STARTPAGE

HUMAN RESOURCES AND MOBILITY (HRM) ACTIVITIES

MARIE CURIE ACTIONS

Research Training Networks (RTNs)

PART B

CiE

B1. SCIENTIFIC QUALITY OF THE PROJECT

B1.1. Research topic

It has been claimed that while the focus in 20th century mathematics was to develop grand formalisms like algebra and topology, the focus in the 21st century will be on extracting data and algorithms.

The research topics described below are interrelated in the sense that they represent foundational or executional work in this direction, and this is also what makes them important. A number of these foundational topics are useful in designing programming languages for new classes of datatypes, a research aim of immediate practical impact. Others provide powerful tools for extracting computational information from ordinary mathematics. A particularly exciting aspect of current developments is that techniques from computability and logic are modified and applied to problems in theoretical computer science, and that there is an increasing understanding of the need for a joint ventureship involving logicians and theoretical computer scientists.

We can see now that the world changed in 1936, in a way quite unrelated to the newspaper headlines of that year concerned with such things as the civil war in Spain, economic recession, and the Berlin Olympics. The end of that year saw the publication of a thirty-six page paper by a young mathematician, Alan Turing, claiming to solve a long-standing problem of the distinguished German mathematician David Hilbert. A by-product of that solution was the first machine-based model of what it means for a number-theoretic function to be computable, and the description of what we now call a *Universal Turing Machine*. At a practical level, as Martin Davis describes in his 2001 book *Engines of Logic: Mathematicians and the Origin of the Computer*, the logic underlying such work became closely connected with the later development of real-life computers. The stored-program computer on one's desk is a descendant of that first universal machine. What is less often remembered is Turing's theoretical contribution to the understanding of the *limitations* on what computers can do. There are quite easily described arithmetical functions which are not computable by *any* computer, however powerful. And even the advent of quantum computers will not change this.

Before computers, computer programs used to be called *algorithms*. Algorithms were just a finite set of rules, expressed in everyday language, for performing some general task. What is special about an algorithm is that its rules can be applied in potentially unlimited instances of a particular situation. We talk about the *algorithmic content* of Nature when we recognise patterns in natural phenomena which appear to follow general rules. Ideally algorithms and algorithmic content need to be captured precisely in the language of mathematics, but this is not always easy. There are areas (such as sociology or the biological sciences) where we must often resort to language dealing with concepts not easily reducible to numbers and sets. One of the main tasks of science, at least since the time of Isaac Newton, is to make mathematically explicit the algorithmic content of the world about us. A more recent task is to come to terms with, and analyse, the theoretical obstacles to the scientific approach. This is where the discovery of *incomputability*, and the theory which flows from it, play such an important role.

It is only in the last century, of course, that computability became both a driving force in our daily lives and a concept one could talk about with any sort of precision. Computability as a *theory* is a specifically twentieth-century development. And so of course is the computer, and this is no coincidence. Today this contemporary awareness and understanding of the algorithmic content of everyday life is still in its infancy, and forms the basis of a rich and deeply relevant research area. Since its inception, computability theory has provided deep conceptual insights, new algorithmic and programming ideas and techniques, and mathematical theories on which to found software technology. For example, in the standard courses on computability one finds the origins of: the universal computer; recursion; lambda calculus; rewrite systems; formal specification of computations; higher types; classification of decision problems; classification of data representations; computational complexity. In each case, seen from contemporary Computer Science, the mathematical investigations in computability theory that led to these fundamental ideas are brilliant theoretical speculations - quite simply, basic mathematics at its best.

Today, computability retains this important speculative role in our quest to understand the big ideas of algorithm, computation, program, machine, and formal system description. A number of computability theorists are now both mathematicians and computer scientists, and European science – including scientists brought together for this project – continue to play a world-leading role. The *Computability in Europe* — or CiE — network promises to provide an invaluable context for the training of a new generation of young European scientists with expertise in this fundamentally important area.

Although our proposed research is conveniently organised under separate headings into various subtopics, there are no clear borders between these subtopics. There is, in fact, a strong synergy effect, which promises to be a distinctive feature of the project as a whole.

B1.2. Project objectives

Computability theory and its applications can be approached from a number of different directions. Our training and research objectives can be grouped under the general description *Computability and Complexity in an Extended Context*. The two main sub-objectives here are to obtain answers to the questions:

I. What is computable in practice, and how can the scope of practical computability be extended?

II. To what extent does the wider non-computable context impinge on and explain the material universe?

We aim to bring to a new generation of researchers the opportunity to work with world leading researchers in different areas of computability, enabling them to experience the growing inter-relationships within the subject, and to master a broad spectrum of techniques and concepts.

1. Programming languages and their mathematical models: The chasm between computing with discrete and continuous data is in urgent need of attention. We will work towards a unified theory of computation on all data. This topic constitutes a major part of the project, with a number of closely interrelated approaches, with further links to a number of other subtopics.

1.1. Notions of computability: Science deals with continuous systems, while classical computability (and computers) familiarly deal with systems which are discrete. Today, it is a pressing and important problem to understand computability on any data, especially, on continuous data, and to delineate the role of computation in problems in algebra and analysis, physical systems, exact computation with real numbers, and programming languages for continuous data.

We will focus on versions of computability of interest in computer science, and applications to computational semantics. There are models which may be extensional (typically categories of domains, picking up what can be computed) or intensional (typically categories of algorithms, which distinguish computation strategies). Then there are constructive interpretations — models for constructive mathematics. The main thrust here is to give a fine-grain analysis of different programming styles in real programming.

There already exists a large number of participants, including world-leaders in the area at both mathematics and computer science departments, working on notions of computability and continuity for generalized datatypes, including: datatypes for nondiscrete data (e.g. real numbers and other spaces that arise in analysis), datatypes arising in type systems (simple types, second-order types, linear types, etc.), datatypes that arise in the study of computational effects (e.g. various computational monads), and supertasks and generalised computation. Often computational effects can best be viewed as a form of generalized datatype, and the study of such generalized datatypes is proving to be important in the field of programming language development (e.g. the use of an "effects monad" in Haskell). The eventual aim is to develop a theory of computability which applies directly to generalized datatypes. We expect a continued interplay between the foundational study of computing and the development of special-task programming languages.

Currently there is an ongoing development in the field of non-uniform interactive computing that has been initiated by noticing the insufficiency of classical computational models to capture non-terminating, interactive and evolutionary computations as realized in nature. A general objective will be to analyse the computational power and the limitations of certain physical models of computability, for example, by the study of analog computers, and of relativistic models of computability from a computability theoretic point of view. It is important to find out whether new computational paradigms such as quantum computing could break the Church-Turing thesis barrier, or at least lead to new algorithms of higher efficiency.

1.2. Computability and complexity in analysis, and its applications: All over the world computers are used for real number computation and numerous software packages are available for applications in science and engineering. The increasing demand for reliable software in engineering and scientific computation requires a sound and broad foundation not only of the analytical but also of the computational aspects of numerical computation. Although Numerical Analysis supplies a profound analytical background for numerical computation, its algorithmic foundation is weak. On the other hand, Computer Science offers a far developed algorithmic theory of computability and computational complexity, but essentially for functions on natural numbers and finite words. It is Computable Analysis which tries to close the gap between these two traditional fields by providing a foundation of the algorithmic aspects of numerical computation. A major objective is to continue the ongoing research projects, aimed at systematically effectivising classical analysis, gauging computational complexity (Turing machine based) of numerical algorithms, applying methods from computability theory and developing new ones for classifying non-computable real numbers and functions, and developing programming languages for numerical computation and studying semantics and verification.

In the last 20 years a large amount of computable analysis has been developed, mostly thanks to Ci E participants. These theoretical results provide a strong base for a serious attempt to bring computable analysis closer to programming practice. We believe this is the right time to invest considerable effort in developing methods and prototypes which could lead to new ways of thinking about scientific computation.

2. Complexity of computations: This has become a very extensive and active area, and contains some of the most difficult and fundamentally important problems in computer science. This includes the so-called "**P**=? **NP**" problem, recognized as one of most important and challenging problems in mathematics. Underlying it is the problem of characterising a number of basic complexity classes. There are also a number of more immediately practical questions with a closer connection with programming. A major open problem is the development of a convincing notion of feasible computability for higher types.

Also the study of different models of computation and the underlying complexity classes give new insights for the development and analysis of algorithms. The classification tools developed in complexity theory help to understand the power of new computation paradigms, like quantum computation.

The necessity of randomisation in algorithms design deserves full understanding. The techniques for eliminating random sources have led to explicit combinatorial constructions of great algorithmic value relating to the most fundamental problems in combinatorics and number theory (e.g. expanders, designs, Riemann hypothesis). Derandomisation of standard complexity classes has become a mainstream area of research for this decade. An important aim is to classify the complexity of problems arising from quantum computation.

From computability theory, we intend to further develop and exploit resource-bounded versions of the powerful measure and category frameworks in structural complexity theory. Also of widespread interest and relevance are algorithmic randomness and algorithmic information theory (Kolmogorov complexity).

Aspects of structural complexity are of particular interest. A main objective will be that of clarifying the map of complexity classes around **P** and **NP**, and refining the complexity of algorithms and proofs for specific computational problems. As well as providing new insights in the theory of NP-completeness, there are potential cryptographic applications. There are also promising connections to quantum computations which require further investigation.

3. Theoretical cross-fertilisations involving computability:

3.1. Proof theory and computability: The deep relationships between "proof" and "computation" have driven much of the most significant research in the "constructive" areas of mathematical logic, since the earliest days of the modern subject over 70 years ago. Today, the results of this fundamental work form the mathematical bedrock of a broad range of major applications in computer science (e.g. logic programming, program synthesis and verification, theorem-proving, hardware design, proof-carrying code, linear logic and complexity). Thus, as Turing foresaw, the interdisciplinary links between mathematical logic and computer science are extremely strong, and both sides of the partnership are substantially enriched by the continuing and increasingly fruitful scientific interaction.

The fundamental question underlying the proof-computation relationship is: "What is the algorithmic content implicit in a mathematical proof, and how can it be read off, and how can its computational complexity be measured ?" Arising from this question are the key concepts of proof mining and realisability, with corresponding inter-related research areas in which European researchers are pre-eminent. Proof Mining will be used as a powerful tool for extracting computational information from proofs in ordinary mathematics. According to the Brouwer-Heyting-Kolmogorov interpretation, a proof is a construction providing evidence for the proven formula. Viewing this interpretation from a data oriented perspective one arrives at the so-called proofs-as-programs paradigm, which associates a constructive proof with a program 'realizing' the proven formula. An important objective here will be to develop and extend this paradigm as the basis of a new practical methodology for the synthesis of provably correct software, also addressing exciting foundational questions on which mathematical concepts are to be viewed constructively.

3.2. Computable models, structures and games: In recent years this has become a very active area, with the deepest work in computable model theory coming out of Russia, and to a lesser extent the USA and Australasia. We welcome the opportunity for such ideas to become better understood in other parts of Europe, where there are already strong links with the Novosibirsk school of Ershov, Goncharov and Morozov. A main objective here will be to improve our understanding of the constructive content of a broad range of model theoretic structures, particularly those which have been found to have special relevance to deep questions in mainstream mathematics, and to applications of mathematics such as game theory.

The computational study of games is by now a fundamental area of research in Computer Science, widely publicised by the Amsterdam school of van Benthem who connect it to mathematical logic (infinite games), linguistics, philosophy and even the social sciences. We also intend to investigate the computability of certain structures with particular applications in software design and theoretical computer science, such as Operators on Regular Euclidean Subsets, and Computability of Algebraic Geometry. We also aim to examine a number of questions concerning the existence of computable presentations of mathematically fundamental algebraic structures, such as Boolean algebras, distributive lattices with relative complements, linear orderings etc. Another related objective is to make significant progress with a range of longstanding and intractable open problems in computable numberings, which have deep connections with research in Computer Science.

3.3. Constructive mathematics: Often results about computability can be neatly presented as results about standard mathematical structures, but formulated and proved within constructive mathematics, from which ramifications for computability fall out "for free". Often results about computability theory are more easily obtained via constructive mathematics. This relationship is symbiotic because, in turn, the development of the theory of computability often requires the development of new constructive mathematics, which is of interest in its own right. The proper application of constructive mathematics to computability theory requires the interpretation of constructive proofs in models built using notions of computability. Constructive set theory provides a particularly convenient mathematical language for formalizing such constructive proofs. We aim to investigate what mathematical structure is needed to model constructive set theories, and how such structure can be derived from notions of computability. One objective is to develop constructive set theory as a good setting for constructive mathematics in general and constructive topology in particular.

It is a challenging project to understand the relation between constructive analysis and computable analysis. This may yield abstract characterizations of computability required to develop realistic programming languages for real-number data types which come close to the thinking of numerical analysts.

3.4. Computational learning theory: Computational Learning Theory is one of the first tentative attempts to construct a mathematical model of cognitive process. The aim here is to further develop theoretical constructs, using techniques from logic and computability, which can improve our understanding of this important area.

4. New developments involving the classical theory:

4.1. Relative computability and degree structures: The concepts of this area are in the center of foundational research in computability (and computational complexity) theory. It also provides a powerhouse of new techniques which become progressively utilised in other areas such as computable analysis, computable model theory, and complexity theory. The most exciting recent work (much of it involving participants in the network) concerns Turing automorphisms and definability, and its modelling implications for the real universe. A major task is to extend and apply the new techniques and to further work out the consequences of the Turing model throughout science and the humanities.

At the technical level, there is a close connection between definability in local structures and longstanding undecidability problems for small fragments of the theory of the computably enumerable (c.e.) Turing degrees. A main aim is to pursue the elusive natural definitions of basic degree classes, which everyone believes to exist, and to answer some basic algebraic questions on the meet operator (related to the longstanding embedding problem for finite lattices, generating sets and automorphism bases).

Enumeration reducibility and enumeration degrees are receiving more and more attention among computability theorists. Enumeration degrees provide a wider context for the Turing degrees, and other notions of relative computability such as the continuous degrees. Enumeration reducibility also arises naturally in applications of computability theory to other areas of mathematics, for instance the analysis of types in effective model theory and the study of existentially closed groups. Our main objective will be to investigate first order theory of the enumeration degrees, with the eventual aim of characterising theories for the local structure.

4.2. Decidability and Generalisations of Hilbert's Tenth Problem: There has been some exciting progress in generalising the famous solution of Matiyasevich and his co-workers of Hilbert's Tenth Problem. This is an area which has increasingly involved model theoretic approaches to decidability, and we are hopeful that with the quality of participants brought together within CiE we can achieve major breakthroughs here.

4.3 Arithmetic complexity and weak systems of analysis: Models of bounded arithmetic, and the low Grzegorczyk hierarchy, have recently attracted renewed interest. The former are important because of the insight advances in this area could give into the nature of the natural numbers. Both are potentially of practical importance because of their relevance to the limits and possibilities for computation and IT. Of course, both topics are of considerable mathematical interest in that they encompass a number of longstanding open problems. The past twenty years have seen a considerable degree of widening and generalization of the original problems (in both topics) which sparked off this boom. Now seems an appropriate time to take stock and combine the extensive joint knowledge of the participants (Manchester is justly famous in this context) into an overall picture from which we aim to build a fruitful strategy for future research.

B1.3. Scientific originality of the project

Computability theory, as it has matured over the past seventy years, has developed in many different ways, each with its own more-or-less distinct outlook and technical resources. Recent research trends in the field point to a number of new sources of interaction and unity between different strands. What is most remarkable and original about CiE is the way in which the research promises to push forward these new developments in a way not yet seen anywhere else in the world, and brings together world leaders and young researchers from varied and complementary backgrounds in computability.

An important example is the proposed work on notions of computability at higher types. Many ideas and results relevant to this project are known, but will be found widely scattered across the literature in recursion theory, constructive logic and computer science, and have not until recently been seen as contributions to a single subject. Already now CiE participants are prime instigators of new work taking a more systematic view of this area, and in developing frameworks in which a more cohesive picture emerges. For instance, the 2000 Journal of Symbolic Logic paper by Dag Normann on *Computability over the partial continuous functionals* is purely mathematical, but solved open problems in theoretical computer science, and led to personal contacts with, in particular, the Edinburgh and Birmingham subcontractors.

There is now a whole range of new approaches to this topic which promise to be pushed forward by the C iE project. For instance, the development of Game Semantics as a systematic tool for studying properties of algorithms gives a focus to the area, and allows for transferral of existing knowledge between settings, and has stimulated new work in domain theoretic models. One particular aim is a better understanding of sequential computations, while recently, the community has begun to address the issue of proof-theoretic models of classical logic. A main priority is work on the Longley Conjecture (which is about sequential computations at higher types) and concurrent systems, and to further analyse degrees of higher type computability, and to provide models for classical proof. Comparison between extensional and intensional models for computing with real numbers gives rise to nontrivial problems in topology. These problems will be looked into.

Another example is how realisability theory has proven to be a useful and powerful tool in many branches of logic and theoretical computer science. In the area of computable analysis it generalizes and gives uniformity to several different "schools of computable analysis" (type two effectivity, recursive mathematics, and domain theory). The use of realisability in computable analysis is not as widespread as it deserves to be, and one goal of the project would be to disseminate ideas from realisability and to show its value in tackling theoretical and practical questions concerning computability in mathematical analysis.

