Brussels, 12 February 2016

COST 010/16

DECISION

Subject: **Memorandum of Understanding for the implementation of the COST Action "European Network on NMR Relaxometry" (EURELAX) CA15209**

The COST Member Countries and/or the COST Cooperating State will find attached the Memorandum of Understanding for the COST Action European Network on NMR Relaxometry approved by the Committee of Senior Officials through written procedure on 12 February 2016.

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MEMORANDUM OF UNDERSTANDING

For the implementation of a COST Action designated as

COST Action CA15209
EUROPEAN NETWORK ON NMR RELAXOMETRY (EURELAX)

The COST Member Countries and/or the COST Cooperating State, accepting the present Memorandum of Understanding (MoU) wish to undertake joint activities of mutual interest and declare their common intention to participate in the COST Action (the Action), referred to above and described in the Technical Annex of this MoU.

The Action will be carried out in accordance with the set of COST Implementation Rules approved by the Committee of Senior Officials (CSO), or any new document amending or replacing them:

a. "Rules for Participation in and Implementation of COST Activities" (COST 132/14);
b. "COST Action Proposal Submission, Evaluation, Selection and Approval" (COST 133/14);
c. "COST Action Management, Monitoring and Final Assessment" (COST 134/14);
d. "COST International Cooperation and Specific Organisations Participation" (COST 135/14).

The main aim and objective of the Action is to exploit Nuclear Magnetic Resonance relaxometry for the profit of medical diagnostics and therapeutics, advanced materials industry, environmental engineering and agri-food science, focusing on : early disease detection and smart contrast agents, energy sources and storage, innovative materials for nano- and bio-technology, properties of food and natural resources.. This will be achieved through the specific objectives detailed in the Technical Annex.

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 80 million in 2015.

The MoU will enter into force once at least five (5) COST Member Countries and/or COST Cooperating State have accepted it, and the corresponding Management Committee Members have been appointed, as described in the CSO Decision COST 134/14.

The COST Action will start from the date of the first Management Committee meeting and shall be implemented for a period of four (4) years, unless an extension is approved by the CSO following the procedure described in the CSO Decision COST 134/14.

TECHNICAL ANNEX

OVERVIEW

Summary

The “European Network on NMR Relaxometry” Action aims to develop a research network focused on NMR relaxometry for fundamental and applied sciences concerned with the molecular dynamics of soft and hard matter.

NMR relaxometry possesses the unique ability to reveal the mechanisms of molecular motion and their characteristic times over a huge range of time scales from picosecond to millisecond, with selectivity in probing the dynamics of molecular and ionic species. This potential of NMR relaxometry will be developed with applications in advanced materials science and industry, medical diagnostics and therapeutics, agri-food and environmental science and technologies. This research is intrinsically related to progress in the understanding of spin relaxation phenomena and in technological development, as both components form the basis for the fundamental and technology-oriented research employing NMR relaxometry.

NMR relaxometry is a scientific and technological asset of Europe. The joint efforts of scientists across numerous disciplines (chemistry, physics, materials science and others), of medical doctors and engineers, regrouped through the networking means provided by this Action, will allow the efficient exploitation of NMR relaxometry in fields that are currently key challenges for Europe, such as early disease detection, energy sources and storage, advanced tuneable materials, food quality, soil fertility, water and sediment performance.

The Action will play a seminal role in facilitating links between the scientific and industrial communities for knowledge exchange and technology transfer to stimulate cross-disciplinary innovations, educating the next generation of talented researchers and developing the full potential of NMR relaxometry in Europe.

Areas of Expertise Relevant for the Action	Keywords
● Physical Sciences: Atomic, molecular and chemical physics ● Physical Sciences: Soft condensed matter (e.g. liquid crystals) ● Chemical sciences: Spectroscopic and spectrometric techniques ● Medical engineering: Diagnostic tools (e.g. genetic, imaging) ● Physical Sciences: Quantum physics	● Nuclear Magnetic Resonance ● Fast Field Cycling NMR Relaxometry ● Spin Relaxation ● Dynamics of Condensed Matter ● Magnetic Resonance Imaging

Specific Objectives

To achieve the main objective described in this MoU, the following specific objectives shall be accomplished:

Research Coordination

- To coordinate research activities by initiating and encouraging networking between physics, chemistry, medicine, engineering and materials science
- To improve mutual understanding across disciplines
- To stimulate innovative scientific ideas
- To promote dissemination of scientific achievements
- To identify industrial interests and applications

Capacity Building

- Addressing the current scientific and technological challenges
- Fostering development of joint research agendas
- Fostering knowledge transfer to a large, diverse community
- Involving industrial partners
- Preparing the next generation of competitive young researchers
- Involving Early Career Investigators and promoting equality and diversity among all participants

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DESCRIPTION OF THE COST ACTION

1. S&T EXCELLENCE

1.1. Challenge

1.1.1. Description of the Challenge (Main Aim)

The aim of the Action is to boost the science of Nuclear Magnetic Resonance (NMR) relaxometry for the profit of medical diagnostics and therapeutics, advanced material industry, environmental engineering and agri-food science and technology, which will benefit the society in general. The Action will focus on innovative materials for nano- and biotechnology, electrolytes and energy storage materials, Fast Field Cycling (FFC) based medical imaging and in-vivo studies, new generation of contrast agents for MRI, food properties and quality and properties of soil, rocks and natural resources. Developments in fundamental science are of primary importance as a stepping stone to achieve these goals.
Therefore, the Action will:

- Exploit the outstanding opportunities to expand the knowledge of molecular dynamics in soft and hard matter and develop a better understanding of spin relaxation phenomena.
- Enhance and promote collaboration between research groups focused on molecular science by means of other experimental methods and computational modelling.
- Transfer the knowledge and disseminate the results to a broad scientific community and to possible stakeholders.
- Enhance the dialogue with and between relevant industry partners to further develop instrumentation and spread-out NMR relaxometry in different technological sectors.
- Educate the next generation of scientists and engineers.

