European Cooperation in the field of Scientific and Technical Research - COST -

Brussels, 21 November 2012

TU1208

MEMORANDUM OF UNDERSTANDING

Subject :	Memorandum of Understanding for the implementation of a European Concerted Research Action designated as COST Action TU1208: Civil Engineering Applications of Ground Penetrating Radar

Delegations will find attached the Memorandum of Understanding for COST Action as approved by the COST Committee of Senior Officials (CSO) at its 186th meeting on 20 - 21 November 2012.

MEMORANDUM OF UNDERSTANDING
For the implementation of a European Concerted Research Action designated as

COST Action TU1208
CIVIL ENGINEERING APPLICATIONS OF GROUND PENETRATING RADAR

The Parties to this Memorandum of Understanding, declaring their common intention to participate in the concerted Action referred to above and described in the technical Annex to the Memorandum, have reached the following understanding:

1. The Action will be carried out in accordance with the provisions of document COST 4154/11 “Rules and Procedures for Implementing COST Actions”, or in any new document amending or replacing it, the contents of which the Parties are fully aware of.

2. The main objective of the Action is to exchange and increase scientific-technical knowledge and experience of Ground Penetrating Radar techniques in civil engineering, whilst promoting the effective use of this safe and non-destructive technique in the monitoring of structures.

3. The economic dimension of the activities carried out under the Action has been estimated, on the basis of information available during the planning of the Action, at EUR 60 million in 2012 prices.

4. The Memorandum of Understanding will take effect on being accepted by at least five Parties.

5. The Memorandum of Understanding will remain in force for a period of 4 years, calculated from the date of the first meeting of the Management Committee, unless the duration of the Action is modified according to the provisions of Chapter V of the document referred to in Point 1 above.

A. ABSTRACT AND KEYWORDS

This Action focuses on the exchange of scientific-technical knowledge and experience of Ground Penetrating Radar (GPR) techniques in Civil Engineering (CE). The project will be developed within the frame of a unique approach based on the integrated contribution of academic researchers, software developers, geophysics experts, Non-Destructive Testing equipment designers and producers, end users from private companies and public agencies. In this interdisciplinary Action, advantages and limitations of GPR will be highlighted leading to the identification of gaps in knowledge and technology. Protocols and guidelines for EU Standards will be developed, for effective application of GPR in CE. A novel GPR will be designed and realized: a multi-static system, with dedicated software and calibration procedures, able to construct real-time lane three-dimensional high resolution images of investigated areas. Advanced electromagnetic-scattering and data-processing techniques will be developed. The understanding of relationships between geophysical parameters and CE needs will be improved. Freeware software will be released, for inspection and monitoring of structures and infrastructures, buried-object localization, shape reconstruction and estimation of useful parameters. A high level training program will be organized. Mobility of early-stage researchers will be encouraged.

A.2 Keywords: Ground Penetrating Radar (GPR), Electromagnetic Direct and Inverse Scattering and Data-Processing, Non-Destructive Testing (NDT), Civil Engineering (CE), Surveying of pavements - bridges - tunnels and buildings - underground utilities and voids.

B. BACKGROUND

B.1 General background

This Action will be focused on the application of Ground Penetrating Radar (GPR) to Civil Engineering (CE) problems. It will therefore address real current problems as well as research opportunities.

GPR is a safe, advanced, non-destructive and non-invasive imaging technique that can be effectively used for inspection of composite structures and diagnostics affecting the whole life-cycle of CE works. GPR provides high resolution images of subsurface and structures through wide-band electromagnetic (EM) waves. It is quick and inexpensive in comparison to other investigation methods and is capable of probing down to a few tens of meters, depending on the system characteristics and on ground conditions.

There are several possible applications of GPR in CE. It can be employed for the surveying of roads, highway pavements and airport runways, bridges, tunnels and for detecting underground cavities and voids, as well as for the inspection of buildings and groundwater/pollution evaluation. It can also be used for utility sensing, for example to map the buried structures in a region, enabling rapid installation of new plant with minimum disruption and damage to the existing one. Gas, water, sewage, electricity, telephone and cable utilities can be localized. Moreover, GPR can be used to perform detailed inspection of reinforced concrete and to locate steel reinforcing bars and pre/post-tensioned stressing ducts. Quality control of pre-cast concrete structures, such as bridge deck beams, can be carried out. Zones of deterioration and delamination on bridge decks can be mapped; also zones of termite attack or fungal decay in wooden bridge beams can be found. An analysis of geological structures can be made with GPR, for the mapping of soil, rock or fill layers in geotechnical investigations and for foundation design.

However, obtaining adequate penetration of the emitted radiation together with good resolution is not straightforward. Penetration and resolution depend primarily on the transmitting frequency of the GPR, the electrical properties of the ground or the surveyed material and the contrasting electrical properties of the target with respect to the surrounding medium. The centre frequency of GPR antennas typically range from 25 MHz to 4 GHz. Generally there is a direct relationship between the transmitter frequency and the resolution that can be obtained; conversely there is an inverse relationship between frequency and penetration depth. High frequencies can therefore be used to detect small and shallow targets, whereas low frequencies allow the sensing of larger and deeper targets. GPR works best in dry ground environments, but can also give good results in wet, saturated materials; it does not work well in saline conditions, in high-conductivity media and through dense clays which limit signal penetration.

Different approaches can be employed in the processing of collected GPR data. The classical strategy can be summarized as follows. Band-pass filtering is applied to remove unwanted high or low frequency noise. Stacking improves the signal-to-noise ratio, moving-average filtering smooth’s out jitter between wavefronts. Background noise removal, via subtraction of mean trace, a moving-average window, or more advanced methods, helps to remove clutter bands parallel to the air-soil interface. With deconvolution filtering, multiple echoes or signal ringing can be removed. A migration algorithm can be applied to focus the diffractions from buried objects to their true positions. By means of gain adjustment algorithms, signal strengths in different regions are balanced. Corrections are applied for variations in surface topographic elevation. The final steps in data processing involve transforming radar data into user usable images of the subsurface.

Once data have been processed, they still have to be analysed. This is a challenging problem, since the interpretation of GPR radargrams is typically non-intuitive and considerable expertise is needed. In the presence of a complex scenario, an accurate EM forward solver is a fundamental tool for the validation of data interpretation. It can be used by GPR operators to identify the signatures generated by targets, especially in the case of uncommon targets or in the presence of multiple structures. It can also be used to perform repeated evaluations of the scattered field due to known targets, in combination with optimization techniques, in order to estimate – through comparison with measured data – the physics and geometry of the region investigated by the GPR. The EM forward solver can be employed for the EM characterization of scenarios as a preliminary step that precedes a survey, or else to gain a posteriori a better
understanding of measured data.