Again, the typed λ-calculus was used by Richard Montague as the key technical tool in his radical development of semantics for natural language, and Moschovakis has developed a refinement and extension of Montague's ideas. This theory appears to have interesting applications to computational semantics, and it also generates some mathematically interesting questions in the Typed lambda-Calculus. One aim would be to develop (in collaboration with linguists) the theory of referential intensions and use it to get a useful, computational theory of meaning. Here we have another novel and informative connection, with Moschovakis' seminal work on the foundations of the theory of algorithms, a natural development of which is the formulation and study of appropriate forms of algorithmic Church-Turing Theses for more abstract algorithms.

We could go on. There are other new aspects we could mention, related to this part of the project alone. Participants in CiE are responsible for literally hundreds of publications related to this topic, and in the space available it is impossible to give more than a brief indication of the resources feeding into the research, and of the variety of potential interactions.

We could point to qualitatively similar aspects of the other research objectives described in the previous section. In relation to computable analysis, the aim of classifying hierarchies of noncomputable real numbers brings together concepts like speed of convergence and arithmetic operations and the geometry of numbers (from analysis) on the one hand, and Kolmogorov complexity and effective randomness (from Algorithmic Information Theory). Other lines of research investigate the relevance of the Borel hierarchy of functions for many problems in analysis, or seek to classify continuous dynamical systems with respect to their complexity, and investigate computational properties of continuous time computation as in integration circuits, continuous dynamical systems and models of the brain.

Exact computation on real numbers is practically useful since current numerical methods, based on floating point representations, sometime are not able to evaluate results with sufficient accuracy. An aim is to obtain certified software for numerical analysis. A particular objective concerns computability for differential equations: we aim to develop methods able to give precise numerical solutions to differential equations, ie. to evaluate pointwise the solutions with arbitrary precision.

More generally, functional analysis and topology provide powerful mathematical tools which are used in numerical analysis and physics. Computational versions of basic theorems are very important in many aspects and in particular they could be and have been successfully applied in the area. Recent work shows that many physical processes cannot be employed to break Church's thesis. Planned objectives include extending recent work on formal methods used to handle rather complicated spaces (such as test function spaces) computationally, and further developing classical functional analysis on Hilbert spaces.

Topological Complexity is (at least inside computer science and mathematics) a very interdisciplinary subject, raising interesting questions for example in descriptive set theory, in algebraic topology, in algebraic complexity theory, in information-based complexity, and in computational geometry. An important goal is to provide a theoretical analysis of the discontinuities that can appear in computation problems.

Computational complexity theory includes questions about mutual relations of basic modes of computation in deterministic, non-deterministic and probabilistic computations. Connections here include propositional proof complexity, circuit complexity and communication complexity, derandomisation and foundations of cryptography, bounded arithmetic, and the design and the existence of algorithms for specific tasks.

Other goals will exploit tools from (finite) model theory, particularly Ehrenfeucht-Fraïssé (EF) games, in solving decision problems in verification. One main use is in characterising the expressiveness of various modal and temporal logics. Also, EF games provide an elegant and illuminating setting for model checking temporal logics, as exemplified by the recent PTIME algorithm for parity games by Obdrzalek and Stirling, which provides the first efficient algorithm for model checking μ-calculus. These questions are naturally connected to their infinitary counterpart: the theory of inductive definition due to Moschovakis and recently investigated in the light of proof theory and computability theory by CiE members.

Kolmogorov complexity has been extensively used in computational complexity, computational learning theory, inference in statistics, physics and computation, dissipationless reversible computing, information distance and picture similarity, thermodynamics of computing, statistical thermodynamics and Boltzmann entropy. Also useful is the notion of fractal dimension, a powerful tool in Physics, Economics, Mathematics and Computer Science. Particular objectives include investigating the structure of function complexity classes and the connection of compressibility and dimension in the time-bounded framework; combining algorithmic randomness and game theory, looking for useful concepts of Nash Equilibrium and applications; developing the comparison of (algorithmic) entropy notions; and the use of entropy in algorithm analysis.

Concerning our objectives listed under "Theoretical cross-fertilisations involving computability", little more need be said. European proof-theorists lead the world in their area, and are at the forefront of cross-disciplinary developments involving computability and applications to computer science. Project participants have developed new methods of extracting reasonable and sometimes unexpected programs from classical proofs. These extend and refine powerful proof-theoretic methods - dating back to Gödel - which allow for a 'constructivisation' of such proofs and hence the extraction of programs. We have already mentioned under Complexity Theory the relationship of proofs to major open problems about the complexity of computation.

In relation to computable models — an area still dominated by the Novosibirsk school and its graduates — there are interesting new developments giving an important link between computability and automorphism groups coming out of joint work between western and Russian researchers.

Ideas in constructive mathematics interact interestingly with some of the work that is more explicitly concerned with computability. Constructive Type Theory is an area of constructive mathematics that links with work on computing with exact real numbers and computing on topological data types. Another focus will be made on connecting type theory with topological algebras on base types.

Computational learning theory has already been transformed by the intervention of logicians. Particular approaches proposed involve extending combinatorial characterizations of various models for learning Boolean functions, and the relationship between polynomial time learnability and pseudorandomness to quantum learning and average case learning. Other approaches involve (from logic) investigating the learnability of some extension of Horn clauses, and probabilistic learning from positive data.

The areas of classical computability listed as being ready for new breakthroughs are each accompanied, within CiE, by established researchers who have made major contributions, of great originality, in the past. Paris has been the prime mover in discovering very down-to-earth statements on the borders of what can be practically proved in everyday mathematical theories. Matiyasevich provided the key ingredient in the negative solution of Hilbert's Tenth Problem. And Cooper, along with Arslanov, Ambos-Spies, Odifreddi and Sorbi, has been at the forefront of current developments concerning definability and automorphisms for the Turing universe and the implications for the world we live in. There is now a new generation of researchers, with the opportunity to share a common research environment with the community of established experts, on whom we will depend to renew this key area.

B1.4. Research method

As will be clear from the previous sections, the CiE project will draw on a wide range of technical and conceptual frameworks from all the main areas of logic, particularly computability, proof theory and model theory, from computer science and from mainstream mathematics itself. It is impossible to do more than touch on a few particular aspects of our methodological approach, but we will attempt to give some more detail in relation to each of the ten research objectives listed in B1.2, focusing as far as possible on new aspects.

Objective 1.1. Notions of computability: It is known from various lines of attack (intuitionistic and constructive mathematics, recursion theory, domain theory, programming language semantics, type-two theory of effectivity) that domains of computation, or data types, are topological spaces, and that computable maps are continuous. Many applications of the topology of data types are known in the theory of computation. A relatively sophisticated example (Bauer, Escardo and Simpson) occurs in the comparison of two proposed paradigms for exact real number computation: Whether they agree at third order types depends on an unanswered topological question. More practically, computational versions of topological continuity and compactness principles play a major role in the discovery of algorithms for tasks such as definite integration, calculation of the maximum value of a function, and other functionals that occur in analysis. So here we have a workable and informative approach to notions of computability via topological, categorical and realisability-based models of datatypes, using these to relate the associated notions of computability to constructive and computable mathematics (including analysis) via the constructive set theories interpretable over such models.

Domain-theoretic models are a powerful tool in the search for tractable and reliable algorithms for computation. A number of participants will work on applications of continuous domains in developing continuous data types in various areas of computation in particular, Exact Real Number Computation, Computational Geometry, Solid Modelling, Initial Value Problems, Partial Differential Equations, Hybrid Systems, and Quantum Computing. The most exciting new developments are the use of domains in ODE's and PDE's on the one hand and in Quantum Computing on the other hand. The domain-theoretic model for Quantum Computing, which leads to a synthesis of the Quantum Paradigm and the Turing Paradigm for computation, is in particular very relevant to the sharp increase in research in Quantum Computing in recent years.

Objective 1.2. Computability and complexity in analysis, and its applications: We already touched on how recent results (due to Matthias Schröder) allow us to extend the formal methods which are required to handle more complicated spaces computationally. But large parts of classical functional analysis on Hilbert spaces have not been developed computationally. For example, a combination of recent results of Brattka on Banach space computability with results of Martin Ziegler on regular subsets will be taken as a starting point for computable convex analysis. What we have not mentioned so far is how many problems turn out to be unsolvable for computational or topological reasons. A classification of these problems according to their degree of non-computability leads to new insights and understandings of these problems, and links up with work under objective 4.1. Understanding and classifying non-computable problems is an important line of research in different fields of mathematics (computability theory, descriptive set theory). These classifications lead to a better understanding of the limitations of existing models.

Objective 2. Complexity of computations: Proof complexity originated as a branch of computational complexity providing insights to the most fundamental questions (**P** vs. **NP**, **NP** vs. co-**NP**). In recent years unexpected connections between the topic of proof theory and seemingly unrelated areas like circuit complexity, finite model theory or game theory have been established. We will develop tools for the analysis and classification of low level proof systems such as Resolution, Cutting Planes, and Lovasz-Schrijver, obtaining applications of these tools in the analysis or improvement of satisfiability algorithms. Another application of these developments comes from the area of automated theorem provers.

A key element of the structural complexity objective is the Graph Isomorphism (GI) problem, i.e., the problem of telling whether two graphs are isomorphic. This is a problem which attracts interest both from an algorithmic perspective as well as from a structural complexity point of view. This is because GI has resisted so far all attempts for a precise characterization of its complexity. It is one of the few remaining candidates for natural problems with complexity intermediate between **P** and **NP**-complete.

Objective 3.1. Proof theory and computability: Proof mining and related techniques for the extraction of realizers from reformed proofs predominate here. Kohlenbach, whose techniques also apply to ineffective proofs in classical mathematics, is a main driving force. Constructive type theories are important tools in this objective. Constructive set theory provides a flexible, workable foundation for constructive mathematics. Non-well-founded set theories are a natural framework for studying circular and coinductive phenomena. Realisability techniques applied to constructive set theory will allow one to enucleate the computational content of its theorems. In the last few years, especially through the work of P. Aczel and M. Rathjen, more has been revealed of constructive set theory — in particular on constructively justified extensions of it by large set axioms and also, more recently, on the theory as a foundation for constructive mathematics. By considering weak subsystems of constructive set theory of computational significance, we will explore new features of this theory, exploiting its constructiveness in a very concrete way. Adding non-well-foundedness should allow us to make it a framework for coinductive and corecursive phenomena as well.

Objective 3.2. Computable models, structures and games: A plethora of techniques and approaches exists here. Specific plans here, each with their own technical contexts, include: a) Solving the problem of complexity of prime models relative to theories with non-maximal spectrum, b) Solving the Morley problem, c) Solving the problem of decidability of Boolean algebras with decidable restricted theory with constants, d) Developing a model for mathematisation of the most general forms of imperfect information games, in both the finite and infinite case, e) Computing complexities of several natural classes of games and using the computations for applications of game theory.

Objective 3.3. Constructive mathematics: Much has been said in relation to applications of this area to other objectives. We just mention some special approaches: The development and interrelationship between Bishop style constructive topology and point-free formal topology; The development of constructive set theory as a good setting for constructive topology of both the pointed and point-free variety; The work on exact real number computation and topological data types. This will involve work also on constructive type theory, which is closely linked with constructive set theory, and the further development of constructive topology.

Objective 3.4. Computational learning theory: Here we focus on the innovative and promising approach via probabilistic learning from positive data. Montagna has found that with respect to some probability distributions, probabilistic learning from positive data is equivalent to learning from positive and negative data. Montagna and Osherson considered a variant of learning called coordination. Whereas in learning the learner has to identify some computable object on the basis of examples, in the coordination paradigm we have two players who simultaneously play 0 or 1 repeatedly, and the goal is to coordinate, i.e., eventually play the same bit. Case, Jain, Montagna, Simi and Sorbi found a number of results related to a probabilistic variant of coordination, and looked at some topological and computability theoretic properties of learnable classes of players. The development of the coordination paradigm in learning theory is still at an early stage.

Objective 4.1. Relative computability and degree structures: Apart from the obvious need here to develop and apply automorphism techniques in various contexts — even for the structures based on strong reducibilities little is known regarding invariance and definability — the most effective approach has arguably always been via the local theory. At the most basic level this involves adding to the already formidable battery of computability-theoretic techniques, and deriving quite basic connections between relations on degree structures — the building blocks of more dramatic definability results. Historically, progress has often come out of work on characterising the complexity of theories of local structures, and here we meet some of the hardest problems. For instance, in relation to enumeration reducibility, it is known that the first order theory of $\boldsymbol{\mathcal{D}}_e(\leq \mathbf{0}')$ is undecidable, and inspection of the proof shows that in fact the Π_5-fragment is undecidable. Given that the $\exists$-fragment is decidable, a challenging but feasible aim is a proof of the undecidability of the Π_3-theory. And application of coding techniques may show that the first order theory of $\boldsymbol{\mathcal{D}}_e(\leq \mathbf{0}')$ is recursively isomorphic to true first order arithmetic.

Objective 4.2. Decidability and Generalisations of Hilbert's Tenth Problem: We have in mind extensions of Hilbert's tenth problem of a fundamental nature, which relate to the general question "what are the limits of computability for the algebraic theories of the commonly used algebraic and analytic domains?" There have been important advances in recent years, allowing optimism that these problems may be solvable with reasonable extensions of the existing knowledge and techniques. It even seems likely that the analogue of Hilbert's tenth problem for the field of rational numbers (a major open problem) may be not too far away. Other approaches, if successful, will almost certainly give elimination techniques with potential for applications to number theory, coding and cryptography.

Objective 4.3 Arithmetic complexity and weak systems of analysis: This is a classical area of research, bringing logic, computability theory and theoretical computer science to bear on problems in number theory, as illustrated by a still unpublished result of van den Dries and Moschovakis: The parallel time complexity $\mathrm{ca}(x, y)$ of any recursive program a which computes the greatest common divisor of two numbers x and y relative to the division operation is at least $C \cdot \log\log(\max(x, y))$ for some constant C and infinitely many x, y. This is one log away from proving that the Euclidean algorithm is optimal among all algorithms relative to division. The proof leads to some new and interesting number-theoretic questions.

B1.5. Work plan

This section discusses the plans in CiE for organising and monitoring our research, training, transfer of knowledge and general networking activities. Table 1 attempts to divide our research tasks between the different teams of CiE. It presents our best estimate of the proportion of the research effort that each CiE node plans to allocate to the research objectives outlined in B1.2. It is worth noticing from the table how closely integrated are the research interests of our teams. This, of course, reflects the underlying unity of the subject itself, and its recognition in our project.

	1.1	**1.2**	**2**	**3.1**	**3.2**	**3.3**	**3.4**	**4.1**	**4.2**	**4.3**
1. Leeds	25	5	3	10	8	10	4	20	5	10
2. Amsterdam	34	0	12	14	24	3	6	0	1	6
3. Athens	14	4	12	2	6	5	0	14	18	25
4. Barcelona	6	5	44	8	0	6	14	0	4	13
5. Heidelberg	12	5	25	9	6	10	4	18	4	7
6. Munich	16	20	12	22	5	10	0	4	3	8
7. Novosibirsk	6	4	8	0	30	6	5	26	10	5
8. Oslo	26	16	20	14	0	9	0	0	4	11
9. Prague	22	8	24	18	0	4	3	12	4	5
10. Siena	7	12	13	8	11	14	10	14	5	6
11. Swansea	28	12	15	14	16	8	0	0	5	2
Totals:	18	8	17	11	10	8	4	10	6	9

Key to research objectives (see B1.2):

1.1 Notions of computability
1.2 Computability and complexity in analysis, and its applications
2 Complexity of computations
3.1 Proof theory and computability
3.2 Computable models, structures and games
3.3 Constructive mathematics
3.4 Computational learning theory
4.1 Relative computability and degree structures
4.2 Decidability and generalisations of Hilbert's Tenth Problem
4.3 Arithmetic complexity and weak systems of analysis

Table 1: Division of research tasks among the nodes

Scheduling and monitoring

Key mechanisms for structuring and monitoring the research and training would be the programme of events to be organised by the Executive Committee (see section B4.1), in cooperation with local organisers and specialist advisers. This would include a CiE Annual Conference and a regular programme of specialist training schools and workshops, as described in B2.1. These conferences, together with other scientific meetings, and the Annual General Meeting, would present opportunities for the continual updating of our plans.

Annual Conference: This is planned to be a large-scale meeting, lasting a number of days, and probably a full week. It is intended to put in perspective the best research of the whole network, the overall picture being augmented by contributions from a small number of leading mathematicians and computer scientists from outside the network. The meeting would serve both a scientific and training purpose: the attendance of graduate students would be encouraged, as would be the organisation of their own seminars. It is expected that young researchers would be prominent among the speakers. The conference would take place at different locations each year, with accompanying regional benefits. We already have expressions of interest in hosting the annual conference from Amsterdam, Athens, Aarhus, Barcelona, Birmingham, Edinburgh, Heidelberg, Oslo, San Sebastian, Siena, Swansea, and Ulm.