NMR is a highly-developed, non-invasive technique which is used for the study of all types of solid and soft matter and involves the resonant detection of interactions between magnetic atomic nuclei and an externally-applied magnetic field. An extremely versatile experimental method, based on NMR, involves measurement of the so-called “relaxation times” of the atomic nuclei for systems in different physical states (liquid, solid) and degrees of complexity (small molecules, electrolytes, macromolecules, biological tissues, soils and foodstuffs).
As the relaxation times are highly sensitive to the motion of the investigated molecules, NMR relaxation studies offer the unique possibility to probe dynamics of soft and hard matter at a molecular (atomic) level. Understanding the nature and mechanisms of molecular motion is a fundamental subject of science with important implications for the technological and economic/societal development. In fact the concept of Magnetic Resonance Imaging (MRI) is based on exposing differences in dynamical properties of water (and hence ^{1}H NMR relaxation) between healthy and pathological tissues. This discovery has revolutionised medical diagnostics and led to the award of the Nobel Prize for Physiology or Medicine to Lauterbur and Mansfield in 2003.
NMR relaxation studies have gained new momentum thanks to the ability to perform them as a function of the strength of the applied magnetic field. Such measurements are called “NMR relaxometry”, and literally bring a new dimension to NMR, that of the variation of the magnetic field strength. They allow probing different frequencies of molecular motion. The available range of magnetic fields spanning from hundreds of nT to about 20 T implies that one can investigate, by a single experiment, motional processes across a huge range of time scales (from ms to ps).
The motion of molecules forming the complex matter around us determines its macroscopic and functional properties so that it raises obvious curiosity. This interest has led to developing elaborate numerical methods and computer modelling of dynamics and structure of molecular systems, also leading to the award of a Nobel Prize in 2013 to Martin Karplus, Michael Levitt and Arieh Warshel. Amazing features of molecular motion predicted by computer simulations increase the desire to “see” experimentally these effects on a molecular level, not only their macroscopic outcome. This is where

NMR relaxometry has earned the name “molecular rheology”, demonstrating its virtue with respect to other established methods such as neutron scattering (NS), dielectric spectroscopy (DS) or optical methods (OM). The advantages of NMR relaxometry are not only the unique ability to reveal mechanisms of molecular motion (besides its characteristic time), but also its selectivity (using different nuclei or by introducing spin labels) and its capacity to investigate non-polar (or nonpolarisable) systems (contrary to DS or OM).

The most efficient way of implementing NMR relaxometry is via a method called “Fast Field Cycling” (FFC). More than thirty European laboratories have been equipped with FFC NMR relaxometers since the beginning of the 2000s and about twenty instruments have been installed outside Europe. These remarkable experimental opportunities have kicked off a whole chain of interdisciplinary research at the interface between physics, chemistry, material science, biology and medicine, stimulating and presenting also new theoretical and instrumental challenges.

Moreover, to fully profit from the unique experimental methodology a parallel progress in relaxation theory is needed. This task has been undertaken by a part of the FFC NMR community with noteworthy success, for instance the theory of Paramagnetic Relaxation Enhancement explaining and predicting the effects of contrast agents used in MRI or a theoretical concept allowing for a straightforward determination of translation diffusion coefficients in condensed matter. The theoretical effort has eventually led to very important achievements, such as the design and production of efficient contrast agents for MRI in collaboration with chemists and materials scientists or the construction of FFC based medical scanners thanks to collaboration with medical engineers and doctors and to progress in FFC technology.

These examples show that such a joint effort is highly profitable and that it should be considerably strengthened, in order to maintain momentum and bolster the clear European lead in FFC technology, methods and applications that is currently enjoyed.

1.1.2. Relevance and timeliness

The goal of this Action is to exploit NMR relaxometry in fields that are currently key challenges for Europe: medicine and healthcare (with early disease detection and smart contrast agents), energy sources and storage (with solid and liquid electrolytes, batteries, capacitors, conducting membranes and cooling media), advanced materials (with nanocrystalline and macromolecular systems), food quality and environmental science (with food transformation and quality enhancement of water, soils and sediments). All macroscopic effects and features have their origin in molecular dynamics and structure therefore NMR relaxometry has a large potential and the topics covered by different groups are very broad. In turn, this makes the research community highly fragmented. To achieve optimal progress there is a need for an over-arching structure within which the necessary transfer of knowledge and resources (theory, software, instrumental improvements) can take place.

The Action scientific tasks, listed below, aim at joining the efforts of the scientific experts of various disciplines and industry partners of the FFC NMR community:

- To advance knowledge on dynamics in soft and hard matter. A thorough understanding of molecular motion in complex systems is still missing impeding scientific and industrial progress, and the community is in danger of losing the expertise in this demanding area as the senior community is approaching retirement without renewal.
- To contribute to the research of advanced, tuneable materials. The gained knowledge will be of great significance for future industrial, biomedical and environmental applications.
- To transfer FFC technology from NMR to MRI and advance the development of targeted contrast agents for MRI in order to enhance diagnosis and the monitoring of treatment.
- To develop methods for the investigation of properties and quality of food and natural resources to improve the well-being of our society.
- To develop innovative theoretical and experimental tools, in particular aimed to render NMR relaxometry exploitable by a broader set of users.

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1.2. Specific Objectives

1.2.1. Research Coordination Objectives

For the success of the tasks outlined forward-thinking research capacities are required that can only be achieved by joint interdisciplinary effort and accumulated knowledge of a critical mass of outstanding researchers. The Action offers the exceptional opportunity to meet the following objectives:

- Coordinate research activities. This Action has two levels: a local and a global one. On the local level it brings close cooperation between experimentalists, theoreticians and instrumentalists working on NMR relaxometry. The Action will allow merging diverse skills of research groups to produce a broad body of knowledge which will form the background to face scientific and technological challenges. On the global level the Action answers a requirement for necessary networking between different disciplines (physics, chemistry, medicine, engineering, materials science, environmental and food science and engineering). The Action will provide means for a large group of researchers to be able to consistently and systematically contribute to the wide-ranging research programme.
- Improve mutual understanding across disciplines. The Action puts great emphasis on ensuring that scientists in different fields reach a better mutual understanding which will spread further for the profit of joint undertakings. To achieve that, careful thought about dissemination activities will be carried out (section 2.2.2).
- Stimulate innovative scientific ideas. The network activities will give new insights and impulses to identify future research directions including research in different fields. The Action will foster development strategies to prepare innovative proposals to successfully participate in EU funding programmes.
- Promote dissemination of scientific achievements. Dissemination of results is crucial to accelerate research progress by sharing knowledge with other communities. Advertising of scientific achievements increases the visibility of the intertwined scientific and technological problems and improves the awareness of their significance for European policies. The Action will promote NMR relaxometry as an important contribution to the advancement of science and technology.
- Identify industrial interest and applications. The Action aims to improve the communication between academia and industry to identify key industrial applications and subjects of which the scientific community may not have previously been aware.

