project administrator at the coordinating institution by the time of submission and by the time of publication. The SPICE project has to appear in an acknowledgement section with the appropriate contract number and reference to the "European Commission's Human Resources and Mobility Programme".

To achieve effective dissemination of the results publications will appear in electronic form (or as reference) on the project www pages. Abstract books will be compiled for the special sessions and a special issue (or book) will be compiled in the fourth year of the project.

Financial management and control (e.g. audit certification) is undertaken by each contractor. The network administrator is collecting the relevant information to prepare the period financial report. In case re-adjustments of the initial budget become necessary, the management panel takes the decisions.

3. Indicators of Progress and Success

3.1 Quantitative Indicators of progress and success to be used to monitor the project

3.1.1 Research Activities

In reporting on progress with the implementation of its research plan the network will provide information and data on the following:

- organisation of or participation in and presentations to external specialist workshops and conferences (number; dates, places, title of event)
- specialist exchange among network teams (number, nature, when, where, who)
- individual and joint publications, directly related to the work undertaken within the contract (number, references)
- patents or patent applications directly related to the contract (number, references)
- development of new scientific and/or industrial collaborations (number, references)
- scientific awards and prizes obtained from the work directly related to the contract (number, details)
- interest expressed in the networks' dedicated Website (number of hits; number of participants to the scientific forum, if any)
- visit of Senior Researchers from inside and/or outside the network (number, name, place and time of visit)
- contacts with relevant users groups whether academic or industrial/commercial (number, name)

3.1.2 Training / Transfer of Knowledge (ToK) Activities

In reporting on progress with the implementation of its training and ToK Plan the network will provide information and data on the following:

- the rate of recruitment of ESR and ER for each participant and for the network as a whole (ratio person-months filled/offered)
- the nature and justification for adjustments, if any, to the original overall number of person-months of ESR and ER as well as to the breakdown of this overall number among the participants (see table contained in Part C)
- the time and duration of each individual appointment.
- the number, names and level of involvement of senior researchers directly associated with the tutoring/supervision of the recruited ESR or ER, at each participant
- the number of ESR that are expected to present their PhD thesis and when
- the number and place of the short visits and secondments, placement in company premises undertaken by each individual ESR or ER either within or outside of the network
- number of visits of the ESR and ER to their home scientific community
- attendance at network meetings by the ESR and ER (number, names, place, date)
- participation in and presentations to workshops and conferences by ESR and ER (number, names, place, date)
- organisation of training events (e.g. schools, training workshop/seminar, hands-on training session on specialised instrument/techniques) at individual participant sites (number, attendees' names, place, date)
- organisation of network-wide training events (number, attendees' names, place, date)
- participation in training events organised outside the network (number, attendees' names, place, date)
- number of internet tutorial and computer based training courses developed/used
- number, place, purpose of any meeting (e.g. workshop) organised by the ESR or ER themselves

3.2 Qualitative Indicators of progress and success to be used to monitor the project

3.2.1 Research Activities

In reporting on progress with the implementation of its research plan the network will provide information and data on the following:

- general progress with research activities programmed at individual, participant team and network level
- highlights on more particularly innovative developments (novel concepts, approaches, methods and / or products)
- citation index for individual and joint publications directly related to the work undertaken within the contract
- expected scientific / technological breakthroughs
- overall progress and possible problems encountered with individual work packages and/or network-wide research activities
- nature and justification for adjustments, if any, to the original research work plan and/or timetable
- progress on cross interaction among disciplines represented within the network
- progress on cross interaction between academic and industrial partners
- progress regarding interaction with industrial/commercial/economic interests outside the network
- access to / use of state-of-the-art infrastructure and facilities

- highlights on wider societal and/or ethical components of the project, such as public outreach activities
- highlights on the scientific community recognition of the network research contribution (awards, invitation to conferences, …)

3.2.2 Training / Transfer of Knowledge Activities

In reporting on progress with the implementation of its training plan and ToK the network will provide information and data on the following:

- general progress with training and ToK activities programmed at individual, participant team and network level (type of guidance, supervision, coaching or mentoring in place to support ESR and ER)
- highlights on the development of more particularly innovative approaches to training and ToK (e.g. specific training packages of network-wide relevance)
- highlights on the exploitation of the "complementarities" between network participants with respect to training and ToK
- nature and justification for adjustments, if any, to the original training / ToK plan and/or timetable (e.g. opportunities for new collaborations regarding training activities)
- career development plans as elaborated by the ESR and ER involved in the project
- career development opportunities/prospects for ESR and ER involved in the project
- achievements regarding the acquisition of complementary skills such as communication, language skills, computer skills, project management, ethics, team building, etc.
- achievements regarding the training/ToK on specialised instruments/equipment's
- level of satisfaction of the trainees (e.g. as expressed in response to questionnaires)