Annual General Meetings: The CiE Annual General Meeting (see B4.1) would be held each year prior to the annual report becoming due, usually in association with the Annual Conference. The agenda of this meeting would include:

- Monitoring the scientific activities of the network and the progress towards our research objectives, updating them as appropriate.
- Monitoring the training activities of the network, in particular the current implementation of fellowships both for early-stage researchers and for experienced researchers.
- Setting guidelines for further exchange visits.
- Discussing a report from the Executive Committee relating to the planning of schools and workshops, and other network activities.
- Collecting data relating to the network.
- Preparing for the annual report and the mid-term review, and setting a timescale for carrying out the work on these.
- Other business and scientific matters of interest to the network.

The first annual conference would take place approximately 9–12 months after the start date (leading up to the first annual report), and subsequent meetings would follow at 12 monthly intervals.

We do not expect any part of the work to be sub-contracted by a participant responsible for it.

Planning for innovation, and the monitoring process: There are strong reasons, to do with the nature of our research, which make it inappropriate for us to list overly-detailed incremental steps towards our main research objectives. One reason is that, although the senior mathematicians and computer scientists in CiE have a good idea of what research they intend to work on, the research projects that have easily predictable outcomes cannot be reliably related to our major research aims; the research topics described in B1.2 certainly entail many problems of this nature, such as are suitable as Ph.D. topics for graduate students. But the really fundamental problems that lead to breakthroughs and new points of view cannot be broken up into easily identifiable sub-tasks. To do so would either be misleading, or inhibit the work towards such major advances. These genuinely new developments will in due course be assimilated into the monitoring process, being disseminated at our conferences and schools as appropriate, and eventually being evidenced in our reports via the lists of publications. Another relevant point is that, as opposed to laboratory-based subjects, we tend to work as individuals, or in very small groups, rather than directing research teams in laboratories using expensive equipment. Our research agenda is thus more flexible than is usual in the sciences, with no requirement that we know in advance which approach to a problem we are going to take.

Many of the leading figures of CiE have been associated with previous successes in running networks and major research projects. For instance, the earlier COLORET network, and the different INTAS projects coordinated by CiE leaders, have each been highly successful (as evidenced by the final reports and their assessments). These led to a large number of publications, including several breakthroughs. We have even higher expectations of CiE. The heightened cohesion of the interdisciplinary aspects, and the remarkable quality and constitution of the research team, give us high expectations that our publication and advances in research should give adequate indications by which to judge our performance.

B2. TRAINING AND/OR TRANSFER OF KNOWLEDGE ACTIVITIES

B2.1. Content and quality of the training and transfer of knowledge programme

Training and transfer of knowledge objectives: Research in computability theory, and the ability to apply it, needs both depth of knowledge of advanced techniques and, increasingly, the ability to draw parallels and make connections between approaches to problems in diverse settings. Thus, our training and transfer of knowledge objectives derive from these two basic considerations. We aim to train our new generation of young researchers in the powerful techniques and conceptual frameworks now available, while actively counteracting the fragmentation seen in many other scientific areas. The new developments in the nature of computability-related research pointed to in Part B1 of the proposal makes the latter aim a particularly timely and essential one. In any case, successful research related to computability and its applications requires skills that are often only available at institutions spread over a number of different countries.

Exploitation of the network potential, and complementarity: CiE brings together a truly remarkable combination of individuals and research groups, one that would until recently have not been thought feasible in terms of its diversity and quality of resources. One has the sense of a window of opportunity, of an idea whose time has arrived, of an opening that, if taken, can have a unique impact on European and world science — particularly those newer areas concerned with computing. It promises to provide an unusually exciting environment for any new researcher (and many more experienced researchers!) to enter into. Complementarity, of course, lies at the heart of CiE, and is integral to the whole proposal. It is also a fact-of-life that critical mass, even in particular areas of research related to computability, is not to be found at the national level, with the notable exception of the United States.

Particular mechanisms for exploiting the potential of the network include most of those found to be useful and effective in the past. There would be a coordinated program of workshops, schools and conferences, both focused on particular areas of expertise or interaction, and bringing together larger groups of researchers from a variety of backgrounds. There would be a carefully worked out programme of secondments of young researchers, based on their individual needs and the resources available at the various nodes and subnodes of the network. There would be the development of network publications, supplementary to the usual research papers, and of web-based resources. And, of course, research visits would as far as possible happen in conjunction with seminars and other ways of facilitating interactions between young and more experienced researchers.

Available resources, and rationale for the requested distribution of early-stage and experienced researchers: There has been considerable discussion among the CiE participants concerning the exact distribution and balance of young researchers. Overall, the initial demand for young researchers based on local circumstances has been somewhat pruned down in our final budget. A number of locally valid solutions have been agreed, and we believe that what is now outlined is especially well adapted to the likely demand from able young researchers, and is balanced both in terms of the overall requirement for researchers in particular areas, and in terms of the regional expectations of different parts of the European community.

We identified the main need for early-stage researchers to be that for assimilating new techniques not available at their home institution; for extended contact with leading experts in their chosen research area; and for a general broadening of research and cultural horizons. All of these needs seemed most effectively satisfied, within the available resources, via shorter visits of between one and six months, with our standard early-stage researcher period of employment being for three months, or roughly one university semester. The assumption is that most early-stage researchers funded will be selected from within CiE — we have a very large number of PhD students at institutions participating in CiE who could benefit. However, the boundaries of our subject extend beyond those set by CiE participation, and there is usually a two-way transfer of knowledge deriving from such visits. So both the network and students from other parts of the EU may benefit from a proportion of recruitment of young researchers (both early-stage and more experienced) from outside of CiE.

For more experienced researchers, we believe CiE can make a decisive intervention in their careers at a formative period of their development, bringing them a number of benefits, such as: An enhanced and accelerated technical development; Helping them achieve some specific (and possibly novel) research outputs; Encouraging the formation of intra-European research links of longer term usefulness; And providing the young researcher with a training in the underlying research outlook on which CiE is founded. These aims seem to us to need rather longer, good results achievable in perhaps nine to twelve months.

The Leeds node is one of the larger teams, containing very active groups with strength in both mathematics and computer science, and great experience in both training PhD students and hosting post-doctoral researchers. From the beginning of next year, Leeds will participate in an Early Stage Training (EST) Marie

Curie project providing PhD training in Logic (in collaboration with Manchester, Munich and Lyon). The balance in favour of early-stage researchers is appropriate to its the extensive training resources (as described in section B3), relating to all the main research objectives. The two experienced researchers would work on topics related to objectives 1.1 and 4.1/1.2. The Amsterdam node has one of the most extensive graduate training programmes in the network, which explains the emphasis on hosting early-stage researchers, and particular research strength in relation to 1.1/3.2, for which the experienced researcher will be recruited. The Athens node runs the Inter-University Graduate Program in "Logic and Theory of Algorithms and Computation", and takes in the large group in Sofia, which also has a large graduate training program. The two experienced researchers would be recruited in relation to objectives 4.2/4.3 and 1.2/2/4.1. Barcelona has great strength and diversity relevant to objectives 2, 3.4 and 4.3, and, as well as detailed plans for early-stage research training in these areas, they would like to recruit two experienced researchers, the exact topics and pattern of secondments depending on the candidates available. The Heidelberg node contains a wealth of experience in networking, organising workshops and conferences, and in training young researchers, apart from which they contain great expertise, especially in relation to objectives 1.1, 2 and 4.1, which is where their recruitment will be targeted. Munich too contains great resources of expertise and training, particularly centred on topics related to 1.1/1.2 (especially Hagen) and 3.1/2/3.3. They have plans for hosting two experienced researchers in these areas. Oslo and its subnodes play a key role in integrating objectives 1.1, 1.2, 2, 3.1 and 4.3, and it is in relation to this unifying project that they intend to recruit early-stage researchers and two experienced researchers, with secondment to Aarhus in mind for one of these. Prague is doing quite unique work related to new approaches to breaching the Turing barrier, and has many research students, mainly associated with Charles University. Their planned recruitment is relatively modest, but will play an important role in relation to objectives 1.1, 2 and 4.1, and their integration. The Siena node, taking in Florence, Padua, Turin and Udine, is a very interesting one, containing special expertise feeding into the interdisciplinary aspects of the research in novel ways. Their emphasis on recruiting experienced researchers in relation to a range of objectives — in particular 2, 3.1, 3.2, 3.3, 3.4 and 4.1 — has been well-argued, and the node contains the depth of expertise and experience in training, networking and organising of all sorts of meetings of benefit to young researchers, to make the use of resources entirely justified. Finally, Swansea offers an intensely active and expert environment for both early-stage and experienced researchers, and is another at the forefront of the new cohesion running through research into computability, and prominent in promoting interactions between mathematics and theoretical computer science. Their plans for recruitment centre around objectives 1.1, 1.2, 2, 3.1, 3.2 and 3.3.

Each team of the network has a long established record of training research students and postdoctoral researchers, and many are prominent as organisers of international conferences, networks, summer schools and workshops. The full resources of leading European universities will be available in support of the researchers recruited. Further details of what is offered by individual nodes can be found in section B3 of the proposal.

Career Development Plan and needs of individual researchers: The scope of the training and transfer of knowledge activities outlined in this proposal is very large, and each early-stage and experienced researcher appointed by the network will be able to choose from a wide range of possible engagements with them. The *Career Development Plan* will provide guidance as to how to do that from the very start of their appointment. For early-stage mathematicians and computer scientists, the Career Development plan will provide:

1. A list of basic books and survey articles, and a list of recent papers to be studied individually and presented at graduate student and other seminars by the fellow or other people from the node.
2. A choice of workshops, research schools and conferences organised inside or outside the network which can be attended by the young researcher with network funding.
3. A plan of visits (funded by the network) of the young researcher to network nodes other than the host node, to enable the researcher to benefit from training and/or transfer of knowledge on topics relevant to her or his research, or to benefit in other ways from expertise and resources not available at the host node. (This may also open up the possibility of a future appointment to another node.)
4. Information and advice regarding career possibilities (such as postdoctoral appointments) following the completion of the thesis.

For experienced researchers the main elements of the Career Development Plan are similar to the above, except that 4 places the emphasis on progress towards a permanent position, and 1 is replaced by

1′. A suggested research plan outlining short-term and long-term research themes related to the CiE research objectives, and pointing to opportunities for joint research with network members from the host node and other network nodes, with the aim of helping the young researcher to acquire the personal training and transfer of knowledge needed to develop full autonomy in research.

These Career Development Plans will be regularly updated and will be made available to the panel of coordinators, to help in the organising of training and transfer of knowledge on a network-wide basis according to the needs of early-stage and experienced researchers appointed by the network.

Training and transfer of knowledge activities: The Career Development Plan provides a framework for relating the individual researcher to the considerable resources in place locally. The Annual Conference not only has an important role in relation to structuring and monitoring the research, but provides a focus for the network-wide training and transfer of knowledge activities. Apart from the full programme of plenary and specialised talks reflecting the progress with the research objectives, there will be provided opportunities for young researchers to speak on their research. Early-stage researchers will particularly be encouraged to get experience of communicating their results and learning to receive and utilise feedback. Other activities in the form of workshops, summer schools, and conferences both those organised within CiE or including Ci E participation, will play an important intermediate role. There is perhaps more enthusiasm from nodes and subnodes for organising these more limited meetings, where the ratio of training and transfer of knowledge benefits to the organisational demands is high, and the topics can be better targeted towards particular research objectives and connectivities. Volunteers to organise schools/workshops on a whole range of relevant topics and their links include: Aarhus, Athens, Barcelona (who propose a week-long school on Propositional Proof Complexity and related topics), Birmingham, Hagen (who have twice before run tutorials on Computability and Complexity in Analysis), Heidelberg, Munich, Prague (topics between logic and complexity), Swansea, Ulm and Zaragoza. Most of these have initiated such events on many previous occasions in different contexts, and have very positive views on their usefulness. However, the strength of this network will be that we bring people with diverging interests together, and this will be an important ingredient in our schools and workshops.

A number of other groups are willing to organise courses in conjunction with other non-CiE meetings. Many of our main participants are closely involved with organising major international meetings, often in Europe. These include LICS (A. Simpson is LICS Publicity Chair), CCA Annual Conference (organised by Hagen once a year since 1995), IMCS Conference on Proof Theory (Hyland), the annual Malcev Conference in Novosibirsk (Goncharov), and Logic Colloquium 2004 in Turin (Andretta). Logic Colloquium 2005 will be held in Athens, and ALT'2006 (Algorithmic Learning Theory) is likely to be organised by the Barcelona group.

Training in complementary skills: All our participating groups take the development of such skills, particularly communication skills, very seriously, and offer opportunities for speaking in small seminars in an informative and supportive atmosphere. There are also opportunities to be involved at an organisational level in the many activities in which the senior researchers of the network are involved. Many of our participating universities offer training courses, open to younger members, in various aspects of academic life, including computer and lecturing skills, and training in the preparation of grant proposals!

Enhanced transfer of knowledge: The large number of sub-nodes, often quite substantial and containing internationally leading researchers, make secondments a prime tool in matching research topics to young researchers' interests and career aims. Another important aspect is the role of the existing CiE website. This will be developed into a major resource, not just in relation to information on CiE organisation, opportunities and participants, but as an interactive aid for workers in the field as a whole. It will play an important role in disseminating new scientific developments throughout the network, and raising the profile of EU science.

Gender aspects: There is considerable variations in the representation of women mathematicians and theoretical computer scientists within CiE. In Athens women are strongly encouraged to participate in all activities of the group and they seem to respond positively: 16 of the M.Sc. students, 3 of the Ph.D. students and 1 of their postdoctoral researchers are women. In Sofia also there is better participation than is usual in mathematically related areas. The Barcelona node too has a relatively good record — in Barcelona one of their senior researchers is a woman, and three of the members of the current node panel are women. In Zaragoza the main researcher is a woman, as is her PHD student, and there they teach graduate and undergraduate level courses in which they actively encourage women to pursue research careers. In San Sebastian the main researchers are women. The Siena node too has better than average participation by women. In Florence two of the three research students and post doc are female, and Laura Crosilla is actively engaged in the organisation of their group. Other nodes have little or no participation by women, which is, unfortunately, not unusual in European mathematics and CS departments (see, for example, Ellen Spertus: *Why are there so few female computer scientists?*, MIT Artificial Intelligence Laboratory Technical Report no. 1315). We strongly support equality of opportunities, will make this explicit in all advertisements in connection with recruitment, and will seek to bring participating women researchers into the higher levels of CiE management, and consult with them on how to improve participation at all levels.

B2.2. Impact of the training and transfer of knowledge program

The European dimension: Most of the CiE participants have strong research links with non-EU partners, particularly with those from North America where there is great strength in computability related areas, and world dominance in the economic exploitation of applications. These links are extremely important to us, and will continue, often supported by national funding. They have certainly benefited the research careers of leading European researchers, sometimes turning them into leading American researchers (we have a number of examples in mind, and the migration is largely one-way). But there has been an associated tendency to fragmentation in the area, a moving away from the broad-based outlook of the early European pioneers in the field, and a negative structural effect in relation to the development of a genuine community of researchers at the European level. Even though some of this is inevitable, and is traceable to quite different causes affecting world-science generally, we see a very important and specifically European role for CiE in restructuring computability in Europe, while playing a world role in relation to a concomitant restructuring of the scientific area.

We decided very early on that our structural and scientific aims were best achieved by giving absolute priority to the European dimension. We have a world-class body of researchers in areas centred around computability on which to base such an approach. We have resisted the strong temptation to import our more prestigious US connections into CiE, and hope our reasons are understood. Our one major non-EU participant brings in the historically important Russian school of logic and computability, which still boasts distinguished and seminal figures in the field. Despite the current economic problems in Russia, there is still a very active network of researchers and training programmes, which we expect in the course of time to be more fully integrated into the European context.

As mentioned earlier, computability theory and theoretical computer science are particularly dependent on networking activities, being an area in which researchers are dispersed across different centres in many countries, while new advances are increasingly dependent on the bringing together of concepts and techniques originating from different research contexts. The research community we are building will benefit from CiE in many ways, some immediate and others stretching far into the future. It will not only create better educated and hence more effective researchers, and encouraging the development of an infrastructure of research links which will take the research and its exploitation to a new level. It will move the world-balance in this area decisively towards Europe, and make the EU a more attractive place to work, both for leading young researchers and more senior figures.

The impact of interdisciplinarity and the transfer of knowledge activities: In the short term we expect to see a number of CiE trained researchers establish themselves internationally and become associated with pathbreaking new research developments. But as we have outlined above, CiE expresses, and seeks to enhance, a number of exciting and important interdisciplinary trends related to computability, logic, theoretical computer science, and their applications in science and information technology. These trends not only lead to novel solutions to basic problems. They demand new ways of thinking about the role of computability in the twenty-first century, and signal a return to a research culture concerned with issues which connect with the concerns and aspirations of ordinary people. Turing himself supplies the best example of this interdisciplinarity in practice. The development of the Turing model of machine computability was prime computer science. The discovery of the universal machine and the working out of its properties and theoretical consequences was pure mathematics. The sum outcome was work which profoundly affected our everyday lives.