1.2.2. Capacity-building Objectives

Much of the work on NMR relaxometry is carried out in Europe, and indeed European academic and industrial teams still enjoy a very clear leadership in this area. The aim of this Action is to provide a structure that will enable European NMR relaxometry research to flourish, realising its full potential. This will be achieved by:

- Addressing the current scientific and technological challenges. There are four relevant directions which will be pursued during this Action: developing strategies to tailor advanced materials, improving diagnostic and therapeutic methods, improving and monitoring food properties and developing means to understand environmental processes. These goals require bridging together separate fields of fundamental and applied science.
- Fostering development of joint research agendas. The outlined research objectives rely on sound scientific bases and can be realistically achieved within the period of the Action with the conduct of joint research plans including theory and modelling, properties of soft and hard matter and instrumental development.
- Fostering knowledge transfer to a large community. NMR relaxometry is currently largely restricted to specialised research laboratories because it requires expert knowledge to operate the equipment and to perform the data analysis. Yet a great potential is perceived for technological transfer to many kinds of laboratories and industry. The Action is an ideal means to extend the

availability of NMR relaxometry by developing user-friendly, straightforward protocols for experimental design and execution and for data analysis.

- Involving industrial partners. This Action will play a seminal role in facilitating links within the scientific and industrial communities. A transfer of scientific and technological knowledge to the industry will foster industrial competitiveness of Europe in the target areas.
- Preparing the next generation of competitive young researchers. A new generation of researchers will be trained. Besides training schools within this Action, senior scientists groups will be created for the provision of advice for Early Career Investigators (ECI). Special emphasis will be put on offering a comprehensive access to theoretical tools as the community is in danger of losing the expertise in this demanding area.
- Involving ECI and promoting under-represented gender. The Action will increase the active involvement of ECI to the joint research (section 2.2.2) and maintain a good gender balance and national diversity in the research teams.

1.3. Progress beyond the state-of-the-art and Innovation Potential

1.3.1. Description of the state-of-the-art

In recent years interest in NMR relaxometry has exploded. The research activities are divided into four main work streams: determination of dynamical and structural features of complex molecular systems, theory and modelling of spin relaxation phenomena, instrumental development and a broad range of applications. NMR relaxation is a very special phenomenon. In fact, it is difficult to imagine another example of a research field that is so multi-faceted. For instance, when looking at the same NMR relaxation data collected from food products, one may see a manifestation of quantum statistical spin relaxation phenomena, or a confirmation of the good quality of this product. Both opinions are correct as the food product contains protein molecules which are immobilised and therefore show peculiar quantum-mechanical relaxation properties which are the fingerprint of the good quality, because they indicate the appropriate fraction of immobilised proteins in the food.

These research activities have seen some important achievements during the last decade, the most important being:

- **Fundamental and applied materials science**. NMR relaxometry has been applied to study dynamics of molecular and ionic liquids. There is little fundamental understanding of how the dynamics of interacting molecules enable the formation of combined entities. Motional correlations are crucial to understand transport properties and self-organisation/aggregation of molecular and ionic species. Ionic liquids raise high expectations as a new generation of electrolytes whose transport properties can be tuned, provided one can relate their conducting properties with the correlated ion dynamics. NMR relaxometry has proven to be a perfect tool to study the complex network of motional correlations caused by ionic interactions.

Dynamics of liquids in confinement investigated by NMR relaxometry has attracted a lot of attention in recent years. The research focuses mostly on water (because of its relevance to biology), ionic liquids and polymers. NMR relaxometry has also turned out to be a prominent tool for studying dynamical properties of macromolecular systems: polymers, liquid crystals and proteins. NMR relaxation studies of polymer dynamics have revealed areas of discrepancies with well-established theories, and that has given rise to controversies which are currently debated and studied.

Understanding the dynamic behaviour of biological macromolecules is increasingly appreciated as it is crucial for understanding their functions. NMR relaxometry has been shown to be an excellent tool for probing internal and reorientational dynamics of proteins and revealing aggregation/oligomerization phenomena in protein systems. A special class of molecular liquids with self-organisation/aggregation properties are liquid crystals. Besides their large impact on technology, these systems show similarities with cell walls and serve as model systems.

Not only soft, but also hard matter is accessible to NMR relaxometry, as shown by the study of superionic conductors, nanocrystalline compounds and, recently, solid electrolytes.

- **Medical applications.** Over the last decade research within Europe has led to the development of Magnetic Resonance Imaging (MRI) scanners which use FFC in order to measure field dependent relaxation in the tissues of human subjects. These scanners use magnets which are totally different to those in standard MRI scanners and have the ability to switch field rapidly (as required in FFC) while the patient is inside the scanner. In vivo applications of FFC MRI are at a very preliminarily stage, though initial results show very considerable promises for the use of FFC MRI in order to improve the diagnosis and staging of a wide range of diseases, including cancer, osteoarthritis and fibrosis. Another important area of medical research employing NMR relaxometry is the development of contrast agents (CA) for MRI. Molecular probes in MRI have potential for early diagnosis, assessment of disease progression and prediction/evaluation of the effectiveness of therapy. NMR relaxometry has proven to be a fundamental technique to determine the molecular parameters responsible for the relaxation enhancement caused by CA. The challenge of further sensitivity improvement of CA has been addressed by developing nanosystems in which paramagnetic complexes are conjugated to platforms of various nature, size and complexity. Magnetic inorganic nanoparticles have been investigated as CA and as suitable systems for combining imaging, drug delivery and therapy (so called"theranostic" agents). Further, remarkable progress has been achieved by encapsulating the complexes in the inner compartment of liposomes, greatly pushing the limits of contrast detection.

- **Applications to environmental and food sciences**. NMR relaxometry plays an important role in monitoring soil quality and evaluating nutrient dynamics towards plant roots. NMR relaxometry studies are a rich source of information to characterise the molecular dynamics of liquids in cement-based materials and natural porous materials such as sandstone and carbonate rocks. The NMR relaxation parameters of foods depend on the chemical composition of the food (water, lipids, and proteins), the heterogeneity of the food matrix, and various processing parameters (drying, storage and aging). This has also been used to detect counterfeit foodstuffs. Additionally, porous properties of foods are known to affect important macroscopic parameters such as water-holding capacity and texture, thereby determining food quality and flavour. These properties can be thus monitored and predicted by applying NMR relaxometry, which offers the advantages of rapidity and sensitivity.
- **Theory and modelling**. Conventional relaxation theories are valid only for high magnetic fields and relatively fast molecular dynamics. Thus, they are definitely not applicable to field-dependent relaxation studies on complex systems. The theoretical challenge is primarily caused by a combination of strong spin interactions and slow dynamics (typical of macromolecular systems, solids, etc.). This issue has been addressed for the first time for paramagnetic systems (contrast agents) leading to the ground-breaking idea of an approach valid for arbitrary motional conditions and interaction strengths. This approach has been further elaborated and extensively verified with experimental results, such as in systems exhibiting quadrupole interactions. This led to innovative concepts exploiting relaxation enhancement in biological systems as an MRI contrast mechanism. There is a growing awareness that in many areas of applications of NMR relaxometry (polymers, biomolecules, and nanocrystals) one faces theoretical problems that present further challenges caused by complex mechanisms of molecular dynamics. This is a strong incentive for scientists to foster the development of advanced spin relaxation theories.
- **Instrumental development**. Field cycling at low magnetic fields (1 T and below) has been thriving for over a decade. Current developments aim at accessing higher magnetic fields using hybrid systems where an electromagnet is combined with a cryogen-free superconducting magnet to reach up to 3 T. An alternative approach involves using the stray field of a high-field NMR magnet. Such a system allows accessing higher magnetic fields (in principle up to 23.5 T, in practice up to 14.1 T) with a shuttle, thereby benefiting from the resolution of high-field NMR. However, this sample-shuttling approach is not applicable to FFC MRI.