In summary, it is possible to identify three areas, in the GPR field, that have to be addressed in order to promote the use of this technology in the CE. These are:

a) increase of the system sensitivity to enable the usability in a wider range of conditions (e.g. on high-attenuation soils/materials);

b) research novel data processing algorithms/analysis tools to ease the interpretation of the results by un-experienced operators as well (that is the 'holy grail' of GPR), thus enhancing the efficiency of the radar survey;

c) contribute to the development of new standards and guidelines and to training of end users, that will also help to increase the awareness of operators.

With respect to the increase of GPR sensitivity, optimum radar system performances are obtained when they are designed around a specific target type or geometry. Thus, it is mandatory to re-address the basic radar signal detection problem if a dramatic improvement in sensitivity is pursued. On this matter, it is necessary to develop new multi-frequency sensors and multi-polarization antennas, having the major advantage to increase the amount and quality of data collected on-site. Sought enhancements shall concern the selection of the optimal working frequency and bandwidth, according to the characteristics of the targets of interest, as well as of the best waveform to be generated by the radar antennas. The design of the layout for the antennas' array may be constrained by specific application's requirements and the influence of emitted waveform polarization can be optimized.

Data processing and analysis methods need also to be revised. Advances in the processing and presentation of GPR data would improve achievable results in CE tasks through this imaging technique.

The solution of the EM scattering problem by subsurface structures and buried objects, being a matter of great interest within the context of GPR, has been investigated by many authors, from a theoretical and a numerical point of view. Different methods have been developed, both in the frequency and time domains. The Finite Element Method, the Finite-Difference Time-Domain (FDTD) technique and the Method of Moments are often used. Among two-dimensional (2D) accurate scattering methods, the Cylindrical-Wave Approach (CWA) has to be mentioned. An advancement of EM scattering techniques is highly desirable, in order to model in a more realistic way the field source, the environment and the targets. At present, objects can often be localized with enough accuracy, but shape reconstruction and quantitative estimation of EM parameters, as the permittivity of dielectric targets and related quantities (e.g. moisture, density), are difficult tasks that need to be further studied. Moreover, it would be interesting to extend the information resulting from GPR data to new physical parameters useful for CE needs.

As far as the standardization is concerned, it has to be pointed out that there are few recognized International Standards (provided by the American Society for Testing and Materials, ASTM) in the field. Furthermore, in Europe the EN 302/066 code introduced by the European Telecommunications Standards Institute (ETSI) regulates the GPR use and its emissions of EM radiation. The Radio and Telecommunications Terminal Equipment (RTTE) directive 1999/5/EC applies to GPR equipment and allows the placing of a GPR product on the market for sale, even if it does not give authority for its use. In order to use the equipment, in the majority of EU Member States a license is required: it is controlled and issued by the radio administration in each country. A decision of the Electronic Communications Committee, ECC/DEC/(06)08, concerns the conditions for the use of the radio spectrum by GPR imaging systems, but it is not legally binding on EU Member States and, to date, less than half the EU Member States have introduced this decision into their legislation. A more harmonized approach, consistent throughout the whole Europe, would be desirable for the advancement of GPR systems as well as for the development of uniform procedures and protocols about the effective use of this imaging technique in CE tasks. In fact, inhomogeneous recommendations for the effective use of GPR are present in different countries and various practices are used. Also the levels of knowledge, awareness and experience regarding the use of GPR in CE vary in different countries. There is a strong need for restructuring studies in this area, integrating and coordinating local initiatives. Knowledge and experience has to be shared. Procedures and guidelines have to be identified and described precisely, so that GPR users know how GPR surveys should be conducted and what the quality level for the results should be. This would ensure a higher efficiency and quality of GPR services and would create a scientific basis for the introduction of EU Standards on the application of GPR in CE.

Close interaction and collaboration should be encouraged between researchers and practitioners

utilizing GPR in the field of CE, geology and archaeology, with researchers and practitioners of other Non-Destructive Testing (NDT) technology. No doubt there is a significant synergy between different disciplines of geophysics and NDT technology that needs to be explored.
Various individuals from Universities and Research Institutes, Small and Medium Enterprises (SMEs), one of the biggest GPR manufacturers, Public Agencies responsible for infrastructure management/maintenance and other end users were involved in the preparation of this Action. The partnership covers, under a very well integrated approach, all the scientific and technical profiles needed to tackle any possible Action risk and to reach an excellent innovation standard. The research will be carried out in all the participating countries and financed by themselves. To establish the network and realize the agreed objectives, coordination and financial support is needed for: travel expenses; organization of meetings, workshops and Training Schools (TS); Short-Term Scientific Missions (STSM); grants for mobility of early career European researchers; promotion of the activities and dissemination of the results. COST is therefore the perfect framework for the needs of this project. One of the main advantages offered by COST networking is the provision of resources for a pan-European effort, so that even smaller laboratories lacking facilities are able to collaborate with other groups. Moreover, a COST Action is typically much more flexible than other programmes: the network, once established, can be enlarged; new collaborations can be formulated; perspectives and activities not foreseen at the initial stage can be included in the project. Such an open mechanism is the best for the support of this project.

B.2 Current state of knowledge

The GPR field has seen great advancements over the past 15 years. Its progress spans aspects of geophysics, technology, electromagnetics, data processing and wide ranging scientific and engineering applications. Hundreds of research papers, special issues on Journals and conference Proceedings are devoted to GPR theory and technology and also to the application of GPR in CE. The European Geophysics Union (EGU) and the Institute of Electrical and Electronics Engineers (IEEE) are interested in GPR topics. The European Association of Geoscientists and Engineers (EAGE) has a Division devoted to Near Surface Geoscience. The European GPR Association (EuroGPR) promotes GPR use, involving users and manufacturers of GPR equipment. The Forum of European National Highway Research Laboratories (FEHRL) is engaged in road engineering research topics and is interested in GPR road monitoring techniques. GPR, as other non-invasive diagnostic procedures, is of interest for several European Technology Platforms, as the European Construction Technology Platform (ECTP), the Advanced Engineering Materials and Technologies

(EuMAT), the Industrial Safety Technology Platform, the European Road Transport Research Advisory Council (ERTRAC) and the European Space Technology Platform (ESTP).

There are international events where high-level discussions and a wide exchange of experiences and results, related to GPR use in CE problems, take place. The "International Conference on GPR" and the "International Workshop on Advanced GPR" are biannual events held since 1986 and 2001, respectively. The annual EGU General Assembly hosts sessions about "Civil Engineering Applications of GPR", "Geoscience and Non-Invasive Methods for the Study and Conservation of Cultural Heritage" and "Electromagnetic Sensing Techniques and Geophysical Methods for Critical and Transport Infrastructures Monitoring and Diagnostics", which are attracting growing interest. Sessions on GPR are hosted also by conferences devoted to EM topics, as the "European Conference on Antennas and Propagation" and "International Union of Radio Science" symposia.