The proposed mixture of early-stage and experienced researchers, and the role of secondments: The proposed mix of early-stage and experienced researchers (as commented on in B2.1 and given in detail in B2.3) is based on overall considerations of likely demand from PhD students, the availability of suitable experienced researcher candidates, related to the research objectives, and consideration of various local factors, such as the availability of a specially good training environment, or the likely availability of a specially promising candidate for a postdoctoral fellowship. Our eventual mix balances the requirements for both categories of researchers 57:43 in favour of early-stage researchers. This seems to us to extract the maximum impact from the available resources. The early-stage visits represent very good value, should be very attractive to young EU researchers in the area, and should impact significantly on the character of the research environment these young people will experience and contribute to. On the other hand, the experienced researchers are an investment in proven research achievement, with greater intensity of individual impact, and greater confidence of immediate research outputs in relation to the objectives described in part B1, and of long-term benefits to the research community.

It needs to be said, of course, that the research centres which make up the network also derive considerable benefit from the mobility and targeted employment of young researchers. This may be in the form of a new direction for seminars or research, or just more lively and interactive local research conditions. There is also a contribution to the culture of interdisciplinarity that we have already mentioned. The role of secondments is a particularly important one in this context. Much important expertise, including world-leaders, is to be found in the various sub-nodes of the network. It is important that the full resources of the network are made available to the young researchers, and that the maximum possible number of centres of the network (spread over sixty-five universities and other research institutions) benefit from this aspect of the networking.

Secondments of early stage researchers will be extensive, and will involve most of the centres where there is a high level of resources and an active group. The secondments of experienced researchers will be directed to internationally leading groups, the exact pattern in some cases to be determined by the availability of suitable candidates. Centres expected to participate at this level include Aarhus (world-leading work in proof-theory and computability), Edinburgh (theoretical computer science and notions of computability), Florence (internationally leading centre in various areas of logic), Hagen (*the* leading group in computability and complexity in analysis), Lisbon (an important subnode of Barcelona, with a specially individual approach to topics connected with complexity), Padua (world-famous group in constructive topology and its applications), Sofia (seminal work in constructive mathematics) and Ulm (a leading centre for topics connected with complexity).

The impact at national, European Community and international levels: In 1999, TIME Magazine published a book titled *Time 100: Builders & Titans: Great Minds of the Century*, which was based on a selection by outside experts and historians, and their own readers, of the 100 most influential people of the twentieth century. Apart from Einstein, there were only two figures who were there for their work in mathematics — Gödel and Turing, founders of computability theory.

Ever since the time of Hilbert, Gödel and Turing, Europe has played an important part in all matters connected with computability, and in the productive relationship between theory and its many practical applications to computing and its role in everyday life. The more theoretical end of this spectrum has always been the domain of a relatively small number of dedicated researchers whose work has had a surprisingly disproportionate impact on the wider world (as already mentioned in B1.1). At the global level, computability is uniquely good value. Although few researchers would aspire to the impact of a Turing, there are still fundamental theoretical barriers to human progress which researchers within CiE are coming to terms with, most noteworthy, what has come to be called the 'Turing barrier', or the problems associated with computability over continuous data, or the theoretical basis of artificial intelligence, or the development of mathematical models based on algorithmic content to explain aspects of the underlying structure of the physical universe. On all these topics computability theorists have something to say, and this is reflected in our research objectives discussed in B1.

There are of course much more mundane, but very basic, benefits to be mentioned. At the local level CiE funding, with its implicit recognition, can mean a great deal to isolated researchers and small groups. More and more research is organised within large groups, not appropriate to computability, or to many other basic areas of research for that matter, and the relatively small amounts of funding available under Marie Curie can have a very big affect on scattered but important areas such as ours. Enabling local groups to organise meetings with international participation does not just develop their complementary abilities and aid their scientific development. It can raise the whole profile of the group and its research area within their local institution, region and national environment.

Career aspects: Many new ideas and concepts originating with computability theorists and theoretical computer scientists are progressively assimilated into the wider community in many different guises, their source often quite forgotten. This underlying relevance brings with it many career openings for the newly graduated or more experienced researcher in the area. Even the very best new researchers (and again, we have examples) can leave the subject to apply their training in more lucrative areas such as banking and software development, and other areas where a training in algorithmic structures and strategic thinking is invaluable.

CiE can play an important role in both development of career possibilities for young researchers, and in consolidating a research community with its internal momentum capable of retaining the most promising researchers in the area. Again, the interdisciplinarity championed within CiE will enhance the prospects for young researchers gaining permanent academic posts. Candidates with a lively interest in the wider context of their subject, and with a range of skills related to computer science (in the case of the mathematicians) or advanced mathematical techniques and frameworks (in the case of computer scientists) will always be more attractive to prospective university employers. And employment within the network will provide evidence of autonomy through mobility, and may well provide that invaluable stepping stone to new and surprising results and a permanent position.

B2.3. Planned recruitment of early-stage and experienced researchers

Our overall target is the provision of 204 person-months for the appointment of early-stage researchers and 162 person-months for the appointment of experienced researchers. Measured in person-months, that gives a ratio of 57:43 between early-stage and experienced researchers.

The typical length of stay for early-stage researchers will be between three and six months, with the norm being around three months. From experience, we know that doctoral students making a training visit to another university generally prefer a fairly short stay. For experienced researchers the appointments will be for longer, to enable both training and collaborative research to be achieved, and here the range is between six and twelve months, with a norm of nine months.

The main source of early stage appointments will be from within CiE, where there are approximately 160 doctoral students who could potentially benefit from appointments. The network management will strongly encourage these students to take advantage of the opportunities offered by the network to improve their thesis preparation through training abroad. We estimate that around 90% of early stage recruitment will be from within CiE and 10% from outside. Appointments of experienced researchers will be more open, and there may well be a number of very well qualified fellows recruited from outside CiE. Fellows from within the network will be strongly encouraged to apply. We will be keen to attract particularly promising European researchers after a period of study outside, for instance those who have recently obtained their doctorate in the United States. We expect around 80% of recruitment of experienced researchers to be from within the network, and 20% to be from outside. We anticipate no difficulties in achieving our proposed level of recruitment. However, we will be flexible in the use of secondments, so as to better match the available candidates to the needs of the network.

We will use a number of different ways of advertising vacancies for both types of researcher. Apart from the CiE website (where job profiles will be published) and local websites of separate teams, there are a number of well-targeted sites and e-mailing lists, such as the Computability Theory and CCA e-mail lists and websites, the LICS Newsletter (edited by CiE member Alex Simpson), the Proof Theory and FOM e-mail lists and the ACM SIGACT News. All of these will be used, along with the various newsletters and mailing lists run by national associations, such as the British Logic Colloquium Newsletter. We will also seek to reach women candidates through *European Women in Mathematics* (providing support and advice to women mathematicians since its conception at the 1986 International Congress of Mathematicians in Berkeley), which maintains links on its website to information about jobs in mathematics. The network itself and our extensive network of personal contacts will, of course, play a large role in recruitment.

Applications will be evaluated locally by a committee formed by the appointing team in accordance with local procedures. The network coordinator will represent the overall interests of the network, receiving copies of all applications, and being adjoined to the appointing committee, usually via e-mail. All decisions will be subject to the agreement of the Executive Committee (described in B3.1), who will consider such factors as the need for coordination of recruitments between participants. The appointments procedure will be made as accessible to interested CiE members as possible, in accordance with the customary openness in CiE affairs, an approach partly made possible by extensive use of the CiE website. We believe these measures are as simple as is consistent with a level of scrutiny which removes any impression of individual manipulation of the appointment process.

The main criteria applying for the selection of early-stage researchers will be based on perceived benefit to the young researcher, in particular the existence of a suitable supervisor and appropriate local training resources. We will rely heavily on recommendations from home-university supervisors, most of whom will be from within CiE or well-known to members of the network, and whose advice we are confident we will be able to assess fairly. For experienced researchers their relevance and potential contribution to the achievement of particular research objectives will be a very important factor. In all appointments we will bear in mind guidelines established at Annual General Meetings, in consultation with the participants, particularly in relation to the role of CiE in structuring the European computability research community. Particular considerations may include the need to foster particular research areas, or to give support to developments at university or national level. The needs of less advantaged areas of the EU and of women researchers will be taken into account.

We will ensure the maximum possible level of involvement of CiE women members in the appointment process. Given the relatively small proportion of senior women researchers available, there exists a valuable opportunity to bring forward younger female researchers, who may have a very powerful contribution to make, and whose involvement in decision-making can be seen as useful training for higher responsibility both inside and outside of CiE.

The following table gives an indicative breakdown of the early-stage and experienced researchers whose appointment would be financed by an eventual contract.

	Early-stage and experienced researchers to be financed by the contract			Other professional research effort on the network project	
Network team	Early-stage researchers to be financed by the contract (person-months) (a)	Experienced researchers to be financed by the contract (person-months) (b)	Total (a+b) (c)	Researchers likely to contribute (number of individuals) (d)	Researchers likely to contribute (person-months) (e)
1.	30	18	48	37	816
2.	39	6	45	18	336
3.	18	18	36	27	442
4.	18	18	36	20	456
5.	18	18	36	19	468
6.	24	18	42	29	480
7.	0	0	0	48	940
8.	12	18	30	13	310
9.	20	12	32	10	235
10.	18	24	42	27	445
11.	15	12	27	17	310
Totals:	212	162	374	268	5238

B3. QUALITY/CAPACITY OF THE NETWORK PARTNERSHIP

B3.1. Collective expertise of the network teams

Node 1: UNIVERSITY OF LEEDS, U.K.

Subnodes: University of Birmingham, University of Cambridge, University of Edinburgh, University of Manchester.

Node Coordinator: Prof. S. Barry Cooper (University of Leeds, U.K.), also network coordinator.

Key scientific staff: *From Mathematics:* Profs. S.B. Cooper, H.D. Macpherson, M. Rathjen, J.K. Truss, S.S. Wainer (Leeds), P. Aczel – also CS, J.B. Paris (Manchester); Drs. J.M.E. Hyland (Cambridge, Math), G.M. Wilmers (Manchester, Math); Researchers A.E.M. Lewis, S. Tupailo (Leeds), C. Urban, N. Gambino (Cambridge). *From Computer Science:* Profs. M.E. Dyer (Leeds), A. Jung, M. Smyth (Birmingham), A. Pitts, G. Winskel (Cambridge), G.D. Plotkin (Edinburgh); Drs. P. Hill, H.H.J. Müller, N. Shakhlevich, K. Vuskovic (Leeds), M. Escardo, P.B. Levy, S.J. Vickers (Birmingham), A. Dawar, M. Fiore (Cambridge), A. Simpson (Edinburgh); Researchers J.R. Longley, M. Schröder (Edinburgh), R. Banach, D. Rydeheard, A. Schalk, H. Simmons, P. Taylor (Manchester). *From Philosophy:* Dr. T.E. Forster (Cambridge, Philosophy).

The senior staff will devote between 20% and 50% of their time to the project. For the network coordinator and junior researchers (including about 30 PhD students) this will be between 50% and 90%.

Research expertise: The Leeds node epitomises the new developments across logic and computer science on which this cross-disciplinary project is based. It contains expertise in all but one or two of areas represented by the research objectives, and boasts a number of seminal contributors to the last thirty years' history of the field. All of the groups of which the node is comprised have claims to being world-leaders in one or more aspects of the proposed research. All of the four main areas of logic, each of which feeds into this designedly protean research project, are represented, especially computability theory in its various guises, proof theory and model theory. Leeds itself is a rare exemplar of the broad approach to logic, as well as having strength in theoretical computer science. At Cambridge and Manchester new and original applications of logic, and ground-breaking computer science go hand-in-hand. The participants from Edinburgh and Birmingham are strong in theoretical computer science, especially applications of domains and topology to new computational paradigms, but their work is complementary to that of the logicians, and is sometimes to be seen published in the best logic journals. Plotkin was an invited speaker at ETAPS 2001, Genoa.

Training experience: The teams involved have a long-standing successful track record in training PhD students and supervising young researchers. The Leeds senior researchers have successfully organised many successful workshops and graduate schools (variously funded by EPSRC, INTAS and the EU) in relevant areas of logic, and organised Logic Colloquium '97 in Leeds. Dr Hill was co-organiser of the International Summer School on Computational Logic (ISCL'02) in August 2002. The Manchester team is heavily involved in running a masters degree course in logic and theoretical computer science, offering ideal graduate training in a whole spectrum of pure and applied topics. The Cambridge team is involved with a wide range of training activities, including extensive supervision of PhD students, while the Edinburgh and Birmingham computer science departments are well-known too as magnets for aspiring young researchers. The members of the Birmingham team play an active role in the Midlands Graduate School in the Foundations of Computing Science.

Links within the network: With such active researchers in an area known for its international infrastructure, it is impossible to do more than mention some of the highlights. Leeds itself has been involved in various EU funded activities, including a proof theory network under Framework 3, the *Complexity, Logic and Recursion Theory* (COLORET) Framework 4 network, and Cooper coordinated a major INTAS project *Computability and Models*, participants from these earlier projects (taking in Leeds, Munich, Heidelberg, Siena, Turin, Barcelona, Amsterdam, Novosibirsk, Kazan and parts of the Scandinavian node) forming the core of this more unconventional and much larger network. In addition to the many existing specialist links, which can be traced via joint publications, a number of participants are already involved in cross-disciplinary research contacts within the network. Particular examples of the latter include Longley and Normann, Truss and Morozov, Plotkin and Hyland, Cooper and Odifreddi.

Two significant recent publications:

S.B. Cooper and P. Odifreddi, Incomputability in Nature, in *Computability and Models: Perspectives East and West* (S.B. Cooper and S.S. Goncharov, eds.), Kluwer Academic/Plenum Publishers, New York, Boston, Dordrecht, London, Moscow, 2003, pp. 137–160.

G.D. Plotkin, Full abstraction, totality and PCF, *Mathematical Structures in Computer Science*, **9** (1999), 1–20.

Node 2: UNIVERSITY OF AMSTERDAM, THE NETHERLANDS

Subnodes: National Research Center for Mathematics and Computer Science (CWI, Amsterdam), University of Utrecht, University of Münster (Germany).

Node Coordinator: Dr. Benedikt Löwe (University of Amsterdam, The Netherlands).

Key scientific staff: *University of Amsterdam:* J. van Benthem, H. Buhrman, P. van Emde Boas, D. de Jongh, M. van Lambalgen, B. Löwe, L. Torenvliet, Y. Venema, P. Vitanyi; *CWI:* F. de Boer, P. Grünwald, J. Rutten; *University of Utrecht:* L. Beklemishev, H.J. Sandor Bruggink, J. van Leeuwen, J. van Oosten; *University of Münster:* M. Möllerfeld, W. Pohlers. The senior staff will devote between 15% and 50% of their time to the project, the approximately 20 PhD students rather more.

Research expertise: In Amsterdam, research in logic and its applications is organized with a strongly holistic attitude in the interdisciplinary research institute ILLC that includes researchers from mathematics, computer science, and applications of logic in the cognitive sciences, the social sciences and philosophy. This fact, allowing lively interaction between researchers from traditionally separate fields and the incorporation of mathematical and highly abstracts methods into modelling techniques for concrete and applicable situations, has tremendous synergetic effects on research of and in connection with Amsterdam logicians.

While Amsterdam and its subnodes have produced research results of the highest international standards in all of the main four research objectives, the current research of the people involved in CiE is focused on four main themes: (a) alternative models of computation (particularly including Quantum computing, recursion in higher types, infinitary computation, supertasks; de Boer, Buhrman, van Emde, Boas, de Jongh, van Lambalgen, van Leeuwen, Löwe, Möllerfeld, Pohlers, Rutten, Torenvliet, Vitanyi), (b) complexity theory (Buhrman, van Emde Boas, van Leeuwen, Torenvliet, Vitanyi), (c) logic and games (particularly including computational complexity of games and infinite games and their connections to higher recursion theory; van Benthem, van Emde Boas, Löwe, Möllerfeld), and (d) computational aspects of proof theory (de Jongh, Möllerfeld, Pohlers). Vitányi (with Li Ming) wrote the standard text: *An introduction to Kolmogorov complexity and its applications*, Second edition, Graduate Texts in Computer Science, Springer-Verlag, 1997. In relation to objective 3.4, Grünwald was invited to speak at the DIMACS workshop on *Complexity and Inference*, 2003, Rutgers.

Training experience: The ILLC in Amsterdam hosts the world's largest Master program in logic (organized by de Jongh and Löwe) preparing numerous young researchers from many countries for their future research careers. There are international contacts with logic programs in other nodes of CiE, in particular Athens.

The Dutch researchers from Amsterdam and Utrecht are members of the *Dutch Research School in Logic* (OzSL), responsible for the education of virtually all logic PhD students in the Netherlands. The quality of PhD education in Amsterdam, Utrecht and Münster is highly respected and many past graduates from these universities are today highly rated international researchers.