1.3.2. Progress beyond the state-of-the-art

The Action will provide outstanding opportunities to develop groundbreaking ideas for fundamental and applied science. The main directions of the novel research are outlined below.

- **Fundamental and applied material science**. In recent years important developments in the field of colloids and dispersions (gels, emulsions, and vesicles) have been achieved. They are, however, mostly focused on macroscopic rheological properties of the systems. The potential of NMR relaxometry as "molecular rheology" will be used in order to develop models encompassing dynamics on micro- and macro-scales. Nanofluids provide a new challenge for NMR relaxometry; they consist of carrier liquids containing nano-objects of different dimensionality and properties (such as nanoparticles, nanotubes, graphene sheets) and raise large industrial interest as cooling media (for instance for solar cells). Their macroscopic dynamical properties do not obey the laws of hydrodynamics and, to date, no studies have attempted to explain this confusing phenomenon at the level of molecular dynamics. NMR relaxometry opens the possibility of investigations of the dynamics of molecular and ionic liquids in bulk and confinement.

The last decade has seen significant interest in developing tuneable materials. This area is so far relatively seldom studied by NMR relaxometry. This Action provides the opportunity to contribute to this extremely relevant branch of research which has huge potential benefit to society. Special attention will be placed on solid electrolytes and nanocrystaline materials.

Resolving the determinants of protein function is a key challenge of fundamental biology and drug development. NMR relaxometry is exceptionally suited to gather unique information on protein motions and it will be used for this purpose.

NMR relaxometry will also be applied to some striking scientific problems that remain unexplored, such as the tracking of stem-cells or the study of condensed matter under high pressure. It is expected that the investigations will lead to breakthroughs in the understanding of thermodynamical laws and properties on the molecular level.

- **Medical applications**. A great challenge is presented by the idea of transferring FFC technology from NMR to MRI, and thus being able to perform localised measurements enabling the characterisation of biological tissues in vitro and in vivo, in turn providing quantitative biomarkers of disease. This idea requires extensive in vivo characterisation of the field-dependent relaxation properties of biological tissues, both theoretically and experimentally.

Design and validation of optimised MRI contrast agents is essential in understanding disease aetiology. Molecular imaging provides a view of the body at the cellular and sub-cellular level, enabling dynamic visualisation of key biological processes within the cell. Further research will be carried out on MRI contrast agents with focus on targeted imaging probes showing chemical control (through the compound design) over relaxation rates with regards to field strength, exhibiting "on and off" switches based on field-dependent relaxivity and being sensitive to physiological parameters such as pH or enzymatic activity. Novel promising applications are offered by paramagnetic nanostructures. The dramatic improvement in sensitivity attained with the use of liposomes loaded with paramagnetic chelates and nanoparticles will be investigated.

Recent theoretical achievements now allow the development of radically new methods for MRI contrast agents based on nuclear quadrupole cross relaxation. The central principle goes far beyond the state-of-the-art by targeting different nuclei and new compounds.

NMR relaxometry will also be applied to some striking scientific problems that remain unexplored such as tracking implanted cells for cell therapies (in therapy with stem-cells or Langerhans islets).

- **Applications to environmental and food sciences**. NMR relaxometry studies will be carried out for high surface-area natural porous materials such as sandstone and carbonate rocks. High surface-area porous materials including granular packing, plasters, cement-based materials and shale oil rocks will be investigated to get insights into fundamental properties for industrial applications such as specific area, wettability, and porosity. It is important to probe in situ the dynamics and wettability of oil, water and gas trapped in the complex microstructure of shale-oil rocks. NMR relaxation studies performed "down-hole" will be an invaluable tool for investigating oil and gas recovery on porous rocks. Innovative heterogeneous material for building materials will also be a topic of intense scrutiny.

Natural and anthropogenic organic matter, used to improve soil fertility and carbon sequestration in order to reduce greenhouse gases effects on global carbon cycle, will be investigated.

NMR relaxometry opens the possibility to monitor the internal structural and dynamical modifications of foods when pedoclimatic conditions change (weather, soil, humidity), or when they are subject to

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different agricultural practices post-harvest, or industrial processing (bleaching, storage, freezing). For this purpose, the unique ability of NMR relaxometry to gather information about the chemical composition and the dynamics of different food components will be exploited. Aging and maturation is an important attribute of several economically important foods, such as wine and cheese. NMR relaxometry offers the possibility to monitor and optimise the duration and environmental conditions of aging and maturation in a large variety of foods, leading to the production of high added-value products.

- **Theory and modelling**. Efforts will be taken towards further development of advanced spin relaxation theories linking relaxation features with dynamical and structural properties of molecular systems of high complexity. These will be of utmost importance to develop concepts of tailored advanced materials for diverse applications and to predict contrast properties of innovative MRI contrast agents, in addition to answering pertinent questions of fundamental science. The theoretical advancements will be implemented using new software tools. Web-based platforms will be created and made freely accessible to distribute up-to-date software for data analysis and interpretation.

The comprehensive approach to spin relaxation is intertwined with other theoretical challenges, which will be undertaken. For instance, nuclear spin states with very long lifetimes can be created on a variety of molecules and spin systems that meet specific criteria (hyperpolarisation concept). These long-lived spin states have important applications in the long-term storage of nuclear spin hyperpolarisation as well as a great potential for sensing applications.

- **Instrumental development**. Sensitivity and specificity improvements are the two main aspects to push NMR relaxometry beyond its current boundaries. The efforts in these domains aim at providing means to preserve the specificity of high-resolution NMR studies (performed at high magnetic fields) in the range of low fields, and also to reach very high sensitivity (or “single spin” experiments).

Recent hardware development combining dynamic nuclear polarization (DNP) with NMR relaxometry is a promising step towards investigating specific dynamics of molecular systems. Thus, efforts to develop an improved set of DNP/FFC probes will be undertaken in order to maximise the enhancement factor on the one hand and the overall sensitivity on the other hand. Probe-shuttling relaxometry will be developed, as the ability to exploit the stray field of the magnet affords high sensitivity and allows taking advantage of the high resolution capacity of NMR.