No COST Actions were ever focused on GPR. Among recent COST Actions, the results of the Action 354 "Performance Indicators for Road Pavements" (ended in 2008) are of interest for this Action.

Among recent relevant European research projects, it is worth mentioning the "Mara Nord" Project, carried out in Finland, Sweden and Norway from January 2010 to December 2011. This project aimed at coordinating and promoting GPR use in the surveying and rehabilitation of Scandinavian roads and led to the publication of guidelines about the use of GPR for the measurement of asphalt air voids content, the control of road construction quality, bridge deck surveys and road rehabilitation projects.

The "Integrated System for Transport Infrastructures surveillance and Monitoring by Electromagnetic Sensing" (ISTIMES) project, financed by the 7th EU Framework Programme (FP7) and coordinated in Italy, started in July 2009 and lasted three years. This project exploited different non-invasive imaging technologies based on EM sensing: optic fiber sensors, Synthetic Aperture Radar, hyperspectral spectroscopy, infrared thermography, low-frequency geophysical techniques, and ground-based systems for displacement monitoring and of course also GPR. The aim of the project was to improve and integrate EM sensing techniques in a system able to couple both the necessities of a long-term monitoring and a quick-damage assessment; the project focused on transport critical infrastructure, but the approach can be extended to other CE structures as dams and buildings.

The "Methodology for fast and reliable Investigation and Characterization of Contaminated Sites" (MICCS) FP7 project was coordinated in Denmark, started in November 2008 and ended in April 2011. In this project, an advanced in-situ investigation method was developed for identifying and characterizing subsurface pollution. An integrated sensor, with micro-chips, electrochemical sensors and spectrometry and optical sensors, was realized and it was combined with GPR.

An “International Outgoing Fellowships for Career Development” Marie Curie Action (MCA) on radar imaging sounders for EM detection, entitled “Radar Imaging: Challenges and New Approaches” (RICANA), was carried out at the University of Vigo, Spain, from June 2009 to November 2011.

A Research&Development Project of Grant Agency No. 103/09/1499 was carried out in 2009–2011, in Czech Republic; it was entitled “Multichannel Ground Penetrating Radar as a Tool for Monitoring of Road and Bridge Structures”.

The FP7 on-going projects relevant to this Action, as well as some other on-going research projects on the Action’s topic, are listed and described in Subsection B.4.

There are also research programs on GPR carried out by the Federal HighWay Administration (FHWA), an agency within the United States (U.S.) Department of Transportation, as well as by Australian and U.S. universities.

Within the framework of a unique approach based on the integrated contributions of civil and electronic engineers and physicists, from universities and research centres, software developers, NDT equipment designers and producers, end users of private companies and public agencies, this Action will address in an innovative and pan-European way all the open problems in the field of CE applications of GPR.

B.3 Reasons for the Action

This COST Action is aimed at both economic-societal needs and scientific-technological advance. The requirement for a European network on CE applications of GPR is deeply felt. This Action will strengthen European excellence in the fields concerning the success of the GPR technique. Moreover, it will allow a wider application, all over Europe, of the safe and non-destructive GPR technique to the monitoring of infrastructures, thus optimizing their management and reducing the severe and fatal accidents caused by infrastructure damage.

This Action will integrate and coordinate local initiatives within Europe, promoting the sharing of scientific, technical, economic and human resources and avoiding fragmentation of research efforts. During this Action, its members will, at the same time, carry out a number of high value national and European projects – thus the Action will enable synergy and European scale added-value.

The benefits of this Action will consist of: (i) a better understanding of the problems, merits and limits of current GPR systems in CE tasks; (ii) a deeper understanding of the relationship between GPR direct and indirect sensed quantities and soil/material functional variables useful for CE needs;

(iii) innovations in the GPR field, increasing efficiency and performances of this technique; (iv) the advancement of data-processing algorithms and EM scattering methods; (v) the networking of well-known scientists and experts in the field, the exchange of knowledge, integration of competences and instruments and the joint generation of new knowledge in the field of CE applications of GPR. The expected results will include: (i) a handbook with protocols and guidelines for effective use of GPR in CE tasks; (ii) the design, realization and optimization of innovative GPR system; (iii) the development of novel data-processing and EM-simulation algorithms, to be disseminated as freeware tools; (iv) the development of new national and international collaborations, between individuals studying different applications of the GPR or other NDT techniques for CE; and (v) the development of research exchanges.

The networking potential offered by this Action will also achieve the expected results thanks to the opportunity to access financial support for research at both national and European levels. This Action will largely profit from the benefits that the COST Programme uniquely offers. The best way to put together different specific projects and to structure and shape the way to the research carried out on GPR, and on its application to CE tasks, is through a network. Among the possible network structures, the COST scheme is the most suitable, since (i) it is wider in scope than a thematic network implemented through the Framework Programme; (ii) it involves the participation of a large number of countries and of different groups for each country; and (iii) additional partners can always join the Action during its life-time. Furthermore, the COST Action does not require a large amount of money to support a limited number of national delegates participating in the meetings and to support a program of STSMs and TSs, while the specific research activities of the participating groups are supported in each country by other institutions, agencies and companies.

B.4 Complementarity with other research programmes

To the Applicant's knowledge, in FP7 the following on-going research projects are relevant to this Action: (i) FP7 project "Tomorrow's Road Infrastructure Monitoring and Management" (TRIMM), Staten Van-Och Trasporforkningsinstitute, Sweden, December 2011 – November 2014; (ii) FP7 – Research for SMEs project on "Smart condition monitoring and prompt NDT assessment of large concrete bridge structures" (CROSS-IT), Cambridge University, United Kingdom, November 2011 – October 2013; (iii) FP7 project on "Radiography of the past. Integrated non-destructive approaches to understand and valorise complex archaeological sites" (RADIO-PAST), Univesitade de Evora, Portugal, April 2009 – March 2013; (iv) FP7 Project "SOIL Contamination: Advanced integrated characterisation and time-lapse Monitoring" (SOILCAM), June 2008 – November 2012;

(v) FP7 Project “NEw Technologies for TUNNeling and underground works” (NETTUN), Ecole Central de Lyon, France, ending in 2017; (vi) MCA on “Active and passive MIcrowaves for Security and Subsurface imaging” (AMISS), CNR, Italy, October 2011 – September 2014; and (vii) MCA on “COMPressive data acquisition and SENSing techniques for sensing applications” (COMPSENSE), TOBB University, Turkey, April 2010 – March 2013.
There are no ongoing COST Actions, ESF and Eureka Projects.
This Action will establish interactions, through its extensive network of contacts, also with other groups involved in recent and ongoing projects. These groups will be invited to join the Action. The Action itself will be executed in close consultation with all the ongoing projects, in order to harmonize the activities and guarantee the highest benefits for Europe. Cooperation via liaisons, cross-project STSMs and joint events will be effected. Moreover, this Action will open the way to future projects. This Action will cooperate with the associations, institutes and consortia mentioned in B2.