Team members from Amsterdam and Utrecht are active in organising and teaching summer schools for doctoral students (ESSLLI, NASSLI). The annual main event of mathematical logic was hosted by Utrecht in 1999 and by Münster in 2002. The international conference series Foundations of the Formal Sciences (FotFS) which intends to incite interdisciplinary research among young researchers (FotFS III was funded under the fifth framework as a PhD EuroConference) is supervised by node coordinator B. Löwe. All subnodes are also active in informal inter-university research seminars chiefly intended for PhD students: the Aachen-Amsterdam exchange, the LiB-ILLC-Days (Amsterdam and Bonn), the Münster-Utrecht exchange, the Colloquium on Mathematical Logic (Amsterdam and Utrecht), the workshop series *Games in Logic, Language and Computation* (Amsterdam, Groningen, Utrecht).

Links within the network: We split up the description of cooperations into the mentioned four areas of research focus. There are more cooperations in the other areas that cannot be mentioned here for lack of space: (a) In the area of *Models of Computation*, there will be strong cooperations with the nodes Leeds, Athens, Munich, Siena, Oslo, and Swansea. (b) In the area of *Complexity Theory*, there will be cooperations with the nodes Athens, Heidelberg, and Barcelona. (c) In the area of *Logic and Games*, we will be in close contact with the nodes Leeds, Heidelberg, and Siena. (d) Concerning *Proof Theory*, we will collaborate with the nodes Leeds, Munich, Oslo, and Swansea.

Two significant recent publications:

Beckmann, Arnold; Pohlers, Wolfram. Applications of cut-free infinitary derivations to generalized recursion theory. Ann. Pure Appl. Logic 94 (1998), 7–19.

Buhrman, Harry; Tromp, John; Vitányi, Paul. Time and space bounds for reversible simulation. J. Phys. A 34 (2001), 6821–6830.

Node 3: UNIVERSITY OF ATHENS, GREECE

Subnodes: Athens University of Economics and Business, Bulgarian Academy of Sciences, National Technical University of Athens, Sofia University (Bulgaria), University of Aegean, University of Crete.

Team Coordinator: Prof. C. Dimitracopoulos (University of Athens, Greece).

Key scientific staff: Profs. C. Dimitracopoulos, E. Koutsoupias, J.R. Moschovakis, Y.N. Moschovakis, V. Zissimopoulos (Athens), M. Mytilinaios (AUEB), L.L. Ivanov, V.A. Sotirov, J.A. Zashev (Bulgarian Academy), Th. Pheidas, K. Skandalis (Crete), F. Afrati, G. Koletsos, S. Zachos (NTUA), A.V. Ditchev, D.G. Skordev, I.N. Soskov, T.V. Tinchev, D.I. Vakarelov (Sofia Univ.); Drs. Ch. Cornaros (Aegean), V. Baleva, D. Guelev (Bulgarian Academy), St.K. Nikolova, A.A. Soskova (Sofia Univ.); Researchers E. Foustoucos, G. Stavrinos (Athens), A. Pagourtzis (NTUA).

The senior staff will devote between 20% and 35% of their time to the project. For junior researchers (including about 12 Ph.D. students) this will be between 50% and 70%.

Research expertise: The Athens node represents two of the strongest research groups in south-eastern Europe that work in the area between logic and theoretical computer science. It contains expertise in several of the areas represented by the research objectives, and has contributed significantly to the field. The Athens group is the one with the broadest approach to computability theory, with members' interests ranging from the study of the foundations of the theory to applications in computer science, e.g. to problems concerning computer networks and online algorithms. A topic of current interest, reverse mathematics, is represented by Mytilinaios (AUEB), who has collaborated with other leaders in the area. The senior researcher Y. Moschovakis has authored various monographs, including *Descriptive Set Theory* and *Elementary Induction on Abstract Structures* (both published by North-Holland/Elsevier), and has been a prime mover in interdisciplinary trends. Members of the Crete group have made original contributions towards determining the limits of computability for algebraic theories. Participants from the Sofia group are strong in the field of abstract recursion theory, as well as concerning applications of computability theory to Analysis.

Training experience: Most of the teams involved have been training Ph.D. students and supervising young researchers for over a decade. The Athens and Sofia teams are responsible for running master's degree programs in logic and theoretical computer science, offering a large gamut of courses. The Athens inter-university graduate program in *Logic and the Theory of Algorithms and Computation*, run by six Departments from three Universities (University of Athens, National Technical University of Athens and University of Patras), with around forty registered students, was started in 1996-97, and trains students for both the MSc and PhD. It is an innovative program which fits well with CiE, placing emphasis on the concept of algorithm, and occupying a dynamic area of research and training based on mathematics, logic and computer science. Within this program, Y. Moschovakis is a valued communicator and charismatic teacher. Of his book *Notes on Set Theory* (Springer, 1994) the *Journal of Symbolic Logic* said " ... the book is a gem, densely packed with fantastic problems, and clear, elegant proofs." Senior researchers of the Athens team have co-organized four international meetings (with support from EU and Greek Universities), with strong emphasis on training young researchers, and will organise "Logic Colloquium 2005" in Athens. Prof. Pheidas has organized several international summer schools and euro-conferences in Crete (1994-2000). The Sofia senior researchers have organized four very successful international summer schools (a proceedings volume was edited by Skordev), a remarkable achievement in the circumstances prevailing. There are plans for Sofia to host the next Panhellenic Logic Symposium, which would be linked to the CiE training programme.

Links within the network: There are many existing links among members of the Athens node, and between them and participants from other nodes: (a) participants belonging to the Athens group have close links with participants from all nodes except three (Novosibirsk, Oslo and Swansea) (b) participants belonging to the Sofia group have close links with participants from the Leeds, Munich, Novosibirsk and Siena nodes. Many of the existing links have been formed recently, but a strong interest for their strengthening has been expressed by both sides.

Two significant recent publications:

Y.N. Moschovakis: On primitive recursive algorithms and the greatest common divisor function, *Theoretical Computer Science*, **301** (2003), 1-30.

I. Soskov and V. Baleva, Regular Enumerations, *Journal of Symbolic Logic* **67** (2002), 1323–1343.

Node 4: POLYTECHNIC UNIVERSITY OF CATALONIA, BARCELONA, SPAIN

Subnodes: University of Zaragoza, University of the Basque Country at San Sebastian, University of Oviedo, University of Lisbon, Lisbon University of Technology, New University of Lisbon, University of Coimbra, University of the Algarve.

Team Coordinator: Dr. A. Atserias (UPC, Barcelona).

Key scientific staff: Prof. J. L. Balcázar, Drs. A. Atserias, M. L. Bonet, N. Galesi, R. Gavaldà, A. Lozano (Barcelona), Dr. E. Mayordomo (Zaragoza), Drs. Montserrat Hermo, Paqui Lucio, M. Navarro (San Sebastian), Dr. E. Fernandez-Combarro (Oviedo), Drs. M. L. Campagnolo, A. Fernandes, F. Ferreira, A. Francisco, P. Gouveia, C. Lourenco, I. Oitavem (Lisbon), Dr. R. Kahle (Coimbra), D. Graca (Algarve).

The senior staff will devote between 20% and 35% of their time to the project. For the node coordinator and junior researchers (including about 12 PhD students) this will be between 50% and 90%.

Research expertise: The Barcelona node contributes to the international visibility of the network through its recognized leadership in computational complexity and computational learning theory, specially in the southern europe area. The senior scientific staff includes world-leaders in both areas settling the background for the younger members of the group whose work emphasizes the interdisciplinary aspects of these topics with mathematical logic. Their work is published in the best conferences and journals in computer science and theoretical computer science, and in some significant cases in the best journals in mathematical logic. The subnodes at Zaragoza and San Sebastian are led by researchers partly trained in Barcelona, and partly specializing in computational complexity and learning theory respectively. The Zaragoza group is recognized as world-leader in a mainstream subfield of computational complexity called resource-bounded measure and dimension. The groups in Lisbon are strong in mathematical logic, in particular in the field of weak systems of analysis, and are developing a novel approach to computational complexity involving differential equations.

Training experience: The Barcelona team has successfully trained PhD students in several areas of theoretical computer science over the last 15 years. The group is involved in research projects with other Spanish universities which involve regular meetings. Students are encouraged to attending these meetings, giving talks, and helping with the organisation. One of the purposes of these projects is the transfer of knowledge from consolidated Spanish universities to the rest. Also, the group has organized many successful scientific conferences (some partially funded by EU funded projects). Dr. Gavaldà was the organizing chair for the *European Conference on Computational Learning Theory* in 1995, and in 1997 Prof. Balcázar was the organizing chair of a workshop for the network *Complexity, Logic and Recursion Theory* (COLORET) under Framework 4, and coordinated the Barcelona node of that network. The groups in Zaragoza and San Sebastian also offer PhD programs, and the Lisbon group runs a master program in mathematics. The Zaragoza group has a research project founded by the Spanish government, "Modelado individualizado de secuencias simbolicas" (MOISES) that will last until November 2005, when they expect to start a new one. This is a coordinated project which involves participation of two other Spanish universities, and regular meetings are held within the project. All PHD students and postdoctoral researchers are expected to help in the organization of these meetings. Mayordomo was involved with a PhD EuroConference in the European Community program "Improving Human Research Potential and the Socio-Economic Knowledge Base - High-Level Scientific Conferences", Viena, 2001. Dr. F. Ferreira will organize a winter school in proof theory in january 2004.

Links within the network: The collaboration of the researchers in the Barcelona node and subnodes with the rest of the network is extensive. Part of it can be traced through publications, but here are some examples: Torán (Ulm) and Bonet (Barcelona), Johannsen (Munich) and Bonet (Barcelona), Pudlák (Prague) and Atserias (Barcelona), Kohlenbach (Aarhus) and Ferreira (Lisbon), Hermo (San Sebastian) and Burhman (Amsterdam). The Barcelona group was involved in the network *Complexity, Logic and Recursion Theory* (COLORET) under Framework 4, (taking in Leeds, Heidelberg, Siena, Turin, Barcelona, Amsterdam). Some training links also exist between Barcelona and Ulm through the exchange of PhD students and co-advising of PhD thesis.

Two significant recent publications:

M. L. Bonet, J. L. Esteban, N. Galesi, J. Johannsen. On the Relative Complexity of Resolution Refinements and Cutting Planes Proof Systems. *SIAM Journal on Computing*, Vol. 30(5). 2000, pp. 1462–1484.

A. Fernandes and F. Ferreira. Groundwork for weak analysis. *The Journal of the Symbolic Logic*, Vol. 67, 2002, pp. 557–568.

Node 5: UNIVERSITY OF HEIDELBERG, GERMANY

Subnodes: University of Ulm, Humboldt-University of Berlin, Brandenburg Technical University Cottbus, Technical University of Darmstadt, University of Paderborn.

Team Coordinator: Prof. Klaus Ambos-Spies (University of Heidelberg, Germany).

Key scientific staff: *From Mathematics:* Prof. K. Gloede, Dr. W. Merkle (Heidelberg); Dr. habil. E. Herrmann (Berlin); Profs. K. Keimel, M. Otto, Th. Streicher (Darmstadt).
From Computer Science: Prof. K. Ambos-Spies, J. Reimann (Heidelberg); Profs. U. Schöning, J. Torán, Dr. habil. R. Schuler, Dr. habil. Th. Thierauf, Dr. W. Lindner, Dr. J. Meßner (Ulm); Prof. J. Köbler, O. Beyersdorff, L. Weizsaecker (Berlin); Dr. X. Zheng (Cottbus); Dr. M. Ziegler (Paderborn).

The senior staff will devote between 20% and 35% of their time to the project. For the junior researchers (including about 15 PhD students) this will be between 50% and 90%.

Research expertise: The chair of mathematical logic and theoretical computer science at the University of Heidelberg is one of the most active research groups in computability theory in Germany. Members of the group made important contributions to the following areas: algorithmic randomness, genericity and dimension; structural complexity theory; and degrees of unsolvability of the computably enumerable sets. The department of theoretical computer science at the University of Ulm is one of the leading centers in Germany in the fields of complexity theory and algorithms. Schöning has made fundamental contributions to the area of complexity theory. He has written several monographs and textbooks in the areas of algorithms, theoretical computer science and logic. Current research projects of the team include the study of probabilistic algorithmic methods applied to logical problems; isomorphism of graphs and other combinatorial structures; Boolean functions; and propositional proof systems. The Darmstadt group has long standing strengths in domain theory, lambda calculus and type theory with strong interests in the modelling of computation and the semantics of programming languages (Keimel, Streicher) and in computable and constructive analysis and constructive mathematics (Streicher). More recently, the expertise in logic and computation has been complemented with a new focus in model theoretic methods and complexity; in particular finite model theory and descriptive complexity (Otto). Darmstadt is a member of the EU Working group(s) APPLIED SEMANTICS I and II. Hofmann and Keimel are co-authors (with G. Gierz, J.D. Lawson, M.W. Mislove, D.S. Scott) of *Continuous Lattices and Domains*, vol.93 (591pp.) of the authoritative Cambridge University Press Encyclopedia of Mathematics and its Applications. Herrmann and Köbler (Berlin) are well known researchers in computability theory and complexity theory, respectively. Zheng (Cottbus) recently made a number of interesting contributions to computable analysis and randomness. Ziegler (Paderborn) works in computable algebra and geometry.

Training experience: The larger teams in the node (Heidelberg, Darmstadt, Ulm) have a long-term record in successfully training PhD students and supervising young researchers. The Heidelberg group recently organized three international workshops in computability theory. In the past academic year it hosted a research year in computability theory with many international long term visitors including senior researchers, postdocs and PhD students. The Ulm group organized the IEEE Computational Complexity Conference at Ulm in 1997. Members of the teams were organizing various Oberwolfach and Dagstuhl seminars.

Links within the network: There are numerous cooperations between teams of the Heidelberg node and teams from other nodes. Heidelberg itself has been involved in the previous EU Framework 4 network *Complexity, Logic and Recursion Theory* (COLORET) and the INTAS project *Computability and Models.* There has been a strong interaction between members of the Heidelberg team and the other teams in the network over the past years. This led to joint publications with members of the teams in Leeds, Amsterdam, Barcelona, and Prague; the supervision of a PhD student in Amsterdam; and a number of long term visitors including two members of the Novosibirsk team who visited Heidelberg as Humboldt fellows. The Ulm team has strong research cooperations with the teams in Amsterdam, Barcelona and Prague. The strongest links of the Darmstadt group are to Leeds, Munich, Novosibirsk and Oslo.

Two significant recent publications:

K. Ambos-Spies, D.R. Hirschfeld and R.A. Shore, Undecidability and 1-types in intervals of the computably enumerable degrees, *Annals of Pure and Applied Logic*, **106** (2000), 1–47.

U. Schöning, A probabilistic algorithm for k-SAT based on limited local search and restart, *Algorithmica*, **32** (2001), 615–623.

Node 6: LUDWIG-MAXIMILIANS-UNIVERSITÄT MÜNCHEN, GERMANY

Subnodes: Fernuniversität Hagen, Universität Siegen, University of Ljubljana, Technische Universität Wien.

Team Coordinator: Prof. Dr. Helmut Schwichtenberg (LMU München, Germany)

Key scientific staff: *From Mathematics:* Profs. W. Buchholz, H.-D. Donder, H. Osswald, H. Schwichtenberg (München); Researchers: K. Aehlig, J. Berger, O. Deiser, P. Schuster (München), A. Bauer (Ljubljana), M. Baaz, A. Beckmann, R. Iemhoff, N. Preining, S. Terwijn (Wien).
From Computer Science: Profs. M. Hofmann (München), K. Weihrauch (Hagen), D. Spreen (Siegen), A. Leitsch (Wien); Researchers: J. Johannsen, M. Lange, H.-W. Loidl, R. Matthes, D. Pattinson, O. Shkaravska (München), V. Brattka, P. Hertling, D. Kunkle (Hagen), A. Ciabattoni, C. Fermüller (Wien).

The senior staff will devote between 15% and 40% of their time to the project. For the team coordinator and junior researchers (including about 15 PhD students) this will be significantly more (up to 90%).

Research expertise: The Mathematical Logic group in Munich is one of the largest and most active groups in Germany, with people covering many different areas of Logic. A focus of the group is Proof Theory and its interactions with Computability, in particular structural proof theory and its relation to lambda calculi, and the extraction of algorithmic content from proofs. Other areas of research activity are Nonstandard Analysis and Constructive Mathematics, and the interaction between these (Osswald, Schuster, Berger). There is also a very active and visible group of researchers working in Set Theory (Donder, Deiser). The Theoretical Computer Science group in Munich is concerned with the application of logic in Computer Science. These applications occur in the study of programming languages and their semantics, in particular programming languages for resource-bounded computation (Hofmann, Loidl, Shkaravska) and computation with higher-order nested datatypes (Matthes, Abel). Other areas of research are logics for the verification of program correctness (Lange), and computational complexity, especially complexity of propositional proof systems (Johannsen). The Theoretical Computer Science group in Hagen is one of the leading European (and World) research groups in Computability and Complexity in Analysis. Bauer in Ljubljana is another expert in Computable Analysis and Constructive Mathematics. The Vienna group is comprised of some leading experts in structural proof theory, in particular proof theory of non-classical logics (Baaz, Ciabattoni). Another focus of the group is automated deduction (Leitsch, Fermüller).