The concept of FFC MRI requires specific hardware developments adapted to targeted applications, as well as the development of imaging pulse sequences and data-processing methods.

Another challenge for FFC instruments is provided by multidimensional and ultrafast experiments.

1.3.3. Innovation in tackling the challenge

The following innovative areas are envisaged as part of the Action:

- <u>Exploiting the FFC technique for MRI and set-up of the FFC MRI scanner</u>. There is a great expectation that the acquisition of MR images over an extended range of magnetic field strengths will provide outstanding diagnostic information, not accessible from the current images acquired at a single high magnetic field strength.
- <u>Applying new concepts for MRI contrast agents</u>. New classes of paramagnetic and superparamagnetic contrast agents with improved relaxation enhancement capabilities will be designed, leading to greater sensitivity of MRI for subtle changes in tissue state and decreased administered dose, two tasks currently of huge interest in clinical settings. A fundamentally new contrast mechanism using large nuclei with quadrupole moments will be exploited. This concept has the potential to push MRI far beyond its current limits.
- <u>Developing innovative ideas for the design of new materials</u>. Further progress in the development of advanced materials heavily relies on a thorough understanding of the mechanisms of molecular dynamics. An excellent example is the area of batteries and supercapacitors for which the mechanisms of ionic transport and interactions with the surface of electrodes is of primary importance. NMR relaxometry is a unique method that is able to guide the design of innovative materials.

- Exploiting NMR relaxometry for quality assurance in the food industry. The ability of FFC NMR to identify signals arising from bound and mobile phases is of paramount importance to assess a number of processes in the agri-food chain (such as ripening, storage or transformation). Furthermore, the potential of NMR relaxometry to differentiate between fresh and aged/matured food products will be explored for authentication purposes (e.g. wine, cheese, etc.).
- Exploiting NMR relaxometry as a tool for "molecular rheology". NMR relaxometry will open new horizons in terms of bridging "molecular rheology" to the macroscopic rheological behaviour of a variety of systems, from complex fluids to macromolecules. The studies will be extended to extreme temperature and pressure conditions.
- Formulating comprehensive theories of spin relaxation. Theoretical models of the complex, quantum-statistical phenomenon of spin relaxation will push forward the fundamental research, merging quantum physics with molecular science. These theoretical developments are crucial for wide-ranging applications-based research (for instance, to identify markers of diseases, indicators of food quality or protocols for materials development).

1.4. Added value of networking

1.4.1. In relation to the Challenge

A majority of the concepts presented can be successfully executed only via a long chain of collaborations of scientists representing different expertise along with industrial partners. The Action will give the opportunity to apply an innovative and thorough research strategy which includes:

- Exploring the potential of concomitant experimental and theoretical investigations including a broad range of other experimental methods supplemented by computer modelling.
- Establishing a close collaboration between scientists representing different areas of fundamental and applied science and pursuing breakthrough ideas stimulated by brainstorming of interdisciplinary teams.
- Fostering extensive collaboration between academic and industrial partners for the mutual benefit of both parties and providing socio-economical advantages.

To pursue this strategy the following means of the Action will be exploited:

- Coordination of research activities, evaluation of the results obtained and definition of further research directions via meetings of Working Groups (WGs) and video conferences.
- Transfer of knowledge between partners by conferences, Training Schools and a large number of Short Term Scientific Missions (STSMs) in order to promote mobility of ECI. Exchanges between interdisciplinary groups of complementary expertises will be especially encouraged.
- Sharing of experimental equipment and theoretical/numerical tools. Moreover, access to specialised European facilities will be provided by some participants of the Action enlarging the experimental potential.
- Dissemination of the results to a broad scientific community and industry. The feedback expected from these parties provides novel scientific and technological ideas and helps to define the expectations of end-users.

1.4.2. In relation to existing efforts at European and/or international level

There are several international programmes aiming at fostering research in the fields of novel advanced materials for nano- and bio-technology, MRI, energy storage systems and computer modelling of molecular motion, for instance:

- Marie Curie ITN project: pNMR (Pushing the Envelope of NMR Spectroscopy for Paramagnetic Systems. A Combined Experimental and Theoretical Approach)
- COST Actions: Molecules in motion (MOLIM), European Network on Smart Inorganic Polymers (SIPs), Modern Tools for Spectroscopy on Advanced Materials: a European Modelling Platform, Exchange on Ionic Liquids, Theranostic Imaging and Therapy: An Action to Develop Novel Nanosized Systems for Imaging-Guided Drug Delivery.

No international programme is however devoted to the development of NMR relaxometry as a wide-ranging tool. These projects (and some others) can in many aspect complement this COST Action and strengthen the scientific concepts of all parties by common workshops and video conferences. In view of the expected computer demand of some accurate and realistic models developed by this Action, cooperation outside the network with specialists of high-performance computing is envisaged. Data collected for biological tissues and pharmaceutical compounds as well as software tools will be available for inclusion into the BioMedBridges shared e-infrastructure to allow data integration in the biological, medical, translational and clinical domains, and thus to strengthen biomedical resources in Europe.

2. IMPACT

2.1. Expected Impact

2.1.1. Short-term and long-term scientific, technological, and/or socioeconomic impacts

The short-term goals are scientific and technological advances, while in the long term society as a whole will benefit from the Action.

Collaboration of renowned European scientists exploiting NMR relaxometry with experts in complementary disciplines in order to address the challenges of the Action will lead to novel findings published in high-ranking journals. These achievements will also have impact on the related disciplines. Educational aspects of the Action are very important, not only from the viewpoint of knowledge transfer, but also to ensure that qualities such as creativity in solving problems, communication skills and entrepreneurship are passed to the next generation of researchers. Enhanced research tools (in terms of improved instrumentation and more straightforward experimental and data analyses protocols) will be delivered to scientists, medical doctors and engineers. It is expected that this Action will result in increased participation in EU projects of currently less-represented countries.

New technological concepts will be developed, stimulating competition and invention in the associated industry. The Action provides outstanding opportunity to overcome the bottleneck between academic research and industry by stimulating a vibrant dialogue between both parties, leading to their mutual profit and hence socioeconomic benefits. This statement is fully justified taking into account that the Action addresses major needs of our society, for instance, by providing new diagnostic tools for a broad range of diseases, by responding to increasing demand for advanced materials for numerous applications, by contributing to the technology enabling the shift from fossil to renewable energies, or by providing means for quality control of foodstuff.

2.2. Measures to Maximise Impact

2.2.1. Plan for involving the most relevant stakeholders

The Action targets the broad, cross-disciplinary scientific community, industry and general public. Due to the extraordinarily broad range of scientific topics to which NMR relaxometry can valuably contribute, the number of relevant stakeholders is very large.