C. OBJECTIVES AND BENEFITS

C.1 Aim

The aim of the Action is to exchange and increase scientific-technical knowledge and experience of Ground Penetrating Radar (GPR) techniques in Civil Engineering, whilst simultaneously promoting throughout Europe the effective use of this safe and non-destructive technique in the monitoring of infrastructures and structures. This Action will establish active links between universities, research institutes, companies and end users working in this field, fostering and accelerating its long-term development in Europe.

C.2 Objectives

Under the main framework coming from the aim expressed in Subsection C.1, this ambitious and interdisciplinary Action is oriented to the following specific objectives and expected deliverables:
(i) coordinating European scientists to highlight problems, merits and limits of current GPR systems in CE applications;
(ii) developing innovative protocols and guidelines which will be published in a handbook and constitute a basis for European Standards, for an effective GPR application in CE tasks; safety, economic and financial criteria will be integrated within the protocols;
(iii) integrating competences for the improvement and merging of both EM scattering and data-

processing techniques and for the development of new methods; this will lead to a novel freeware tool for the localization of buried objects, shape-reconstruction and estimation of geophysical parameters useful for CE needs;
(iv) networking for the design, realization and optimization of innovative GPR equipment;
(v) comparison with GPR technology and methodology used for other applications, such as rover-based planetary exploration, archaeological prospecting and cultural heritage diagnostics, detection of explosive remnants of war and humanitarian demining, geology and geophysics, agriculture, environment research, forensics and security;
(vi) comparison with other NDT techniques for CE applications, such as ultrasonic, radiographic, liquid-penetrant, magnetic-particle, acoustic-emission and eddy-current testing;
(vii) promotion of widespread, advanced and efficient use of GPR in CE; and
(viii) organization of a high-level modular training program for GPR European users.

C.3 How networking within the Action will yield the objectives?

Collaboration and information exchange and sharing are essential in order to make the most efficient use of research, capacity building and budgets.
The objectives will be achieved by investigating novel theoretical paradigms – under a multidisciplinary approach – for GPR and EM applications to CE problems; by defining, comparing and testing procedures for advanced GPR use in various CE applications; by implementing new approaches and related software codes; by designing, realizing and testing advanced prototypes; and by employing GPR in new case studies and applicative domains. An electronic communication and information platform will be created. Mobility of early-stage researchers will be encouraged and supported. This Action will disseminate and promote its activities in order to involve a growing number of participants and attract an increasing interest from the community of end users.
The success of the Action during its lifetime will be evaluated, in relation to its scientific and technological objectives, by considering the number of peer-reviewed publications, conference presentations and invited papers of the participating scientists on the Action subjects, as well as the organization of Special Issues on Journals and Sessions in relevant events. Furthermore, the number of STSMs, patents, apparatus and prototypes realized and tested, novel protocols proposed and software developed will constitute achievements giving a quantitative idea of the Action progress. Another significant parameter will be the number of trans-national collaborative research proposals prepared and financed, involving groups participating in this Action.

The effectiveness of the Action in promoting the wiser and more widespread use of GPR in infrastructure monitoring will be evaluated by considering the new activities and projects carried out by end users during the Action lifetime. In particular, the number of initiatives will be considered, contemplating the use of GPR throughout the various stages of a structure's life: from new-construction quality control, to verification of as-built conditions, through health monitoring, to residual lifetime prediction, management and restoration and the monitoring of demolition, as well as damage assessment after a crisis event. The number of participants from industry and commerce in the Action's meetings and the number of students in the Action's Training Schools open to company members, will also be significant parameters for the evaluation of the Action's success in achieving its objectives.

C.4 Potential impact of the Action

This Action will offer innovation in the GPR field, increasing the efficiency and quality of this technique, with technological, scientific, economical and societal benefits. Moreover, this Action will lead to durable international collaborations, strengthening EU scientific networking and capacity building.

From a scientific point of view, this Action will create an efficient interlink among European laboratories interested in its topic. The activities to be carried out within the framework of this Action will increase knowledge in basic physics. They will lead to increased understanding of the interaction between EM waves and subsurface targets and the environment hosting them, as well as a deeper comprehension of the relationship between geophysical parameters and soil/material functional variables useful for CE needs. Obviously, the improvement of advanced GPR data-processing algorithms yields benefits also to other imaging techniques. The development of new EM scattering methods has implications in many branches of science as acoustics, microwaves, optics, information technology, clean-room monitoring, quality control of silicon wafers manufacture, scattering microscopy in biology and material science.

The technological impact is clear when considering the innovative GPR equipment that will be designed, fabricated and tested through the activities of this Action.

The societal and economic benefits derive from the more effective and widespread application of GPR that will take place thanks to the Action's activities. Many structures and infrastructures are affected all over Europe and throughout the world, by diffused poor condition (of course the situation is inhomogeneous). As is well known, the poor structural condition of infrastructure can

and does influence the safety of citizens. Let's think, for example, to the safety of highways, roads and bridges, buildings and constructions. Moreover, where structural rehabilitation is ineffective or even entirely absent, or where sub-standard management planning is adopted and ineffective traditional tools are used, the cost of maintenance will dramatically increase.
Besides CE, other areas using GPR will take advantage of this Action, such as archaeology, detection of landmines and explosive remnants of war, planetary exploration, geology and geophysics, agriculture, environment research, forensics and security. No doubt that the results of this Action will be extended to these fields.

C.5 Target groups/end users

This Action already received the interest of various key end-users, who were involved in the preparation of the Action. Among them, due to the high social impact of the project, are national Public Agencies involved in road and building management or safety issues. There are also Private Companies and SMEs, providing services in this field or involved in technology development.
An appropriate training plan for young researchers and company workers, realized through a programme of STSMs and Training Schools organized within the framework of this Action, will strengthen the academic research and its connections with companies and with the key technological issues relevant to the Action's topics. This will reinforce the linkage between universities, research centres and industrial/commercial institutions, thereby improving the European position in the field of GPR and its application in CE tasks.