Training experience: All the senior team members have supervised numerous PhD students, among them several who are nowadays active researchers, some working in other CiE nodes. The Munich group organises the Graduiertenkolleg "*Logik in der Informatik*", a PhD school devoted to logic in Computer Science, which is headed by Schwichtenberg. The Vienna group hosts a graduate program on Computational Logic, and organises a regular "Dissertantenseminar" (researchers' seminar). Members of the team have on several occasions taught courses at the European Summer School ESSLLI (e.g., Baaz, Beckmann, Hofmann, Johannsen, Leitsch, Matthes). In 2003, the ESSLLI summer school was organized by the Vienna group, along with CSL 2003, KGC 2003 (Computer Science Logic and Kurt Gödel Colloquium), as well as Logic Colloquium 2001. The Hagen group organised tutorials on *Computability and Complexity in Analysis* in Feb. 2000 in Hagen, and Sep. 2002 in Wittenberg (at "Theorietag Automatentheorie und Formale Sprachen").

Links within the network: The Mathematical Logic group in Munich is in close contact to the groups in Amsterdam, Münster and especially Leeds (Wainer), and more recently with Swansea (Berger, Setzer). PhD graduates from Amsterdam (Terwijn) and Leeds (Crosilla) have worked as postdoctoral researchers in Munich. The Theoretical Computer Science group in Munich has close links to Darmstadt (Streicher), Edinburgh (Plotkin, Simpson) and Birmingham (Escardo), as well as contacts with Barcelona (Atserias, Bonet, Galesi) and Prague (Pudlák, Krajíček). Both groups in Munich are part of the FP5 working groups *Applied Semantics II* and TYPES, which both involve several other CiE nodes. The Vienna group hosts several postdoctoral researchers who are PhD graduates of other CiE nodes, in particular Amsterdam, Heidelberg and Münster (Terwijn, Iemhoff, Beckmann). There are close contacts with the group in Prague (Hájek, Krajíček, Pudlák).

Two significant recent publications:

Klaus Aehlig, Helmut Schwichtenberg: A syntactical analysis of non-size-increasing polynomial time computation, *ACM Transactions on Computational Logic*, 3(3): 383–401 (2002).

Ning Zhong, Klaus Weihrauch: Computability theory of generalized functions, *Journal of the ACM* 50(4): 469–505 (2003).

Node 7: NOVOSIBIRSK STATE UNIVERSITY, RUSSIA

Subnodes: State Universities of Kazan, Omsk, St. Petersburg, Tumen, Ulyanovsk, and Ivanovo Technological Institute; Steklov Institute of Mathematics, St. Petersburg; Kazakh National University (Kazakhstan); University of Tbilisi (Georgia).

Team Coordinator: Prof. Sergey S. Goncharov (Institute of Mathematics of Siberian Branch of Russian Academy of Science and Novosibirsk State University , Novosibirsk, Russia.)

Senior scientific staff: Novosibirsk: Profs. Yu. Ershov, S. Goncharov, A. Morozov, V. Selivanov, D. Palchunov, Drs. S. Podzorov, O. Kudinov, S. Odincov, P. Alaev, A. Khisamiev , S. Denisov, V. Vlasov, N. Kogabaev, A. Stukachev, V. Puzarenko, M. Korovina; St. Petersburg: Profs. Yu. Matiyasevich, N. Kossovski, E. Hirsch; Kazan: Prof. M. Arslanov , Dr. I. Kalimullin; Tashkent: Prof. N. Kasymov; Kazakhstan: Profs. S. Badaev, V. Dobrica, N. Khisamiev, Drs. A. Romina; Z. Khisamiev; Omsk: Prof. V. Remeslennikov, Dr. A. Ashaev; Ulyanovsk: Prof. Sh. Ishmukhametov; Ivanovo: Prof. B. Solon; Tbilisi: Prof. R. Omanadze; Odessa: Prof. V. Bulitko; Tumen: Prof. A. Degtev, Dr. S. Zakharov.

The senior staff will devote between 25 - 45% of their time to the project. For the junior researchers (including about 15 postdoctoral researchers, 10 PhD students and 15 Master degree students) this will be between 50% and 80%.

Research expertise: The department of mathematical logic at the Institute of Mathematics of Siberian Branch of Russian Academy of Science in Novosibirsk is one of the most active research group in computability theory in Russia. Members of the group made important contributions to following areas: degrees of unsolvability of computably enumerable sets, the theory of computable and decidable models, the theory of hierarchies, computable numberings, computable functionals, denotational semantics and generalization of computability by definability. Ershov and Goncharov are specially well-known internationally for a large number of deep and important results concerning computable structures and models. The main groups of researchers from different part of fSU have very close and active connections with the Novosibirsk group. The chair of algebra and logic of Kazan University is a world-leading center in the theory of Turing and enumeration reducibilities and the classical theory of computability. M. Arslanov has contributed fundamental results in the theory of Turing degrees of representatives of classes of the Ershov hierarchy, some ground-breaking results in the theory of fixed points, and a number of others. The St. Petersburg group has very important results in the theory of computability and complexity. The most fundamental result of this group is the famous Matiyasevich theorem providing a solution to Hilbert's tenth Problem. The logic group from Kazakhstan has many important results in the theory of computable numberings and computable models and their applications in algebra, logic and Computer Science. V. Bulitko, R. Omanadze, Sh. Ishmukhametov proved interesting results in the theory of different degree structures. The Russian school of computability is world-leading in the theory of strong reducibilities. The Omsk group of logicians has very interesting results in the theory of generalization of computability on abstract models and some applications to algorithmic problems in algebra.

Training experience: The largest teams in the node (Novosibirsk, St. Petersburg, Alma-Ata, Kazan) have a long record in successfully training Bachelors, Master and PhD students and supervising young researchers. The Novosibirsk group recently organized the Annual Conference on Algebra and Logic, and will host the Ninth Asian International Conference on Logic in 2005. The Kazan and Kazakhstan groups also have good experience in organising meetings, such as the All-Union and International Conference on Computability Theory and Mathematical Logic.

Links within the network: The members of the Novosibirsk group have successfully carried out various international projects with universities involved in the CiE project, and continue to work on existing projects, funded by DFG-RFBR (with the universities of Darmstadt and Siegen) and INTAS (with the Universities of Siena and Heidelberg). There are many other research links. Morozov has spend one year in Heidelberg as a Humboldt Research Fellow. Arslanov and Cooper held a Royal Society collaborative grant, and Kalimullin visited Leeds as an INTAS fellow. Other fruitful research collaborations involve members of the Novosibirsk group and other CiE participants, for instance: Goncharov, Badaev and Sorbi; Morozov and Truss; and others.

Two significant recent publications:

S.S. Goncharov and J.Knight, Computable structure/non-structure theorems, *Algebra and logic*, 41 (2002), 351–373.

Y.L. Ershov, S.S. Goncharov, *Constructive Models*, Kluwer Academic/Plenum Publishers, New York, 306pp., 2000.

Node 8: UNIVERSITY OF OSLO, NORWAY

Subnodes: Uppsala University (Sweden), Oslo University College (Norway), University of Bergen (Norway), University of Århus (Denmark), Luleå University of Technology (Sweden)

Team Coordinator: Prof. Dag Normann (University of Oslo, Norway).

Key scientific staff: *From Mathematics:* Profs. D. Normann, H.R. Jervell, T. Langholm (Oslo), V. Stoltenberg-Hansen, E. Palmgren (Uppsala); Dr. J. Blanck (Luleå) ; Researchers I. Rummelhoff (Oslo), M. Djordjevic (Uppsala).

From Computer Science: Profs. M. Bezem, M. Haveraaen (Bergen); Drs. L. Kristiansen (Oslo), U. Kohlenbach (Århus), Researcher: P. Oliva (Århus).

The staff will devote between 15% and 50% of their time to the project. There will be about 13 Ph.D. students supervised by network participants. The majority will devote 75-90% of their time to the project.

Research expertise: The expertise of the scientific staff of the Oslo node covers many relevant areas of the network. Normann (Oslo) is a leading expert in computability and higher types, both within the classical theory (he is the author of a still used Lecture Notes on the subject) and the novel development. Stoltenberg-Hansen (Uppsala) is the main author of a standard text-book on domain theory. Bezem (Bergen) is one of the authors of a recent text-book on rewrite systems. Normann, Stoltenberg-Hansen and Blanck (Luleå) has been involved in forming a semantical basis for investigating computability over the reals and other continuous datatypes. There is a close collaboration between Stoltenberg-Hansen, Blanck and Tucker (Swansea) on these issues. Haveraaen (Bergen) comes from numerical analysis. He is collaborating with Tucker on computability of real numbers, in particular on the abstract structures that can practically be used in computer science. Bezem is interested in the computational aspects of logical formalisms, including typed versions, and he is one of the leading scientists in the area. He is currently collaborating with Langholm (Oslo) on computational linguistics. Kristiansen (Oslo) is currently working on the relationship between syntactical formalisms and complexity classes. Kohlenbach (Århus) and his group is the leading one in proof mining, where algorithms and new mathematical insight is obtained from analysing proofs of theorems of existence. The formal theories in which original proofs from analysis are formalised use higher types, and the semantical basis for these formal theories are similar to those used for typed programming languages. (Kohlenbach is in demand as a plenary speaker, e.g., at this year's ASL Annual meeting in Chicago.) Jervell (Oslo) is a proof theorist, with an interest in applications of proof theory to computer science. Palmgren (Uppsala) is interested in constructive logic and mathematics. Rummelhoff (Oslo) is interested in realisability-semantics for second order type theory.

Training experience: The Bergen, Oslo and Uppsala teams have long traditions in training young scientists. The Århus team is associated with BRICS, which is established by support of the Danish National Research Foundation in order to improve research, including the training of young researchers, in the basics of computer science. This year, Kohlenbach was involved with organising a BRICS mini-courses given by Edalat from Imperial. At all four cites, there are active seminars where Ph.D. students and young researchers regularly will give talks. The Ph.D. students have been both in Mathematics (Oslo and Uppsala) and in Computer Science (all four teams). Stoltenberg-Hansen has on several occasions been a teacher at the Marktoberdorf Summer School, and Normann has been teaching at a summer school in Copenhagen 1999.

Links within the network: The most longstanding link with someone outside the node has been between Stoltenberg-Hansen and Tucker in Swansea, a link that was established when Tucker was in Oslo back in the 70'ies. Berger (then in Munich, now in Swansea) and Normann independently initiated an abstract study of totality in domain theory, a study that later was coordinated under the EU-Twinning Project "Proof and computation". Berger spend a year inUppsala, initiating cooperation with Blanck and Stoltenberg-Hansen. Over the last few years, Normann has had much contact with Longley and Simpson in Edinburgh, with Escardó in Birmingham and with Bauer in Ljubliana. Darmstadt (Keimel, Otto, Streicher) is another important link. Haveraaen is cooperating with Tucker; see above. Kohlenbach has natural links with Munich (Hofmann, Schwichtenberg).

Two significant recent publications:

D. Normann, Computability over the Partial Continuous Functionals, *Journal of Symbolic Logic*, **65** (2000), 1133 - 1142.

V. Stoltenberg-Hansen and J. V. Tucker, Computable and continuous partial homomorphisms on metric partial algebras, *Bulletin of Symbolic Logic* **9** (2003), 299 - 334.

Node 9: ACADEMY OF SCIENCES OF THE CZECH REPUBLIC, PRAGUE, CZECH REPUBLIC

Subnodes: Charles University, Prague

Team Coordinator: Prof. J. Wiedermann (Academy of Sciences, Czech Rep.)

Key scientific staff:
Academy of Sciences: P. Hájek, J. Krajíček, P. Pudlák, J. Sgall, J. Šíma, J. Wiedermann, S. Žák; PhD students: P. Cintula, D. Coufal, L. Petrů, T. Tusarová, E. Kotrč, Z. Haniková, M. Šaturka.
Charles University: A. Kučera, L. Kučera; PhD students: J. Hanika, Emil Jeřábek, M. Rössler, T. Tichý, M. Bílková.

The senior staff will devote between 20% and 35% of their time to the project. For junior researchers (including about 12 PhD students) this will be between 50% and 90%.

Research expertise: The Czech node includes not just the finest representatives of Czech research into theoretical computer science, but contains world leaders in a number of areas related to the project. It has a long-standing record of research within core areas of theoretical computer science, relevant to both complexity and computability theory. The respective group, although not too numerous, regularly achieves results reported at worldwide renowned computer science conferences and published in the best theoretical journals. Its senior members often give invited talks and have produced several monographs in the fields of their scientific interest. In logic, Krajíček is one of the five members of the ASL Committee for Logic in Europe, and wrote the authoritative *Bounded arithmetic, propositional logic, and complexity theory* (Cambridge Univ. Press, 1995). Pudlák is editor for the ASL Perspectives in in Logic series.

In complexity theory, attention has been paid especially to computational models and complexity of computations and proofs, including complexity of logical systems, in particular of fuzzy logics. Within the former area a number of internationally regarded results have been achieved mainly in the field of circuit complexity, classical Turing machines, branching programs, and neural computing. Within the latter area, fundamental problems in computational complexity theory have been studied and results on mutual relations of basic modes of computation (deterministic, non-deterministic, probabilistic, and fuzzy ones), communication complexity, derandomisation, bounded arithmetic, arithmetical hierarchy etc., have been achieved and published.

Within computability theory, central problems have been traditionally addressed, such as algorithmic randomness and variants and relativisations of this concept, classification of real numbers, extensions of Peano arithmetic, etc. In the cooperation with the Utrecht (via the Amsterdam node), new computational paradigms are also present, concerning computations beyond Turing limit. In the latter area the group belongs among the most advanced groups world wide.

Training experience: The personalities involved have a long-standing successful track record in training PhD students and supervising young researchers. The Prague senior researchers have successfully organised conferences of European and world-wide importance (such as several conferences from the series MFCS - Mathematical Foundations of Computer Science, one ICALP conference, Logic Colloquium), and also international conference of central-European importance (e.g. SOFSEM, running annually from 1974). Numerous summer schools, workshops, and seminars have been organized each year, too.

Links within the network: Thanks to its reputation the group has numerous links (and vice versa, of course: thanks to its international cooperation, the group has won its reputation), based mostly on the personal basis and joint scientific interests, with researchers from e.g. Amsterdam University, Utrecht University, University of Athens, Barcelona, Ulm, Munich, Lisbon, Turin, Humboldt University, etc. To name a few persons, we mention e.g. B. Cooper (Leeds), P. Vitanyi (Amsterdam), E. Mayordomo (Zaragoza), K. Ambos-Spies (Heidelberg), J. Reimann (Heidelberg), W. Merkle (Heidelberg), N. Mihailovic (Heidelberg), F. Stephan (Heidelberg), X. Zheng (Cottbus), P.H. Hertling (Hagen), M.M. Arslanov (Kazan), F. Montagna and A. Sorbi (Siena), P. Odifreddi (Turin), D. Zambella (Turin), J. van Leeuwen (Utrecht), F. Esteva and L. Godo (Barcelona) and others. The level of cooperation with the above mentioned institutes and persons can be inferred from numerous joint publications.

Two significant recent publications:

J. van Leeuwen, J. Wiedermann: The Turing Machine Paradigm in Contemporary Computing, In: *Mathematics Unlimited - 2001 and Beyond* (Ed.: B. Engquist, W. Schmid), Berlin, Springer 2001, pp. 1139–1155.

A. Atserias, N. Galesi, P. Pudlák, Monotone Simulations of Nonmonotone Proofs, *Journal of Computer and System Sciences*, 65 (2002), 626–638.

Node 10: UNIVERSITY OF SIENA, ITALY

Subnodes: University of Florence, University of Padua, University of Torino, University of Udine.

Team Coordinator: Prof. Andrea Sorbi (University of Siena, Italy).

Key scientific staff: A. Sorbi, F. Montagna, G. Simi (Siena); A. Cantini, P. Minari, P. Crescenzi (Florence); G. Sambin, S. Valentini; A. Andretta, P. Odifreddi, D. Zambella (Turin); P. Di Gianantonio, F. Honsell, A. Marcone (Udine). Researchers: M. Giorgi, F. Cozzi, G. Curi, M.L. Affatato, L. Spada , G. Gherardi (Siena); M.L. Crosilla, R. Bruni, V. Santini (Florence); M. Maietti, C. Faggian, S. Sadocco (Padua).

The senior staff will devote between 20% and 50% of their time to the project. For junior researchers (including 6 PhD students) this will be between 50% and 90%.

Research expertise: Siena, Florence, Padua, Turin, and Udine cover expertise in several branches of logic and computer science, and the participants are internationally renowned scholars in many of the areas which are relevant to the present project. The Siena team has given several contributions to computability theory and its applications (including learning theory), proof theory and fuzzy logic. Among Sorbi's various research interests, his major contribution has been to the theory of enumeration reducibility, as evidenced by his many publications and research collaborations. Florence has an excellent group in proof theory and foundations of mathematics; Crescenzi in Florence is an internationally leading expert in computational complexity. Padua has given important and original contributions to constructive topology, substructural logics, and the foundations of mathematics. Odifreddi in Turin is a well known logician, author of several books in logic, including the two volume monograph *Classical Recursion Theory*, and has particular expertise concerning strong reducibilities, partly arising from his various contacts with Russian computability theorists; Andretta is a renowned expert in descriptive set theory, a branch of logic which is strictly related to computability theory; important applications of computability theory (e.g. in Kolmogorov complexity) have been given by Zambella. Udine has given contributions to the field of computable analysis and to the formalization of computable analysis inside logical frameworks; and to computability theory and its applications to the foundations of mathematics (e.g. reverse mathematics, a focus of much recent research).