The Universities ranked within the top 200 that possess faculties either in life science/medicine or materials science comprise about 300 potential stakeholders. This figure would be hard to estimate if one adds other similar Universities with lower rank, but it would undoubtedly be large. These stakeholders will be addressed through the dissemination network described in Section 2.2.2 (below).

Industrial stakeholders from the following activities will be prioritised as targets for the Action: pharmaceuticals (contrast agents), chemistry (advanced materials, oil/petroleum), high technology (solar cells, capacitors, batteries, and displays), environment (soil fertility) and food production (food quality). The Action will include feasibility studies to help develop innovative solutions that match the market needs. Industry Transfer Managers will be appointed to advertise these solutions to potential industries. Representatives from industry will be invited to meetings and industry-dedicated

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videoconferences will be organised. Public Affairs units present at many European Universities will be engaged to maximise impact through social media releases and policy interviews.

2.2.2. Dissemination and/or Exploitation Plan

An ambitious programme of dissemination will be implemented to reach a broad audience, from scientists to the general public. A Dissemination and Exploitation Group (DEG) including the WGs members and industry partners will be established to provide and promote a thorough approach to dissemination and impact of the Action, while respecting the rights of intellectual property. It includes:

- Publications in international journals (open access if possible), reviews, monographs, specialised books and text-books. To increase the visibility of the Action, themed issues in international journals will be proposed.
- Organisation of WG meetings, conferences, workshops and STSMs. The last two will increase the number of ECI trained to work on interdisciplinary problems using NMR relaxometry.
- Participation in external conferences. To raise awareness of the scientific community on the potential of NMR relaxometry it is important to present the results of the Action.
- Creation of a dedicated website. The website will describe the Action for scientific, industrial and lay audiences. It will present the results with links to open-access publications, reports of the Action and tutorials. The form of communicating the results will be tailored to each audience including all stakeholders and beneficiaries (researchers, companies, hospitals among others). The website will also be used for video-presentations of courses and lectures held during the Action conferences, workshops and meetings, demonstrations of experimental and data analysis protocols.
- Sharing data and software. Non-commercially-sensitive research data and software tools developed for data analysis and modelling will be made available to the community.
- Setting up an “intra-network” (Think Tank) of ICS. This is meant to build their confidence and ensure that they contribute to the Action at an equal level with experienced scientists. This networking will create a platform for exchanging knowledge, seeking advice and asking questions which they might hesitate to address to the wide forum.
- Setting up a “forum of experts”. The group will carry on a blog (as a part of the Action website) including an e-dialogue with the community, discussions of controversial subjects and an educational part (Wikipedia-like).

2.3. Potential for Innovation versus Risk Level

2.3.1. Potential for scientific, technological and/or socioeconomic innovation breakthroughs

The Action is intended to create a competitive interdisciplinary network capable of defining and solving high-level scientific and technological challenges. The long-term vision and breakthrough targets are highly ambitious and require high levels of expertise. The novelties of the ideas pursued imply high potential of the Action, but also a high risk level. The Action is aware of several risk factors:

- Theoretical models being insufficient for comprehensive and consistent data analysis.
- Ambiguous interpretation of the origins of specific relaxation features of complex systems as a results of many degrees of freedom.
- Insufficient sensitivity/selectivity of instrumentation to fully meet the technological challenges.

NMR relaxometry has evolved in the last decade, providing many theoretical, instrumental and applications-based contributions and overcoming serious conceptual and implementation obstacles. In several of the outlined areas the research community is currently obtaining very promising results (Section 1.3.1). As a consequence the knowledge already acquired is advanced and the community possesses superb experience which will be resourcefully used by profiting from the networking means offered by the Action. Thus, there is a high level of confidence that the research and development goals will be successfully addressed.

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The risks factors will be continuously monitored and mitigated. WGs meetings will play a very important role to correct for mid- to long-term risk realisations while frequent video-conferences will take place (Section 3.1.2) to quickly cope with short-term issues and appearing uncertainties.
A key factor decreasing the risk probability is continuous, mutual cross-validation. Therefore participants are expected to make their results available to other research groups involved in the Action (experimental data, theoretical models, and numerical tools).

3. IMPLEMENTATION

3.1. Description of the Work Plan

3.1.1. Description of Working Groups

WGs will conduct their activities within five work streams: Fundamental and applied materials science (WG1), Medical applications (WG2), Food and environmental sciences (WG3), Theory and modelling (WG4) and Instrumental development (WG5). The research agendas of WGs are deeply intertwined so the scientific programmes of the WGs will be carried out in close cross-correlation and the participation in more than one WG will be promoted. The scientific aims of the individual WGs are presented below including Milestones and Deliverables (M&Ds) for each WG. M&Ds of the whole Action are described separately.

WG1: Fundamental and applied material science. This group will focus on dynamics of complex molecular and ionic systems in liquid and solid states, encompassing small molecules, macromolecules, electrolytes and crystals. The research will encompass extensive experimental studies in a very broad range of temperature and pressure to reveal remarkable properties of matter under extreme conditions. Thorough theoretical analysis by means of dedicated, advanced theoretical models will be performed to disclose dynamical properties of these diverse systems. The analysis will seek for generic laws of molecular motion and their in-depth explanations. The potential of ”molecular rheology” will be exploited to link the molecular (atomic) dynamics with macroscopic behavior of the systems. The studies will be aided by complementary experimental methods and computer simulations.
The efforts of WG1 will aim at the following objectives:
O1.1: Exploring dynamics of complex systems on a molecular level in order to address open questions of fundamental science.
O1.2: Identifying links between molecular and macroscopic properties of matter to provide guidelines for materials tailoring.
The most important research tasks are summarised as follows:
T1.1: To analyse motional correlations in liquid and solid electrolytes against their conducting properties.
T1.2: To examine the effect of increased complexity of soft matter (from “simple” liquids to macromolecules) on its motional properties across a huge range of time scales.
T1.3: To analyse the influence of confinement and solid/liquid surface interactions on molecular dynamics, thermodynamical and rheological properties of liquids.
T1.4: To inspect dynamics of (nano) crystalline materials and amorphous solids.
Milestones: Obtaining representative systems for study by the different stakeholders; Identification of the origin of the most characteristic relaxation features of different classes of systems and correlation with their macroscopic properties; Establishment of guidelines for appropriate analysis of NMR relaxometry results.
Deliverables: Report on NMR relaxation data for representative classes of systems, Strategies to improve properties of advanced materials, guidelines for NMR relaxometry data analysis.