3.2.3 Management

In reporting on progress with its management the network will provide information and data on the following:

- effectiveness of the "internal" communication and decision making between the co-ordinator, team leaders, supervisors, down to the ESR and ER, including feedback processes
- effectiveness of the communication between the network and the Commission Services (frequency, efficiency, timely feedback's), particularly regarding the conformance with contractual provisions and the implementation of contingency plans where needed
- effectiveness of network communication with industrial and other stakeholders (anticipation of outcomes and possible end-users interests, contact preparation, follow-up and contractual agreement where appropriate)
- network self-assessment through benchmarking activities (exchange of best practices among participants and/or development of ad hoc performance indicators regarding cost management, staff selection, measurement of research/training/ToK outputs, young researchers' involvement, etc.)
- overall quality and efficiency of the "external" communication strategy of the network (Cordis; personal, team and network web sites updates; newsletters; etc.)
- effectiveness of the recruitment strategy of the network in terms of equal opportunites (including gender balance) and open competition at international level
- development of any specific planning and management tool(s) and databases
- management of intellectual property and commercialisation of network research output

Appendix: Table 1: Task and subtask involvement. **Task related** milestones are indicated by vertical broken lines. Further document- and meeting-type milestones are listed in Table 2.

Partners	Subtasks	Description	Project month
T1 www interface			2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44 46 48
1	T1.1 Project www page set up	Central information point of project, maintenance through coordinator	
All partners	T1.2 Training material and modules	Powerpoint, PDF Documents with course material	
1	T1.3 Software archive	Installation and maintenance of archive with verified algorithms	
T2 Data handling			2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44 46 48
1	T2.1 Data access tools	Data access through www interfaces, interactive data extraction	
All partners	T2.2 Storage standards	Development of standards to store simulation data	
T3 Benchmarks simulation and imaging			2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44 46 48
All partners	T3.1 Test models	Assembly of test models for benchmark simulations	
All partners	T3.2 Comparative studies	Comparative studies and verification of computational algorithms	
1	T3.3 Archiving	Archiving of verified codes in data base	
T4 Planetary scale			2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44 46 48
1,2,3,4,5,6	T4.1 Spherical grids	Grid methods for wave problems in spherical geometry	
1,2,3,4,5,6,11	T4.2 Global wave propagation	Forward modelling in 3D global earth structures	

1,2,3,4,5,6,11,14	T4.3 Deep earth imaging	Imaging global structure with 3D methods	
T5 Local scale			2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44 46 48
1,2,3,6,7,9,10,13,14	T5.1 Earthquake scenarios	Shaking hazard estimation for specific areas, multiple scenario calculations	
1,3,6,7,9,10,12,14	T5.2 Dynamic rupture	Development and application of dynamic rupture modelling, incorporation of crustal scattering, source parameter inversion	
1,7,9	T5.3 Nonlinear effects	Simulation of non-linear ground motion effects	
T6 Small scale			2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44 46 48
1,6,7,8,9,10,12,13,14	T6.1 Topography and waves	Topographic effects on wave motion	
1,3,9,12,13	T6.2 Volcano seismology	Wave propagation inside volcanoes, scattering and volcanic sources	
1,8,13	T6.3 Porous media	Wave propagation through porous media	
1,8	T6.4 Reservoir studies	Wave propagation in reservoirs	

PART C: CONTRACT DELIVERABLES (from A4b of the CPF forms)

Proposal Number	504267	Proposal Acronym	SPICE

OVERALL INDICATIVE PROJECT DELIVERABLES BY PARTICIPANT						
Participant No.	Early Stage Researchers			Experienced Researchers (4-10 years – MCRTN only)		
	Full-time Person Months	Indicative number of researchers	Stipend (%)	Full-time Person Months	Indicative number of researchers	Stipend (%)
1	36	1	0	48	2	0
2	36	1	0	23	1	0
3	36	1	0	23	1	0
4	36	1	0	22	1	0
5	36	1	0	22	1	0
6	0 (see Swiss contractor)	0	0	0 (see Swiss contractor)	0	0
7	36	1	0	22	1	0
8	36	1	0	22	1	0
9	36	1	0	22	1	0
10	36	1	0	22	1	0
11	36	1	0	22	1	0
12	36	1	0	22	1	0
13	36	1	100	22	1	0
14	36	1	0	22	1	0
Sub-Total	468	13		314	14	