Training experience: The Siena senior staff has experience in managing national and international projects in areas which are relevant to the project: Sorbi has directed several training programs, workshops and research visits within European projects (he has been the coordinator of the Human Capital and Mobility network *Complexity, Logic and Recursion Theory* under Framework 4, and its related PECO extension; he is currently the coordinator of the INTAS Project *Computability in Hierarchies and Topological Spaces*; and the supervisor of a Marie Curie Fellowship). Padua is a particularly successful training environment for logic, to the extent that many young Italian logicians (some of them already well known by the scientific community) have trained in Padua under the direction of G. Sambin. All centers host excellent graduate schools. In particular Siena hosts a PhD program in Mathematical Logic and Theoretical Computer Science which has attracted and trained in the past many young researchers from all over Italy. In Udine Honsell has organized two graduate schools in computer science. Florence, Padua, and Siena have organized many national and international workshops in logic and the foundations of mathematics (the logic group in Florence has organised the 1995 *Logic, Methodology, and Philosophy of Science* meeting. The Padua logic group has organized the 1988 *Logic Colloquium*. The Turin logic group is organizing the 2004 *Logic Colloquium*), and the local scientists are involved in many national and international research projects.

Links within the network: Thanks also to several past European funded projects (including those mentioned in the previous item) there are already strong research links (divided grossly into groups according to different research topics and goals. These groups of links mostly reflect already existing links, and links which will be hopefully established within the project) between Siena, Leeds, Amsterdam, Barcelona, Heidelberg, Turin, Prague, Siegen, Vienna, Novosibirsk and Kazan; between Florence, Leeds, Manchester, Munich, Ljubljana, Vienna, Lisbon, Swansea, Uppsala, Edinburgh, Siena; between Padua, Siena, Udine, Uppsala, Birmingham, Manchester, Cambridge, Swansea, Siegen, London, Munich, Darmstadt, Udine; between Udine, London, Birmingham, Edinburgh, Munich, Hagen, Ljubljana. A number of interdisciplinary aspects of the research objectives find their natural homes in the context of the Siena node and its constituent teams.

Two significant recent publications:

P. Di Gianantonio, An abstract data type for real numbers, *Theoretical Computer Science*, 221 (1999), 295-326.

G. Sambin, Some points in formal topology, *Theoretical Computer Science*, 305 (2003), 347-408.

Node 11: UNIVERSITY OF WALES SWANSEA, U.K.

Subnodes: Imperial College London, University of Bristol

Team Coordinator: Prof. John V. Tucker (University of Wales Swansea, U.K.).

Key scientific staff: Profs. Faron G. Moller, John V. Tucker (Swansea), Abbas Edalat (Imperial), John C. Shepherdson (Bristol); Drs. Edwin Beggs, Ulrich Berger, Neal Harman, Roger Hindley, Phil Grant, Yoshinao Isobe, Oliver Kullmann, Markus Michelbrink, Markus Roggenbach, Monika Seisenberger, Anton Setzer, Jiang-Lun Wu (Swansea), Herbert Wiklicky (Imperial).

The senior staff will devote between 20% and 30% of their time to the project. For the node coordinator and junior researchers (including about 10 PhD students) this will be between 50% and 90%.

Research expertise: The Swansea node brings research expertise into the project with many connections and applications of computability in logic, mathematics and computer science. At Swansea a major research theme is *computation on continuous data.* This includes work on domain theoretic models of computability, exact real number computation, computability on topological data types, and physically based theories of computability; there are also applications in computer graphics. Another research theme is the study of *logical formulations of computability and computational complexity* and this includes work on decision problems, such as the SAT problem, and on the analysis of complexity for higher order functionals, models for concurrency, and interactive computability. A third research theme in Swansea is rooted in *proof theory of constructive logic and computable mathematics.* We concentrate on the scope and limits of constructive logic and type theory and are involved in the development of computer aided theorem provers based on intuitionistic type theory and their application to program specification, verification and synthesis. The team at Imperial also works on *computation on continuous data* and especially on the *applications of domain theory* in developing continuous data types for many areas of computation, in particular: exact real number computation, computational geometry, solid modelling, initial value problems, partial differential equations, hybrid systems, and quantum computing. In all these areas, the issues of computability are examined and tractable and reliable algorithms for computation using the domain- theoretic models are developed. Members of the team are often observed as speakers or organisers at international conferences (Edalat was an invited speaker at ETAPS 2000 in Berlin). Shepherdson is a Fellow of the British Academy, and, while still active in research (see recent papers with Paris, node 1, and Hájek, node 9), is a seminal figure in the history of the subject.

Training experience: The two sites at this node have a long-standing successful track record in training PhD students and supervising young researchers. They also offer a variety of masters degree courses in areas related to computing: MRes. in Logic and Computation, MSc. in Computing and Software Technology (Swansea), MSc. in Computing, MSc. in Advanced Computing, MSc. in Computing for Industry (Imperial). The highly active research colloquia and seminar series run by both sites provide an ideal learning and training environment for young researchers. Staff of both teams are well experienced in teaching postgraduate students in Europe having given courses at other sites (e.g. at the EEF Summer School on Logical Methods at BRICS, Aarhus, 2001, and the National Graduate School in Mathematical and Computational Sciences, Uppsala, March 2003.). The departments support the regular attendance of graduate research students at summer schools, conferences and workshops. Swansea has organized and hosted many successful conferences and workshops in the area of logic and computation (e.g. at Swansea, Computer Science Logic '93, BCTCS '95, Computability and Complexity in Analysis 2000, Conference on Logic, Model Theory and Computation, 2001; and we have workshops on functionals over the ordinals and the computational content of proof-theoretical analysis planned in 2004).

Links within the network: The teams maintain active research links with most sites of the network. For example, there is a longstanding research collaboration between Swansea, Uppsala, Oslo, Luleaa, Hagen and Siegen on domain theory, exact real, number computation and computability in higher types. Swansea also has strong links with Leeds, Uppsala, Munich, Münster, Aarhus and Manchester in the area of proof theory and type theory. These links can be traced via joint publications, numerous research visits and joint organization of workshops and conferences.

Two significant recent publications:

U. Berger, W. Buchholz and H. Schwichtenberg. Refined Program Extraction from Classical Proofs, *Annals of Pure and Applied Logic* 114, 3–25, 2002.

A. Edalat and A. Lieutier. Foundation of a computable solid modelling. *Theoretical Computer Science*, 284(2):319–345, 2002.

B3.2. Intensity and quality of networking

Networking works most creatively on the basis of independent but interactive development of disciplines. The promise of CiE rests on its existing complex infrastructure of collaborations and quality of participation, and the as yet unexploited potential for vital new contacts. Section B1 focused on a number of interdisciplinary developments, involving existing and projected collaborations across subject and national boundaries. Our diversity of research resources is our strength: we seek the opportunity for a cohesive implementation. In the space available, here is just one example of how such networking in the area of computability works in practice, illustrating the potential for creative convergence between computer science and computability theory.

One of our main objectives (1.1) is to develop usable notions of computability on continuous data, including practical approaches to exact computation with real numbers. During the 1970s, Dag Normann worked on the recursion theory of the continuous functionals. Via his computer science student, Anne Salvesen, he got interested in constructing classical models for Martin-Lof type theory, and through the EU Twinning-project involving Oslo, Munich and Leeds he had contact with Ulrich Berger, and learned to use domain theory. This and his background from generalised recursion theory played an essential role in his novel proof the Cook-Berger Conjecture that all continuous functionals with recursive associates would be Kleene-computable over the hierarchy of partial continuous functionals. Another networking event led to contact with Plotkin in Edinburgh, and it turned out that Normann had actually proved an interesting theorem about PCF, with consequences for the understanding of Milner's fully abstract model for PCF. Notice that the key events here were the interdisciplinary sparks that produced something new and unexpected out of interactive normal sciences. The outcome was not just a solution to an isolated problem. There is now an ongoing venture of forming a unified approach to higher type computability over discrete and continuous data-types, there is a subnetwork based on e-mailing and direct contact consisting of, Bauer, Blanck, Escardo, Di Gianantonio, Longley, Normann, Schröder, Simpson, Stoltenberg-Hansen and Weihrauch with impulses from Abramsky, Edalat and Hyland. They bring in expertise from generalised recursion theory, constructive mathematics, realisability semantics, denotational and operational semantics for programming languages, domain theory and lambda calculus. This core of researchers involving teams 1, 6, 8, 10 and 11, and its many joint publications, will form the basis for more extensive collaborations, involving a number of new contacts and based on novel methodological interactions. For instance, domain-theoretic semantics of exact-real number computation links in teams 1 (London, Edinburgh), 6 (Munich, Hagen, Ljubljana, Siegen), 8 (Oslo, Luleaa), 10 (Udine), while the topological approach to data types adds Uppsala (8), Swansea (11), Darmstadt (5) and Novosibirsk (7). Applications of constructive topology, will add Manchester (1) and Padua (10). Particular abstract frameworks Moschovakis and Skordev (3) and Ershov (7), while Kohlenbach's (team 6) proof mining approach brings in various researchers, including teams 1, 2, 4, 6, 10, 11. Applications of our exact computational models to examining how physical systems can be said to compute functions will involve teams 1 (London), 2 (Utrecht), 4 (Lisbon), 8 (Uppsala, Luleaa), 6 (Hagen) and 9 (Prague), 11 (Swansea).

What is interesting about existing CiE collaborations is not just their richness of infrastructure, but their role in erasing faultlines, based on the historical divisions between countries and research disciplines. The former gives CiE an immediate collaborational momentum, and the latter an important structural role in relation to the longterm development of computability related research in Europe. As we have outlined in B1, there are new developments in the research area itself which underpin the potential for new interdisciplinary developments within CiE. Our practical strategy is based on exploiting the overall connectedness of the network. There are chains of contacts and many fruitful collaborations (as outlined in B3.3) which will provide a basis for planning visits, meetings and augmentation of research partnerships, which extend that activity already existing within more conventional organisational frameworks. Our annual conference will be the most explicit expression of this approach. But our schools and workshops will also foster links between approaches, and not just isolated methodologies. And we will encourage research visits which are new in content. Of course, we still expect a large proportion of high quality research output involving relatively unsurprising collaborations. Independent but interactive development of disciplines will be the key to the success of CiE.

The projected network has participation from ten of the fifteen EU member states, from the four associated states Bulgaria, Czech Republic, Norway and Slovenia, and from three third countries Georgia, Kazakhstan and Russia (grouped under node 7). Our network is comprised of eleven nodes, spread over sixty-five institutions and seventeen different countries. This composition is indicative of the efforts we have made to include and give organisational support to a number of smaller research groups and individuals (including some less experienced teams and ones from Candidate Countries and other Associated States), and to research groups from Eastern Europe who are still emerging from their historical isolation. All of these groups have some level of existing links with the core teams, often in the form of joint publications. We have two nodes (Athens and Swansea), and four individual teams (in the Algarve, Cottbus, Crete, and Oviedo) situated in Less Favoured Regions.

B3.3. Relevance of Partnership Composition

CiE has its roots in a variety of earlier collaborative initiatives, although the full range of research resources is assembled here for the first time. In 1992–94 researchers from nodes 1, 6 and 8 joined in an EU Twinning Project in proof theory, coming out of the longstanding collaboration between Wainer and Schwichtenberg. In 1989 Sorbi invited Cooper to Siena for a 3 month CNR funded visit, and from this flowed one of the most productive and enduring research relationships in the subject, leading to Sorbi coordinating the successful COLORET ("Complexity, Logic and Recursion Theory") HCM network under Framework 4. COLORET involved a number of researchers from CiE nodes 1, 2, 4, 5 and 10. Recently, two INTAS projects, *Computability in Hierarchies and Topological Spaces* (coordinated by Sorbi) and *Computability and Models* (Cooper coordinator) involved many researchers from node 7 with ones from 1, 5, 6 and 10. These earlier initiatives involved research themes which are very relevant to objectives 2, 3.1, 3.2, 3.3, 4.1 and 4.3, with smaller links to other objectives. Despite its origins in the earlier projects, the present network is a much more ambitious and radical enterprise: The interdisciplinary aspects are more fully developed, and cohere better, partly because the subject itself has progressed, and partly due to the makeup of the constituent research teams; The quality and depth of the participation is extraordinary, bringing together seminal figures in the field, together with the large cohort of younger researchers who have little experience of the earlier networks; The longer-term ambitions for restructuring the field, and for an enhanced world role for European computability go beyond anything seen before; And the training aspects are much more emphasised and potentially better resourced. C iE embodies a new concept. New and existing collaborations will be fostered via our programme of meetings and research visits. A role of the Training and Innovations Group (see B4.1) will be to build new interactions.

Particularly relevant to objectives 1.1, 1.2, 2, 3.2 and 4.3, and to a lesser extent to 3.1, 3.2 and 4.1, researchers from almost all nodes have been active in the network *Computability and Complexity in Analysis*, run by the Hagen group, which has organised annual meetings and other networking activity since 1995. There are many international organisations, such as the A.S.L. and L.I.C.S. (with a number of our members on the Organising Committee) which involve our members in activity related to the research objectives (see also B4.3). The large body of joint publications involving members of the network and relating to its research objectives attests to the relevance of the partnership composition. The following small selection should provide a snapshot of the richness and aptness of the collaborations they depend on. A long-standing cross-disciplinary collaboration is that of Stoltenberg-Hansen (node 8) and Tucker (11) (see, for instance, their 2003 article in the *Bulletin of Symbolic Logic*). The Edinburgh and Birmingham teams have participated in numerous productive partnerships, both within node 1 and with Streicher (5), Hofmann (6), Bauer (6), Edalat (11). Many of these, including Keimel (5), are involved in the EU "Applied Semantics I, II" Working Group. Edalat (11) collaborates with Pattinson (6). Johannsen (6) has joint papers with Bonet, Esteban and Galesi (4), and with members of the Vienna team (6), while Pudlák has published with Atserias and Galesi (4). Ambos-Spies has numerous collaborations related to objectives 2 and 4.1, with nodes 1, 4, 7 and 10. Merkle (5) organized a Dagstuhl seminar with Vitanyi (2). Heidelberg (5) has many research visitors relevant to the network, including several researchers from Novosibirsk (7), Morozov staying for one year as a Humboldt fellow, and Kučera from Prague (9). Amsterdam collaborations take in nodes 1, 3, 4, 6 (Beckmann, a recent Marie Curie fellow, has strong connections to Münster), 9 (involving Wiedermann and van Leeuwen) and 10. Amsterdam regularly exchanges students with Athens, and has plans for a formal pairing of the M.Sc. programs. Beckmann (6) just spent a semester in Münster as a Guest Professor. Isabel Oitavem (4) had a research position in Munich (6). Sorbi (10) has many papers with Cooper (1), and with many others including Arslanov, Badaev, Goncharov, Podzorov (7). Sorbi's group regularly receives visiting researchers, particularly those related to objectives 3.2 and 4.1. Elvira Mayordomo (4) was in the COLORET project, and besides long-standing links with Ambos-Spies (5), has collaborated with Buhrman (2) on Kolmogorov randomness. Streicher, Keimel (5), and Escardo, Jung, Longley, Simpson (1) co-operate within the EC-funded working group APPSEM2. Hirsch (7) and Schöning (5) have a 2002 paper in *Theoretical Computer Science*. Keimel (5) has participated in funded projects with Novosibirsk (7) and others. Spreen (6) coordinates the German end of a joint German-Russian project funded by Deutsche Forschungsgemeinschaft and Russian Foundation for Basic Research with Ershov (7); participants in Russia include Ershov (Russian coordinator), Goncharov, and Morozov.

The inclusion in Node 7 of the researchers from Russia, Kazakhstan and Georgia is very natural in scientific terms — how could a *Computability in Europe* network exclude the research schools of Ershov and Matiyasevich? — and a significant element in the longterm development of a European scientific community.

There are a number of small-scale links with industry, involving nodes 1, 2, 5, 6, 7, 8 and 11, and links with Intel, Fraunhofer Institute FIRST, Microsoft (twice), Philips Research Labs, Absint Angewandte Informatik GmbH, Airbus France, SIEMENS, and "Literal – Information Technologies", an IT company in Slovenia.

B4. MANAGEMENT AND FEASIBILITY

B4.1. Proposed management and organisational structure

The networking activity will be organised within two interactive structures:

I. The Programme of Events

This will support the research and training aims of the network in a coordinated but flexible way. Particular events and associated mechanisms will include:

- An annual one-week CiE Conference (see B1.5) with an appropriate balance between plenary lectures, and the many shorter talks giving all CiE researchers an opportunity to report on their work in connection with the CiE research objectives.
- A number of smaller schools and workshops aimed at raising the skills level and interdisciplinary potential of the network, organised by individual nodes, or partnerships of nodes.
- A programme of research visits and exchanges.
- One or more meetings during the course of the project organised by and for the early-stage and experienced researchers recruited by the network, the exact frequency and form of such meetings to be decided by the young researchers in consultation with the network coordinator.
- Participation of network members in outside meetings relevant to the network research objectives.
- The CiE webpage will both support communications within the network (with the addition of a network forum), and be developed as a useful resource for workers in the field generally.