D. SCIENTIFIC PROGRAMME

D.1 Scientific focus

The most important research tasks to be coordinated by this Action are the following:
(i) study of the problems, merits and limits of current GPR systems and of procedures for the application of GPR in CE tasks (also through comparison with GPR technology and methodology used in other fields and with other NDT techniques used in CE);
(ii) definition of innovative protocols and guidelines for the effective use of GPR in CE;
(iii) development of improved and new EM scattering methods, for the fast and accurate simulation of subsurface scenarios involving buried composite structures;

(iv) development of improved and new algorithms for the numerical processing of data measured by GPR in CE surveys;
(v) improving the shape-reconstruction of buried structures and the estimation of geophysical parameters useful for CE needs, from GPR experimental results; and
(vi) synthesis, fabrication and optimization of innovative GPR equipment, with increased resolution and advanced dedicated software.
The project is based on a strong multidisciplinary approach that is mostly effective thanks to the participation of civil and electronic engineers, software developers and geophysicists from both the academic world and commercial companies manufacturing NTD equipment. Moreover, the contribution of experts from service companies and public agencies helps in turning the high research context to practical problems and to strategic and actual applications. The involved partners will share human and technical resources as well as GPR and other NDT equipment, measuring instruments, computers and software, manufacturing machinery and vehicles to set GPR prototypes and will also carry out validation activities.
STSMs mobility of early-stage researchers will be encouraged. A high level school will be organized, lasting 3 years.

D.2 Scientific work plan methods and means

The following four Working Groups (WGs) will be present:
WG1 **–** Novel GPR instrumentation;
WG2 **–** GPR surveying of pavements, bridges, tunnels and buildings; underground utility and void sensing;
WG3 **–** EM methods for near-field scattering problems by buried structures; data processing techniques;
WG4 **–** Different applications of GPR and other NDT technologies in CE.
In this Subsection, the scientific and technological methodology and the associated work plan are presented. The objectives of each WG and its synergies with other WGs are also explicated.

The WG1 will focus on the design of innovative GPR equipment dedicated for CE applications, on the building of prototypes and on the testing and optimization of the new system.
The synergy with the WG2 and the WG4 will be useful for a deep understanding of the problems, merits and limits of currently available GPR equipment. This will help in selecting the working parameters for the new GPR, according to the application's requirements. In fact, it is likely that

there will be different versions of the equipment, each one capable to accomplish the requirements of a specific application (e.g., the monitoring of pavements, bridges, tunnels, or the monitoring of buildings, or else the sensing of underground utility and voids).

One of the key decisions in the design will concern the selection of the most suitable antenna frequency and bandwidth that impose the resolution and penetration range to be featured by the system.

It is also foreseen that the architecture of the novel system will assume the use of an array of antennas, operating simultaneously and lined up in the transverse direction with respect to the direction of movement. In fact, the use of a dense antenna array is essential for providing a clear image of the surveyed structure, or material and for improving the detection probability of sought targets.

A further benefit of using array architecture is the possibility to survey the site with a regular grid, allowing the use of advanced data-processing techniques. This is a key aspect, since these techniques and tools may be helpful to improve the consistency of performance by removing the variable contribution – the “human factor” – from the reliability of results achievable by the new GPR equipment. The interaction with the WG3 will be fundamental for the implementation of the advanced data-processing techniques.

It is also worth specifying that the use of an array of antennas enables a faster data collection, provided that the GPR controller unit is fast enough to support the data through-put. This is important for GPR operators that work on roads and cope with live traffic.

In summary, the ultimate task for the WG1 is the design of a GPR able of constructing a real-time lane wide three-dimensional (3D) high resolution image of the investigated material, structure or infrastructure.

Another topic to be analysed by the WG1 is the possibility of collecting data with different polarization. As a matter of fact, it has been proven that different polarization of the electric field transmitted by judiciously deployed sensors, provide benefit in terms of detection and target characterization. For instance, metallic targets such as rebars or cables are best detected when illuminated by an electric field parallel to them. In addition to this, is expected that a radiation pattern with a main lobe wider on the so called H-plane than on the E-plane will help in reducing reflections from undesired objects (clutter).

In close cooperation with the WG3, other research themes will be investigated; amongst those, the possibility of designing a beamforming network for the transmitting antennas, in order to develop equipment able to focus the EM waves at specific depths and at focal areas of specified size, according to the needs of the various CE applications. Furthermore, it will be necessary to interact with the WG2 for the development of advanced calibration measurement procedures as well as, finally, to test and optimize the fabricated prototypes in laboratory experiments and in real case studies.

The WG2 will focus on the surveying, through the use of a GPR system, of pavement, bridges, tunnels and buildings, as well as on the sensing of underground utilities and voids.
Initially, information will be collected and shared about state-of-the-art, on-going studies, problems and future research needs, in the application of GPR to the above-mentioned CE applications. Based on the experience and knowledge that will be gained from the above investigation and documentation, the extension of GPR application to railways track ballast assessment may be also demonstrated.
Test scenarios will be defined, representing both typical and unusual situations that may occur in the various CE tasks, for an advanced comparison of available inspection procedures (taking advantages of the interaction with the WG4), GPR equipment (interacting with the WG1), application of EM forward-scattering simulators and data-processing algorithms (thanks to the cooperation with the WG3).
Subsequently, the available equipment, inspection procedures and algorithms will be applied to the test scenarios as a joint effort of the WG1, WG2 and WG3. On the basis of these studies, innovative inspection procedures will be outlined in the WG2 for the inspection of pavement, bridges, tunnels and buildings and for the detection of underground utilities and voids. The new procedures will be tested through laboratory experiments and in real scenarios, in synergy with the WG1 and the WG3. Of course, also the fabricated prototypes of the novel GPR equipment will be used for such validation activities. A deep analysis and critical review of the obtained results will lead, at the end of the Action lifetime, to the development of a handbook with protocols and guidelines at EU level.
Particular attention will be paid in the WG2 to the main issues concerning the inspection of transportation infrastructures and the monitoring of constructions.
The application of GPR for the surveying of roads, highways and airports pavement generally include measuring pavement thickness, detecting voids beneath pavements, identifying and classifying defects and damages, distinguishing the location of reinforcing bars, identifying pavement structure changes and mapping of underground utilities.
Regarding to bridge inspection, theoretical studies and experimental investigations are typically carried out to understand the frequency effects of the GPR signal, of the temperature, of the water and chloride content and of the concrete constituents, on EM wave velocity and attenuation. Much more efforts have to be spent with the scope of developing GPR novel reliable and efficient

waveform inversion techniques and to implement algorithms for a better understanding of the influence of delamination cracks on the GPR signal (interaction with WG3).

Special care will also be paid in the WG2, to collect all the available knowledge and experience of the partners involved in the Action for the determination, by using GPR, of the volumetric water content in structures, sub-structures, foundations and soil. Approaches, models and algorithms will be compared, in cooperation with the WG3, in order to define common protocols and methods for measurements and evaluations. A crucial improvement is expected and strongly needed in this field. In fact water infiltration is often a relevant cause of degradation of structures and pavement and of corrosion of bars. It is worth noting that the estimation of water content is an important topic also in hydrology and hydraulic science, as well as in agricultural/irrigation and industrial applications.

The WG3 will focus on accurate and fast EM-scattering methods for the characterization of scenarios that are of interest in GPR and CE fields and also on effective data-processing algorithms for the elaboration of GPR data collected during CE surveys.