PART D: COMMUNITY CONTRIBUTION (from A5b of the CPF forms)

Proposal Number[3]	504267	Proposal Acronym4	SPICE

Overall Maximum Community Contribution[53]										
Year[42]	Eligible expenses for the activities carried out by the researchers					igible expenses related to the activities of the host organisatio				Maximum EC contribution
	A Monthly Living Allowance	Transnational Mobility B Travel Allowance	Transnational Mobility C Mobility Allowance	D Career Exploratory Allowance	E Participation expenses of the eligible researchers	F Research/ raining/transfe of knowledge	G Management and Audit Certification	H Overheads	I Other types of eligible expenses	
	Costs (in euros)	Costs (in euros)	Costs (in euros)	Costs (in euros)	Costs (in euros)	Costs (in euros)	Costs (in euros)	Costs (in euros)	Costs (in euros)	(in euros)
1	544851,03	25000,00	122611,20	50000,00	64800,00	156000,00	66000,00	117270,00	143500,00	1290032,23
2	1009564,70	26000,00	230403,00	2000,00	124000,00	142000,00	66000,00	162990,00	30000,00	1792957,70
3	623122,87	25000,00	151470,20	2000,00	85600,00	91000,00	66000,00	107412,00	30000,00	1181605,07
4	259535,18	14000,00	65883,00	0,00	38400,00	65000,00	66000,00	51378,00	5000,00	565196,18
5	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
6	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Total	2437073,77	90000,00	570367,40	54000,00	312800,00	454000,00	264000,00	439050,00	208500,00	4829791,17

Form 4a Partner 6, Switzerland.

Contract Preparation Forms

EUROPEAN COMMISSION
6th Framework Programme
on Research, Technological
Development and

Marie Curie Actions :
Research Training Networks(RTN)

A4a

Proposal Number[3]	504267	oposal Acrony	SPICE	Participant No.[14]	6

Indicative Periodic Project Deliverables by Participant[43]

Year[42]	Early Stage Researchers[49] (< 4 years)				Experienced Researchers[50] (4-10 years)			
	Full-time Person Months[44]	Indicative number of researchers			Full-time Person Months[44]	Indicative number of researchers		
		Total Active during period[45]	Newly appointed for[46]			Total Active during period[45]	Newly appointed for[46]	
			< 12 months	>= 12 months			< 12 months	>= 12 months
1	6	1		1	6	1		1
2	12	1			12	1		
3	12	1			4	1		
4	6	1						
5								
6								
Totals	36		0	1	22		0	1

% of Early-Stage Researchers with stipends[47]	0%	% of Experienced Researchers with stipends[47]	0%

Average Travel Allowance[48] (Euro)	1000

Appendix: Form 5a Partner 6, Switzerland.

Proposal Number[3]	504267	oposal Acrony	SPICE	Participant No.[14]	6

Maximum Community Contribution per Participant[52]										
Year[42]	Eligible expenses for the activities carried out by the researchers					gible expenses related to the activities of the host organisati				Maximum EC contribution
	A Monthly Living Allowance	Transnational Mobility B Travel Allowance	Transnational Mobility C Mobility Allowance	D Career Exploratory Allowance	E Participation expenses of the eligible researchers	F Research/ raining/transfe of knowledge	G Management and Audit Certification	H Overheads	I Other types of eligible expenses	
	Costs (in euros)	Costs (in euros)	Costs (in euros)	Costs (in euros)	Costs (in euros)	Costs (in euros)	Costs (in euros)	Costs (in euros)	Costs (in euros)	(in euros)
1	48391,20	2000,00	10857,60	4000,00	4800,00	10000,00	5000,00	36000,00	25000,00	146048,80
2	96782,40	2000,00	21715,20	0,00	9600,00	10000,00	5000,00	0,00	15000,00	160097,60
3	57678,40	2000,00	13728,00	0,00	6400,00	10000,00	5000,00	0,00	15000,00	109806,40
4	19063,20	1000,00	4867,20	0,00	2400,00	10000,00	5000,00	0,00	10000,00	52330,40
5	0,00	0,00	0,00	0,00	0,00	0,00				0,00
6	0,00	0,00	0,00	0,00	0,00					0,00
Total	221915,20	7000,00	51168,00	4000,00	23200,00	40000,00	20000,00	36000,00	65000,00	468283,20