WG2: Medical applications. WG2 aims at developing and refining the performance of NMR relaxometry in diagnosis, focusing mostly on transferring FFC technology to MRI and developing new types of contrast agents with enhanced relaxivity and superior sensitivity to tissue state.
The main objectives and main tasks are:

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O2.1: To transfer FFC technology to MRI and develop protocols to obtain a wealth of extra diagnostic information that is not available to standard MRI.
O2.2: To develop novel contrast agents for FFC MRI and high-field MRI scanners.
T2.1: To refine and develop experimental and numerical tools and protocols for FFC MRI.
T2.2: To thoroughly study NMR relaxometry of tissue-mimicking systems and tissues in normal and pathological states to reveal disease biomarkers.
T2.3: To investigate the contrast potential of new nanostructured paramagnetic and super-paramagnetic contrast agents in aqueous suspensions, in vitro (in cells) and in vivo.
T2.4: To model and synthesise efficient contrast agents based on interactions with quadrupole nuclei.
T2.5: To explore the possibility of tracking implanted cells for cell therapies.
Milestones: Demonstration of successive progress in the development of FFC MRI scanners, Approbation of FFC MRI clinical studies, Identification of robust biomarkers of diseases, Identification of diverse relaxation mechanisms and factors enhancing the contrast properties of highly-promising systems, Demonstration of the performance of contrast agents based on entirely new contrast mechanisms and/or exploiting new classes of compounds.
Deliverables: List of biomarkers available in FFC NMR and their interpretation in the target diseases, Stabilised FFC MRI prototypes working at low and ultra-low field with streamlined protocols, Report on the potential of the currently approved contrast agents for FFC MRI, Examples of novel contrast agents with specification of the parameters determining their efficiency at selected frequencies.

WG3: Food and environmental applications. WG3 will gather researchers focused on environmental and food science, with the following objectives:
O3.1: To develop tools to investigate food properties and quality, maturation and authentication.
O3.2: to evaluate soil fertility and relate soil transformations to agricultural practices.
O3.3: To understand dynamical properties of liquids (water, oil) in natural high-surface porous materials.
These goals lead to the following tasks:
T3.1: To investigate dynamics of nutrients in soils amended with pyrogenic carbon systems.
T3.2: To reveal markers of quality, maturation and authenticity through comprehensive studies of relaxation features of diverse food products.
T3.3: To reveal factors influencing the texture and stability of food products during their shelf life.
T3.4: To investigate and model liquid dynamics in shale oil rocks, cement-based and granular materials.
Milestones: Setup of protocols for NMR relaxation experiments for various food products, soil and natural materials of high porosity, Explanation of the most prominent characteristic relaxation features (markers) of food products in terms of food composition, processing, maturation and storage, Demonstration of down-hole experiments for oil in rocks.
Deliverables: Procedures for the determination of food condition, quality and authenticity from NMR relaxation, Numerical tools for detecting oil parameters from down-hole experiments.

WG4: Theory and modelling. WG4 will gather groups experienced in quantum-mechanical foundation and mechanisms of spin relaxation phenomena and theory. The objectives of WG4 are:
O4.1: To develop a deeper understanding of quantum-mechanical relaxation phenomena in complex spin systems.
O4.2: to formulate advanced theoretical models linking spin relaxation features of molecular systems with their dynamical and structural properties.
The group will conduct its activity within two main work tasks:
T4.1: Robust quantum-mechanical framework of spin relaxation in systems of high complexity.
T4.2: Theoretical models of relaxation processes dedicated to a variety of systems, including different relaxation pathways and diverse mechanisms of motion .

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The description will be formulated in a way suitable to be applied in general scientific cases by other researchers. Thus, the strict theoretical formulations will be (if possible) accompanied by their simplified counterparts, embracing the most essential features of the spin dynamics phenomena.
Milestones: Provision of theoretical break-through quantum-statistical approaches leading to relaxation theories valid for arbitrary motional conditions and interactions strengths, Demonstrations of the ability of the relaxation theories to reproduce the features of NMR relaxation data collected for diverse materials, tissues, foodstuff and in vivo studies, Demonstration of the consistency of the results obtained by NMR relaxometry and other, complementary techniques.
Deliverables: Survey of available relaxation theories, their underlying assumptions and validity regimes, Comprehensive theory of relaxation for liquid and solid systems of increasing complexity and robust numerical tools for analysis of relaxation data for these systems, Theoretical models of field-dependent relaxation enhancement caused by diverse classes of contrast agents placed in surroundings of different physico-chemical and biological properties accompanied by software package for modeling and predicting contrasting effects, Software package for detecting, extracting and quantitatively describing markers for tissues and food products, Numerical guiding tools for tailoring advanced materials with main focus on electrolytes and nanocrystals.

WG5: Instrumental development. WG5 will gather research teams involved in the development of NMR relaxometry from the instrumental side, of advanced experiments and of software.
The main objectives of WG5 are:
O5.1: To improve sensitivity and selectivity of the FFC technique.
O5.2: To develop and to validate technology for in vivo imaging.
O5.3: To optimise FC magnets for experimentation.
They are associated with the following tasks:
T5.1: Extend the frequency (magnetic field) range to enlarge the time-scale of motional processes accessible by NMR relaxometry.
T5.2: Explore the potential of sample/probe shuttling methods to enhance the sensitivity and selectivity of FFC NMR studies.
T5.3: Develop an improved set of tools for DNP and hyperpolarisation enhancement methods.
T5.4: Develop in vivo imaging protocols including state-of-the-art MRI and FFC MRI sequences.
Milestones: Demonstration of NMR relaxation experiments at ultra-low and high magnetic fields, Experiments on nuclei with low gyromagnetic factors, Demonstration of the instrumental capability for FFC MRI.
Deliverables: FFC NMR systems with enhanced stability and homogeneity, Alternative FFC NMR systems based on sample and/or probe shuttling.

The Action will also provide other Milestones, common for all WGs. They are:
- Management Committee (MC) meetings, WGs' meetings, mid-term conferences and reviews and reports (after 18 months, 30 months and at the end of the Action).

Regarding the Deliverables, these include:
- publications in high ranking journals, reviews, books, protocols, reports of the Action.
- conferences, workshops, training schools and diverse scientific and educational materials resulted from these Activities.

This work plan will be carried out by the many groups that already expressed an interest in this Action, keeping open possibilities for other groups to join the network during the course of the Action.

3.1.2. GANTT Diagram

The Action will last for four years. Altogether four MC and Core Group (CG) meetings, twenty WG meetings (one per year per each WG), forty WGs video sessions (two per year per each WG), at least two international conferences, two workshops, three Training Schools and forty STSMs are planned as shown below .
Meetings will be organised, if possible, as satellites of conferences and workshops.