Initially, information will be collected and shared about state-of-the-art of the available EM-scattering and data-processing methods. As already mentioned, test scenarios will be defined, interacting with the WG2 and the WG4.

For what concerns EM-scattering methods, particular attention will be paid to the FDTD technique and to the spectral domain CWA and Spherical-Wave Approach (SWA). When the sought targets are long and thin, 2D methods have to be employed, being more effective and faster than 3D ones; on the other hand, with 3D approaches it is possible to characterize more complex scenarios.

The FDTD, CWA and SWA algorithms will be applied to the test scenarios. They will be further developed and improved during the Action’s lifetime, as explained in the following. The accuracy of the improved codes will be benchmarked and validated with respect to laboratory measurements.

In the well-known FDTD technique, the Maxwell's equations are solved through space and time discretization. A freeware and versatile tool for the simulation of buried objects already exists and is well-known in GPR community. Its developers are interested in joining this Action. This tool will be further tested and improved during the Action lifetime. In particular, the WG3 will work on the introduction in this tool of a more realistic representation of the soil/material hosting the sought structures and of EM source. Moreover, more advanced absorbing boundary conditions will be developed and employed, in order to limit the computational domain and improve the execution speed of the model. A Graphics Processing Unit (GPU)-based solver will be implemented, that will allow the computation of 3D models in workstations using GPUs.

In the CWA, the field scattered by subsurface 2D targets with arbitrary cross-section is expressed as a sum of cylindrical waves; use is made of the plane-wave spectrum of such waves to take into account the interaction of the scattered field with the interfaces between different materials that constitute the medium hosting the sought targets. With this accurate technique, all the multiple reflections and interactions between targets are taken into account and results for the EM field can be obtained in any point of the space and in both the frequency and time domains. During the Action's lifetime, this method will be further tested and developed by the WG3: in particular, more realistic EM sources will be considered (different from the monochromatic or pulsed plane-wave already implemented). The available codes will be optimized in order to become faster and allow the simulation of more complex scenarios.

In the SWA, the field scattered by subsurface 3D targets is expressed as a sum of spherical waves; use is made of the plane-wave spectrum of such waves to treat the interaction with interfaces between different materials. This method is just emerging and is very promising, with some preliminary but very encouraging results being presented for the first time this year, in international conferences. The method needs to be further tested, significantly extended and improved. During the Action's lifetime, it will be implemented for arbitrary-shape targets (at present only spherical-shape targets can be simulated). More realistic environment and sources will be modelled.

As far as data-processing algorithms are concerned, advanced techniques will be studied, exploiting the regular grid of data collected by the array of antennas of the novel GPR equipment.

Moreover, particular attention will be paid to the improvement and automation of GPR data time-varying deconvolution algorithms. The automation will mainly focus on the time-varying band-pass filtering procedure (empirical-mode decomposition and complex-spectrum smoothing techniques). Algorithms for spectral balancing and zero-phase deconvolution will be developed. Blind deconvolution will be investigated to manage the model uncertainty.

The EM and data-processing methods will be employed to study shape-reconstruction of targets and quantitative estimation of EM parameters, as the permittivity of dielectric objects and related quantities as density and, as already mentioned, water content. In cooperation with the WG2 and the WG4, an extension of the information resulting from GPR data to new physical parameters useful for CE needs will also be studied.

Due to the EM experience of individuals working in this group, the WG3 will also interact with the WG1 concerning beamforming aspects, as outlined above.

At the end of the Action, a freeware tool will be released, including novel EM and data-processing algorithms, for the benefit of the GPR community. Easy-to-use Graphical User Interface (GUI), examples and manuals will be available for the new software, in order to make it easily accessible and useable by researchers and professionals. Comparison between the results of this software and of well-known commercial software will be carried out and will be worth for the end-users.

The WG4 will work on the different applications of GPR and on other NDT techniques for CE. The possible applications of GPR and NDT methods already employed within CE will be explored. The methodology and technology used in CE will be compared with those employed in such areas as rover-based planetary exploration, archaeological prospecting and cultural heritage diagnostics, detection of explosive remnants of war and humanitarian demining, localization of buried and trapped people, geology and geophysics, agriculture surveys, environment research, forensics and security. The integration of other NDT techniques useful for CE tasks with GPR systems will be studied. Among such techniques there are ultrasonic testing, radiographic testing, methods employing surface waves, approaches involving the using of an open co-axial probe combined with a vector network analyser, liquid-penetrant testing, magnetic-particle testing, acoustic-emission testing and eddy-current testing.

In the field of CE, several methods that are commonly used in solid earth geophysics have their counterparts in non-destructive testing. In fact, the most used construction materials are mineral aggregates, such as concrete (mineral aggregates, cement, additives) or asphalt (mineral aggregates, bitumen, additives); soils and rocks are mineral aggregates, too. Thus, it is possible to effectively use earth-monitoring methods for CE applications, of course the scale of structures and infrastructures is much smaller rather than the one of the earth and an adaption of the methods is recommended and required. For example ultrasonic testing is used for NDT rather than seismic testing. Typically, the focus of inspection and testing in CE is on structural information, such as layer thicknesses, bar corrosion and positions of fittings (e.g. tendon ducts), or else it’s on material properties, such as bulk density, compaction or water content. In these applications, it will be studied how ultrasonic and impact-echo methods can be integrated with GPR technique, improving the potential of the combined technology.

One of the most important equipment coupled with GPR that received recently a wide attention is the Falling Weight Deflectometer (FWD) and its Light version (LFWD). It is a mobile device consisting of a variable weight that can be dropped from different heights, a loading plate for uniform force distribution, a load cell for measuring the applied pulse, one or several deflection sensors and a system for recording and displaying the deflection data. Young moduli are calculated from the propagation speed of mechanical waves in the medium through a back calculation approach once the thicknesses of the materials are measured using GPR. This kind of device and its joint use with GPR will be further studied.

Electric and other EMmethods will be also considered. Self-potential methods and DC methods can

be used for the inspection of reinforced concrete, particularly for locating near surface metal structures such as rebars.
The infrared thermography seems to be the best candidate for detecting defects through the map of the surface temperature of objects.
The points of weakness and the points of strength of integrating these, and other, novel technologies with GPR will be analysed within the activities of the WG4, with the aim of optimizing the methods and the equipment and finding new reliable survey procedures.
Synergies of the WG4 with other WGs have already been explicated.
The scientific work plan of the Action is intended to be open, to ensure that interested experts who did not participate in the preparation may join the project at a later stage if their countries accept the MoU.