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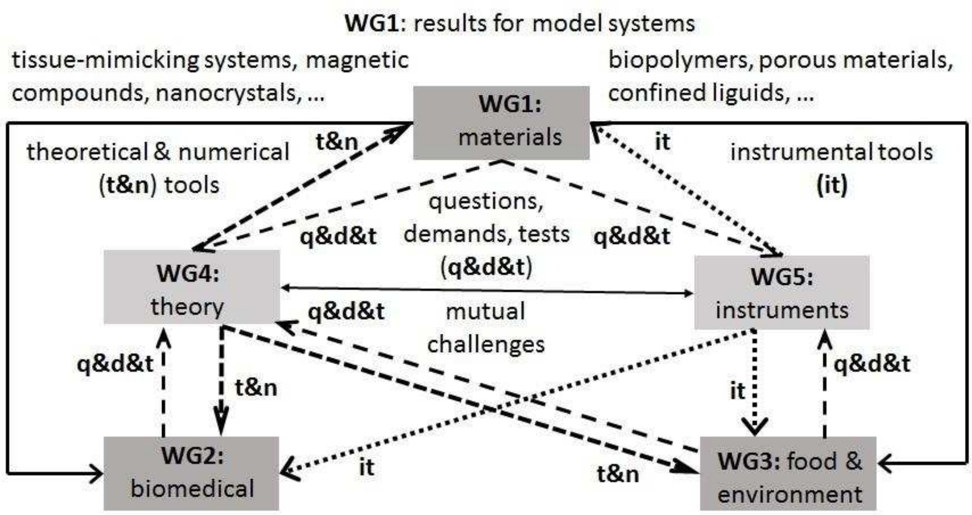
Action	Year 1				Year 2				Year 3				Year 4			
Kick-off meeting																
MC meeting																
WGs meeting																
WGs video session																
Conference																
Workshop																
Training School																
STSM	10				10				10				10			

3.1.3. PERT Chart (optional)



3.1.4. Risk and Contingency Plans

The experience and knowledge of the internationally distinguished research groups involved in the Action minimize the risks of failure of the scientific objectives. Excellent experimental facilities and theoretical resources are available at the participating institutions. As stated in Section 2.3.1, risk factors directly related to the research concepts and results will be continuously monitored by regular meetings, frequent e-sessions and discussions dedicated to specific problems. Great care will be taken to make the results of the involved research groups immediately available to others and "open for discussion"and comparison (cross-checking).
The tasks of the WGs are highly intertwined as shown in Section 3.1.3. Thus, it is very important to ensure close communication between researchers and to rigorously keep the schedule on time. For this purpose a detailed agenda of M&D associated with individual tasks will be set up (preceded by a critical risk analysis in combination with the interplay between tasks) to avoid situations that delay deliverables and negatively impact other related tasks. In case research groups face difficulties, expectations will be adjusted to a level achievable within the schedule to mitigate the influence of the delay on the achievement of the Action. A second type of risk is related to the success of the networking and dissemination activities. The carefully thought-through dissemination plan (Sections 2.2.1 and 2.2.2) will ensure the appropriate level of propagation of the results of the Action. The level will be continuously monitored by the Core Group (CG) (Section 3.2) and measures will be taken to improve the weaker channels of dissemination. Good participation to the STSM programme is very important for the Action. Therefore to fully recognise the interests and needs of ECI and students, their feedback from the Training Schools and STSMs will be carefully considered. Moreover, to improve the gender balance, organised childcare possibilities will be offered to participants interested in STSMs. Furthermore, the STSM coordinator will be actively seeking for candidates from under-represented countries potentially interested in the Action.

3.2. Management structures and procedures

The Action will be coordinated by Management Committee (MC). During the first MC meeting the Action Chair (AC), Vice-Chair (AV-C) and Grant Holder (GH) will be elected. Additionally, the Work Group Leaders (WGLs), the Training Schools Coordinator (TSC), the STSM Coordinator (STSMC), the Dissemination Manager (DM), the Industry Transfer Manager (ITM) and Equal Opportunities Manager (EOM) will be appointed. The AC, AV-C, GH, WGL, TSC, STSMC, DM, ITM and EOM will form the Core Group (CG). CG meetings will take place at least once a year preferably in combination with the MC meetings to reduce costs.

The MC will be responsible for implementation and management of the Action's activities, budget planning and allocation of funds, coordination of the dissemination of results, coordination of admission of new research groups and WG members, establishment of criteria for the evaluation of STSM proposals and preparation of the annual and final reports. The CG will organise the activities of WGs, plan the programme of Conferences, Workshops and Training Schools, monitor and manage the STSM expectations and achievements and ensure communication between WGs and MC. The WGLs will be responsible for coordinating the joint research within their WGs, arranging scientific meetings and reporting research progress.

The TSC will be responsible for organising the Training Schools. The STSMC will organise and oversee STSMs. The ITM will take care of advertising and promoting innovative solutions with potential for application to various sectors of industry, as well as organising dedicated meetings with industrial partners. The DM will be in charge of organising the dissemination policy of the Action, seeking opportunities to address all groups of stakeholders. The EOM will be responsible for fulfilling the requirements of gender balance, involvement of ECIs and under-represented countries.

A representative of the "intra-network"of ECI will be appointed to assist the CG in coordinating the activities of this group of researchers and ensuring that its requirements are acknowledged.

3.3. Network as a whole

In the first step, the partners were chosen so that they provide high expertise in NMR relaxometry and access to FFC NMR laboratories. Then, the network was extended to include research groups with know-how in computer modeling and experimental methods complementary to NMR relaxometry. The next target groups selected for the Action Network of Proposers were leading specialists in materials science and nano- and bio-technology. Then for the final shape of the networking, medical doctors, engineers and applications-oriented scientists from different disciplines were invited. As a result of this strategy the Action network includes at the proposal stage, twenty COST Country Institutions and two International Partners institutions who represent outstanding expertise in FFC NMR instrumentation and macromolecular (polymer and liquid crystals) science.

The Network of Proposers covers all the disciplines required to achieve the objectives of the Action. It includes renowned scientists involved in numerous national and international projects which guarantees appropriate research funding and hence ensures that the networking means offered by the Action will be efficiently used for the profit of both the projects and the Action. The Network of Proposers provide access to many FFC NMR facilities and numerous complementary laboratories as well as to large computing centers.

It is desirable to increase the contribution of industry partners to the network. For this purpose the actions outlined in Section 2.2 will be applied, coordinated by the ITM. Several target industry partners were already identified by the Network of Proposers. Similarly, it is desirable to increase the contribution of food and agriculture scientists. This branch of NMR relaxometry studies has been so far mostly developed by chemists and NMR relaxometry is not yet established in agriculture science. The means outlined in Section 2.2 will be enhanced by actively seeking partners in the field and addressing them personally.