E. ORGANISATION

E.1 Coordination and organisation

The organization of the Action conforms to the "Rules and Procedures for Implementing COST Actions" (document COST 4154/11). The research will be carried out in and financed by the participating countries, while COST will provide the necessary coordination.
The Project Management structure will be based on a Management Committee (MC), following the rules given in the above mentioned document. The MC will coordinate the Action, supervise its progress and stimulate necessary activities. It will coordinate the WG's activities in the four areas set out in the scientific programme. The MC will report on the progress of the Action to the COST Office on a yearly basis and through a Final Report that will be issued as a book produced by a recognized publisher, as well as through the Handbook of guidelines and protocols for effective use of GPR in CE tasks.
A project Editorial Board (EB) will be instituted. It will deal with dissemination of the Action's activities. It will also deal with the above mentioned Handbook and Action's reports (which distribution and publication will be decided in cooperation with the COST Office). A Technical Editor will be appointed, managing the Action website. An Editorial Coordinator will coordinate the activities of the EB.
STSMs and mobility of early-stage researchers will be encouraged and supported. Applications will be selected by the MC and will initiate or strengthen bilateral cooperation, thus completing Action goals. A STSM Manager will be appointed.

There will be a Training School Manager.

A Steering Group (SG) will be instituted. It will comprise the MC Chair and Vice Chair, together with the WG Chairs and Vice Chairs, the Editorial Coordinator, the STMSs and the Training School Managers. The SG will implement the MC's policy decisions and moreover it will contribute to the building of COST Action events (meetings, workshops, conferences, STMSs, Training Schools), to the dissemination of Action findings and to the managing of the Website.

The Action will take care of coordinating national research, through the SG and the MC. Possible common research teams will be created among Action compatriots and national conferences, workshops and seminars will take place, as well as exchanges between laboratories, national training schools and national websites.

The main milestones crucial to the future direction of the Action will include:

(i) Founding Conference (start of Action);

(ii) MC Meetings (two per year);

(iii) SG Meetings (two per year, co-located with MC Meetings);

(iv) WG Meetings (two per year, co-located with MC and SG Meetings), to plan activities and analyse results;

(v) Annual Conferences, for the presentation and discussion of results (end of each year);

(vi) Annual Training Schools (from the second to the fourth year of the Action), providing theoretical, methodological and technological training;

(vii) STSM Workshops, regarding activities carried out during STSMs (from the second to the fourth year of the Action, co-located with Training Schools); and

(viii) Final Conference (after the end of the Action).

The Founding Conference will see the participation of Action's members and will also be open to external participants. This will facilitate the starting of efficient networking between participants' labs, help Action's community to identify themselves and their research areas, make the Action visible to the outer world and also attract new parties to participate actively to the Action.

An end-user database will be created; it will be integrated as new expressions of interests will come.

In order to serve the needs of the participants, to create easier partnership integration and with the specific aim of ensuring the dissemination and exploitation of the results of the Action, a communication system will be set up and a specific website will be created.

The website will be launched at the start of the Action and kept updated. A major update of the Website will take place after each MC-WG-SG Meeting, Annual Conference, Training School and STMSs Workshop and of course after the Founding and Final Conferences. The Action's news, opportunities, collaborative projects, findings, innovations and applications will be published on the website. The latter will give the Action a high profile, making it more dynamic and optimizing dissemination to Action's participants as well as to other experts, professionals, companies, politicians, public-funding authorities and citizens. Password protection will allow Action's members to share confidential information, while there will be unrestricted public access to more general information. The popularity of the website will be measured in terms of the hit rates for its main pages. The website will be registered in appropriate portals, in order to increase traffic flow. The purpose of the unrestricted access section of the website will be to give the Action maximum visibility and reach as wide an audience as possible. In the password-protected section, there will also be a collaboration platform (mailing network, forum, chat rooms and blogs), giving WG members an interactive space for the purposes of communication within and between WGs, keeping track of the Action's progress, disseminating calls for papers, events and financing opportunities, exchanging ideas and electronic resources, publishing of intermediate reports, minutes of meetings, reports by STSM researchers, results and also researchers' CVs and pre-publication research. The Website Manager will manage the updating of the website and coordinate its content, after validation and in accordance with the line decided by the SG.

E.2 Working Groups

There will be 4 WGs:

WG1 – Novel GPR instrumentation;

WG2 – GPR surveying of pavements, bridges, tunnels and buildings; underground utility and void sensing;

WG3 – EM methods for near-field scattering problems by buried structures; data processing techniques;

WG4 – Different applications of GPR and other NDT technologies in CE.

The effectiveness of this scheme will be checked after its first year and will eventually be modified, considering the actual number of active participants in each WG and the number of new participants that join the Action. The structure of the WGs will always be kept as flexible as possible, in order to enable other participants to join the Action. All the participants, when joining the Action, will be invited to provide basic information on their experience, interests, current research projects and WG preference. Each participant can belong to two WGs (one WG must have priority).

Each WG will be managed by a Chair and a Vice Chair (both SG members). The WG meetings will be an opportunity to present activities, results and plans for the future. Between meetings, the

Website and more particularly the collaboration platform (restricted access), will be used to interact.

E.3 Liaison and interaction with other research programmes

Every effort will be made to interact with other COST Actions and other European and international research programmes.
The Action will contact groups carrying out relevant recent projects, as those mentioned in Subsection B.1, and on-going projects, as those mentioned in B.4. They will be invited to join the Action. Many experts involved in on-going and recent projects were contacted and contributed to the preparation of this Action. The Action will be executed in close consultation with on-going projects, in order to harmonize the activities and guarantee the highest benefits. Cooperation will be carried out via liaisons, exchange of information, cross-project STSMs and joint events.
It is very important to establish cooperation between this Action and EGU, IEEE, EAGE, EuroGPR and FEHRL.
Whenever possible, the Action events will be organized just before or just after important international events related to GPR use in CE. This will facilitate the participation of Action members in these events, whilst attracting more researchers to attend the Action event, thus improving the exchange with other research projects, the Action visibility and its success.

E.4 Gender balance and involvement of early-stage researchers

This COST Action will respect an appropriate gender balance in all its activities and the MC will place this as a standard item on all its agendas. This Action will also be committed to considerably involve early-stage researchers. This item will also be placed as a standard item on all MC agendas. This Action will especially encourage young researchers to contribute actively in its activities. Early-stage researchers will be nominated as Chairs of WGs, whenever feasible. STSMs will represent an important mean toward capacity building for early-stage researchers. This Action will promote and support the involvement of young researchers in Training Schools and events, encouraging their personal presentation of contributions.
Gender balance is a priority of this network and the Action Proposer is a female. Effort will be made to pursue gender balance in the Action participation, in the MC membership and in the nomination of WG Chairs. The Action will take care to ensure that the distribution of beneficiaries

of the STSM scheme is gender-balanced and the same with participation in Training Schools. Action events will be planned and organized so that they will be accessible to researchers with family duties.

F. TIMETABLE

The duration of the Action will be 4 years.

The Action will start with a Founding Conference, with presentations by all partners; the Action Management Structure will be founded.

Annual Conferences will be held at the end of each year.

MC Meetings will be organized at the end of each Action General Meeting (WG & SG & MC Meetings). There will be two Action General Meetings per year. The Action General Meeting taking place at the end of each year, shortly after the Annual Conference, will be considered as a milestone of the Action, when progress will be evaluated and necessary actions and initiatives will be taken.

Annual STSM Workshops and Training Schools will be held jointly during the second, third and fourth years of the Action.

Three months after the end of the Action, there will be a Final Conference; six months after the end of the Action, the Final Report will be produced.

Year 1

Participants will collect and share information about state-of-the-art, on-going studies and problems in the field of GPR CE applications. Test scenarios will be defined, representing both typical and unusual situations that may occur in CE applications, for an advanced comparison of available GPR equipment, inspection techniques and data-processing algorithms, to be performed during the next year of activity. An end-user database will be created. The communication system and website will be set up.

Month 0: Founding Conference

Month 6: Action General Meeting

Month 11: Annual Conference

Month 12: Action General Meeting

Year 2

Participants will apply and compare, in a multidisciplinary and multinational way, GPR equipment, inspection practice and algorithms. A strong researcher exchange will occur, mostly involving PhD students and young researchers. Also instrumentation and other resources will be shared.

Month 3: STSM Meeting and 1st Training School

Month 6: Action General Meeting

Month 11: Annual Conference

Month 12: Action General Meeting

Year 3

On the basis of the activity carried on during previous years, innovative inspection procedures will be outlined and tested. Improved EM and data-processing algorithms will be developed, for a full-wave characterization of GPR scenarios and for an accurate estimation of geometrical and geophysical parameters. Novel GPR equipment will be designed and realized, able to construct real-time lane 3D high resolution images of the investigated areas.

Month 3: STSM Meeting and 2nd Training School

Month 6: Action General Meeting

Month 11: Annual Conference

Month 12: Action General Meeting

Year 4

A comprehensive study and critical review of results obtained during preceding years, will lead to the development of a handbook with protocols and guidelines at EU level. The new equipment will be tested and optimized. Graphical user interface (GUI) and manuals will be realized for the new software, to be released as a freeware tool for the benefit of the GPR community.

Month 3: STSM Meeting and 3rd Training School

Month 6: Action General Meeting

Month 11: Annual Conference

Month 12: Action General Meeting

Month 15: Final Conference

Month 18: Final Report

G. ECONOMIC DIMENSION

The following COST countries actively participated in the preparation of the Action and confirmed their interest in joining it: AT,BE,CH,CZ,DE,EL,ES,FI,FR,IT,NL,PL,PT,TR,UK. On the basis of national estimates, the economic dimension of the activities to be carried out under the Action has been estimated at 60 Million € for the total duration of the Action. This estimate is valid under the assumption that all the countries mentioned above but no other countries will participate in the Action. Any departure from this will change the total cost accordingly.

H. DISSEMINATION PLAN

H.1 Who?

The target audience for the dissemination of the results of the Action includes:
(i) researchers working in the field, with special attention to early-stage researchers and PhD. Students;
(ii) commercial companies working in the field, as service providers or as manufacturers of GPR equipment;
(iii) Public Agencies and Institutions responsible for the management and maintenance of public structures and infrastructures;
(iv) associations and project consortia working in the field;
(v) audience from other research frameworks;
(vi) International Standard Bodies;
(vii) Politicians;
(viii) general public.

H.2 What?

The dissemination of information, activities, findings and recommendations produced by this Action will be tailored to each of the above mentioned audience categories.
General information will be posted on the Website, while more specific information will be targeted at individual groups.
For scientific communities and experts from commercial companies, the dissemination methods will include:
– articles in peer-reviewed scientific and technical Journals;
– state of the art reports, intermediate, annual and case-study reports, proceedings of scientific events, handbook of protocols and guidelines, software manuals and final reports;
– workshops, meetings, conferences and seminars organized by the Action;

– Training School;
– distribution of free CD-ROMs, DVDs or USB pendrives, featuring documents and other multimedia resources emanating from each of the four research areas;
– contributions to international and national conferences and symposia;
– a mailing list (with summaries of the Action's main findings and scientific events);
– specific mailings to interested laboratories, associations and consortia;
– subscriptions to a newsletter via the Website (with detailed presentations of findings and scientific events);
– internet discussion forum;
– password-protected section of the Website.

For Public Agencies and Institutions responsible for the management and maintenance of public structures and infrastructures and for commercial companies, dissemination methods will be the following:

– articles in non-technical Journals and publications;
– flyers and brochures explaining the Action and its potential applications;
– distribution of free CD-ROMs and DVDs featuring documents and other resources (texts, slides, videos);
– invitations to Training Schools, workshops and conferences;
– demo activities;
– access on the website to non-technical pages, publications, recommendations and other downloadable resources; and
– final reports.

International Standard Bodies will find interest in many of these dissemination initiatives and resources and in the handbook of protocols and guidelines that will be published at the end of the Action.

For European citizens and politicians, the Action activities and results will be disseminated through the public-access section of the Action's website, through television, radio and newspaper interviews, posters in public places, press releases and news items posted on popular websites and discussion forums.

H.3 How?

Information relating to the Action will be continuously disseminated throughout the 4-year duration. The nature of this information will, of course, take into consideration the progress of the Action as well as the results of its evaluation, will change as the research projects near completion and will keep step with the calendar of events.

The reports on all the Action's activities will be systematically posted on the COST network, thereby ensuring a high level of visibility.

The advances reported at the scientific meetings, conferences and Training Schools will give rise to proceedings-style joint publications. The results of the workshops will primarily give rise to articles in peer-reviewed Journals. The volume of guidelines, protocols and recommendations will increase as the Action's work advances, while information will be regularly provided to the general public. The dissemination plan will be in accordance with the MC's recommendations.

All publications, documents and disseminated resources will be archived in an appropriate e-print repository of the COST Office and in the Action's website.

The Action will organize many of its events co-located with recognised international events, in order to assure a wide audience and impact. The WGs of the Action will organize special topical sessions at main events, with a large participation of the Action's members.

An important part of the dissemination activity will be targeted at young researchers. With this aim in mind, three Training Schools will be organised during the lifetime of the Action. The schools will deal with basic, applied and advanced topics, will be open to industrial participants and, in order to address properly the needs of industry, the programme of specific sessions of the School will be discussed and decided in agreement with representatives of companies interested in sending members of their staff as students. On the other hand, for students coming from participating institutions, the programme of the School will be completed by means of a short visit to one of the participating laboratories supported through the STSM programme.

The Action will promote and support the publication of joint scientific and technical papers, containing the results obtained in the framework of the Action and authored by members of the Action, in peer-reviewed scientific and technical Journals.