II. The Management Structure

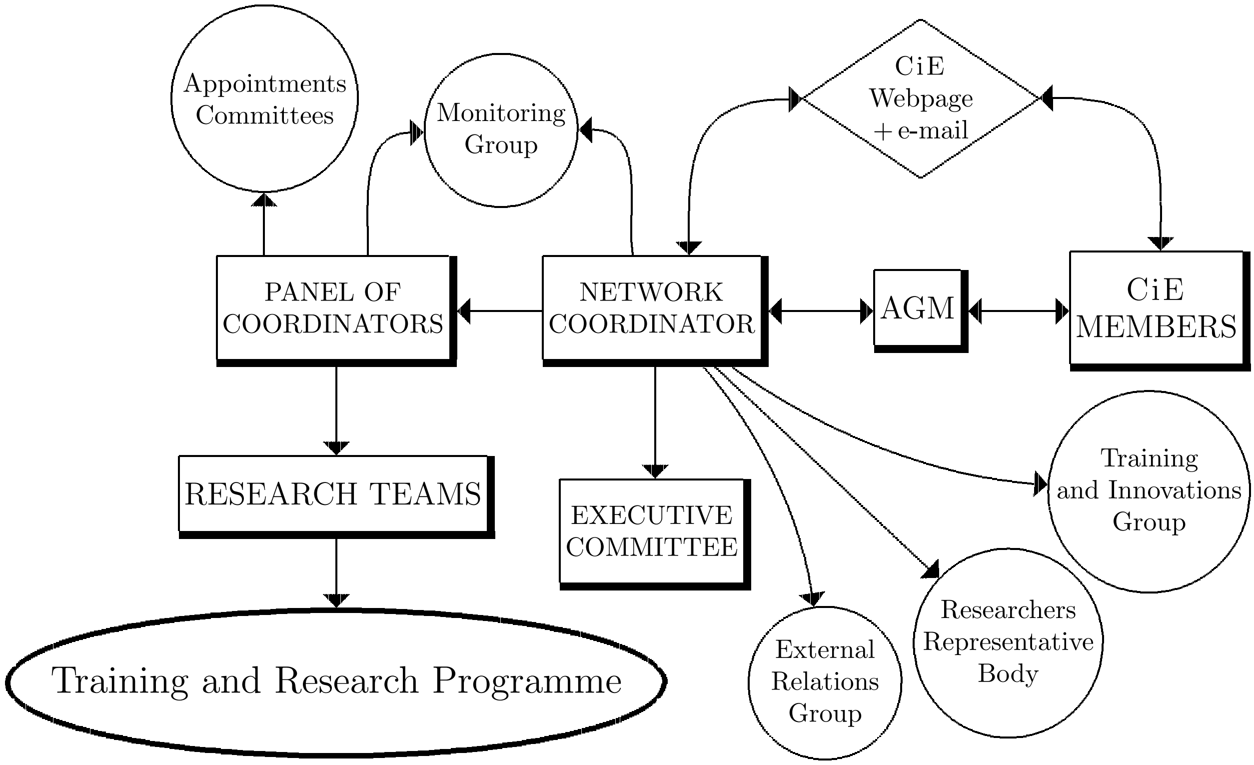
While the coordinator will have ultimate responsibility, as set out by the workplan and EU rules and guidelines, there will be mechanisms for delegation, consultation and appropriate devolving of organisational experience to younger researchers. The main features of the Management Structure include:

The Network Coordinator (NC). Responsibilities of the NC, in consultation with the Executive Committee and Coordinators' Panel, include: Coordinating the research and training activities of the network, including the appointments of the early-stage and experienced researchers; The periodic collection and collation via the Monitoring Subgroup of information on the scientific activity of the network, and the preparation and submission, with the approval of the Coordinators' Panel, of the annual and mid-term reports; The organisation during the annual conference of an Annual General Meeting (AGM); The maintenance, with local assistance, of the CiE website; The overall financial management, in co-operation with local administrative assistance, of the network (see below).

The Executive Committee (EC). This will be a small group comprised of node coordinators willing to join their experience and energies to those of the NC, and play a consultative and executive role in the day-to-day coordination of the network. Currently there is an acting EC comprised of the network coordinator, and the node coordinators from the Amsterdam, Oslo and Siena nodes. This has been invaluable during the preparation of this proposal. The EC will be set up by the NC in consultation with the Coordinators' Panel, and may make ad hoc co-options. At this and at all levels of the Management Structure we will try to involve less senior members in the running the network, while taking care not to disrupt their main scientific work.

The Panel of Coordinators (PC). The PC will consist of all Node Coordinators and their assistants, and, between AGMs, will attempt to coordinate and represent in a consensual manner the interests of the membership, and will be consulted on any significant matter to do with direction and finance of the network. The coordinators will usually be leading researchers, with appropriate experience of administering grants, and of other organisational activities. Each node coordinator will work with a Node Panel formed of representatives of the subnodes (see B4.3). The more senior such coordinators, for instance those with other major administrative commitments (some currently head their departments) may appoint an Assistant, who will help by taking care of some of the more routine demands on the coordinator, such as responding to requests from the NC for information. There are currently three such acting assistants, for the Heidelberg, Munich and Swansea nodes. The assistant coordinators will be full members of the PC. Particular duties of the coordinators are: Setting up local Appointments Committees, in consultation with the other node members and the NC, to decide appointments of early-stage and experienced researchers to the node, in accordance with network policy; Co-operating with the NC in setting up an organising committee for any local individual training or scientific meeting agreed by the network, such as an Annual Conference, or workshop, school or tutorial; Working with the Advisory Groups set up to monitor, coordinate and guide the activities of the network.

The Advisory Groups. The Advisory Groups will be small ad hoc groups set up by the NC to give special attention to important aspects of the network activities, who will periodically report to the network coordinator, and the AGM. These will include: A Monitoring Group, representing all the scientific objectives, and concerned with gathering data to be used by the network in making policy and drawing up reports; A Training and Innovations Group, concerned with furthering the interdisciplinary impact of the network, and making recommendations concerning the organisation and content of its research and training activities; An External Relations Group concerned with monitoring and stimulating the international impact of the network's scientific activities; A Researchers Representative Group, drawn from the network members appointed, or eligible for appointment, as early-stage or experienced researchers. This group will bring particular matters of interest to the younger researchers to the notice of the NC, and decide on the form and timing of the Young Researchers' Conference(s).



Some specific aspects of the network management include:

The Financial Strategy. In the interests of flexibility, the funds will be managed centrally. The Leeds node contains excellent financial support resources, includinga faculty financial officer with wide experience in helping in the financial administration of large research grants, including Framework 5 funding. The advance payment will be distributed according to the proportions in the overall budget, but with adjustments being made to the periodic payments according to the timing of appointments (which may be adjusted to suit local factors, such as the availability of suitable candidates), and the locations of the centrally planned training activities, such as the Annual Conference. The proportion of the funds retained by the coordinating entity would be approximately 2%. In practice the NC will propose to the PC a repartition of funds for the first and second periodic payments, the initial payment being distributed according to the proportions in the overall budget. The repartition of the third periodic payment will entail a return to the proportions of the overall budget as specified in the contract, after the removal of costs associated with meetings and schools, and any adjustments to allow for centrally incurred costs (such as for auditing). The EC financial contribution towards management and related money will be used for the administrative and financial costs of the network, including those associated with schools and conferences and the CiE website.

Methods for ensuring good communication, monitoring and reporting progress. In the above description, we would highlight the role of the Annual Conference and AGM, that of e-mail and the CiE webpage (at www.maths.leeds.ac.uk/ pmt6sbc/cie.html), and of the Monitoring Group.

Effective dissemination of results. Beyond the usual publication and reporting of results at international conferences, we will build the CiE webpage as a source of information on our research. Other measures, such as the publication of books based on CiE research outputs, will be discussed by the External Relations Group.

B4.2. Management know-how and experience of network co-ordinator

Prof. S. Barry Cooper, the proposed coordinator of CiE, is Professor of Mathematical Logic at the University of Leeds, England, and completed his PhD under Ruben L. Goodstein (student of Wittgenstein) in 1971. He is active in research, having around fifteen publications this century, including co-editing with the Novosibirsk coordinator S. Goncharov *Computability and Models: Perspectives East and West*, published by Kluwer Academic/Plenum Publishers in their University Series in Mathematics, and *Computability Theory* (Chapman Hall/CRC Press, 2003) which is expected to become a standard graduate text for the area. Cooper has visited and lectured widely, including visiting lecturer at the University of California at Berkeley, 1971–73 (supported by a Senior Fulbright Grant), visiting professor at the University of Chicago, 1985–86, and at the University of Siena on a number of occasions, including a three month CNR funded visit in 1989. While at Berkeley, Cooper founded the *Recursive Function Theory Newsletter*, which he co-edited with others for most of the period 1972–97, and is currently in the process of setting up a web-based archive.

Invited plenary lectures at major international conferences include the 9th International Congress of Logic, Methodology and Philosophy of Science, Uppsala, Sweden, 1991; the European Meeting of the Association of Symbolic Logic on three occasions, including Logic Colloquium '90, Helsinki, Finland, 1990; Logic Colloquium '95, Haifa, Israel, 1995; Logic Colloquium '98, Prague, Czech Republic, 1998; the Annual Meeting of the Association of Symbolic Logic, University of California at Irvine, 1995; the Sixth Asian Logic Conference, Beijing, P. R. of China, 1996; the 49th British Mathematical Colloquium, Royal Holloway, London, 1997; the AMS-IMS-SIAM Joint Summer Research Conference in *Computability Theory and Applications*, University of Colorado, Boulder, 1999; and the International conference *Logic and Applications* honouring Yu.L. Ershov on his 60th birthday, Novosibirsk, Russia, 2000. Cooper will be a keynote speaker at Turing Conference 2004, marking the fiftieth anniversary of the death of Turing, next year in Manchester, England, and supported by the BSHM (British Society for the History of Mathematics) and the BLC (British Logic Colloquium).

Since 1990 Cooper has administered six major research grants, employing a total of four post-doctoral fellows, and one senior visiting professor, and a large number of smaller grants (including a British Council research grant to work with A. Sorbi, Siena coordinator, and a Royal Society Joint Project Grant to work with M. Arslanov, Kazan team leader, and a number of LMS grants for short-term research visitors). The value of these grants totals around 500,000 Euros at current exchange rate. Some of this funding has been in association with substantial organisational work. Cooper organised (with S. Wainer) the *Leeds Recursion Theory Year*, 1993–94, involving a whole-year visit by T.A. Slaman from Berkeley, many shorter visits by leading international researchers, and an international meeting. Cooper was Leeds coordinator in the E.C. scientific and technical co-operation network *Complexity, Logic and Recursion Theory* (COLORET), involving other centres in Amsterdam, Barcelona, Heidelberg, Sienna and Turin, 1993–96. He was Programme Committee Chair and member of the Organising Committee for *Logic Colloquium '97*, European Meeting of the Association of Symbolic Logic, in Leeds, August 1997, organising and administering the scientific part of the meeting (which attracted around 250 participants) and set up and maintained the conference website. He co-edited with J.K. Truss a two-volume conference proceedings *Models and Computability* and *Sets and Proofs*, London Mathematical Society Lecture Note Series 258–59, Cambridge University Press, 1999. From 1999 to 2002 Cooper was the coordinator of the INTAS/RFBR Research Project *Computability and Models* (with partners in Heidelberg, Sienna, Turin, Novosibirsk, Almaty, Kazan and Ivanova), and was responsible for co-organising associated conferences in Heidelberg, Kazan, and Novosibirsk. He has served on many scientific committees, including the British Logic Colloquium Committee, the Sacks Prize Committee and numerous programme committees for international conferences.

Cooper has extensive experience of internal university committees, and of organisations contributing to the social and cultural life of the city of Leeds, playing an innovative and coordinating role in many contexts. He currently leads the Leeds Logic Group, which is one of the largest such groups in Europe, collectively very active in many spheres, with a traditionally broad coverage of areas in logic, and with close connections with computer science. While managing to avoid all-consuming administrative commitments of a non-scientific nature, he has represented his department on various university committees (particularly to do with research policy and promotions), and currently is part of the head of department's inner advisory panel. He is known for his student-based approach to teaching, having introduced student assessment of lectures into the department in the 1970s, before such things became part of university policy. He has served on the local committee of the Association of University Teachers, and has an understanding of the sorts of issues which affect young researchers on fixed-term contracts, and has a keen interest in helping young researchers get the sort of training and career advice which may help them achieve permanent academic posts. He currently supervises two PhD students, and another has just been awarded an EPSRC research fellowship to continue his work in Leeds.

B4.3. Management know-how and experience of network teams

Node 1: LEEDS, U.K.

Node 1 contains five internationally respected research groups. Each will contribute its considerable scientific expertise, and training and organisational experience, and will be involved in the secondments of young researchers. Birmingham and Edinburgh want to host the Annual Conference and/or a smaller school/workshop.

Coordination and communication within each node will be aided by the group of local coordinators for the constituent teams (the Node Panel). The node panel for the Leeds node currently consists of Aczel, Cooper, Escardo, Hyland and Longley. Management know-how experience contained within the node includes:

Leeds: Cooper's contemporary Wainer is hugely experienced, having served as head of department, been a member of the ASL Council, Chair of the BLC, and organised many EPSRC funded graduate schools in proof theory. Truss has been treasurer of the BLC, and is editor of the Journal of the LMS. Macpherson is coordinator of the new Marie Curie Early Stage Research Training partnership involving Leeds, Manchester, Lyon and Munich. Hill co-organised the International Summer School on Computational Logic (ISCL'02).

Birmingham: Jung is Director of the Midlands Graduate School in the Foundations of Computing Science, set up to provide PhD students with a sound basis for their research. He has been local coordinator of ESPRIT projects "CLICS 2", and "APPSEM", and currently coordinates the ESPRIT project "APPSEM 2". Jung has organised around 10 conferences in Darmstadt and Birmingham, including ESSLLI 2000 with over 350 participants. Escardo has organized the Workshop on Domains VI, and has edited various journals.

Cambridge: Cambridge runs numerous seminars and schools, and participated in the APPSEM Esprit Working Group, 1998–2002. All the senior members of the group are very experienced, and Forster is Director of Studies in the Department of Pure Mathematics and Mathematical Statistics.

Edinburgh: Simpson is LICS (Logic in Computer Science) Publicity Chair. Edinburgh are proud of their graduate training programme and welcome short-term visitors. They organised CSL'02. Plotkin edits several journals: TCS, MSCS, Inf. & Control, ACM Transactions on Computational Logic, and is on the ASL Council. He was Program Chair for LICS 2001.

Manchester: The first logician at Manchester was Alan Turing, of course, and there continues to be a world-leading group in logic, with strong CS connections. It runs an EPSRC funded MSc programme in Mathematical Logic and the Theory of Computation (directed by Wilmers). Paris is a British Academy philosophy section standing committee member, and has been president of the BLC.

Node 2: AMSTERDAM, THE NETHERLANDS

Node 2 includes the large Amsterdam group, and closely related subgroups at CWI, Utrecht and Münster. Amsterdam hopes to host a CiE Annual Conference and other training activities. Secondments of early-stage researchers to Münster and Utrecht are planned. The node panel is currently Löwe, Pohlers and Beklemishev.

Amsterdam, inc. CWI: Amsterdam is exemplary in research and training, with a distinctive interdisciplinary approach. Its large Graduate Programme in Logic, organized by the Inst. for Logic, Language and Computation ILLC (directed de Jongh and Löwe), had 32 PhD students and 29 MSc students from 15 countries in 2003. The proposed node coordinator B. Löwe stands for the inclusion of young researchers into the core of the network: a young researcher himself, he is already experienced in organising scientific activities. He is coordinator of the interdisciplinary conference series *Foundations of the Formal Sciences* FotFS which traditionally caters for young researchers. He coordinated the project HPCF-2000-00040 in the 5th Framework Programme, and is well versed in dealing with international high-level research projects. He was a member of the Organising Committee for Logic Colloquium 2002 in Münster (with Pohlers and Möllerfeld). Löwe was also a member of the Organising and Scientific Committee for Colloquium Logicum 2002 in Münster, and of the Executive Committee Mathematics/Computer Science in Bonn (2001-2003). Van Emde Boas was the team coordinator of the Amsterdam node in the COLORET network, and will add his experience in questions of Europe-wide networks and in management tasks to the node panel. Van Benthem was first director of the ILLC, and first chairman of FoLLI, the European Association for Logic, Language and Information, and initiated the new series of summer schools NASSLI which had its inaugural installment at Stanford 2002 (with van Benthem as Chair of the PC). The Quantum Computing and Advanced Systems Research research group, first led by Vitanyi (a CWI fellow) and now Buhrman, is a world leader in quantum computing and related topics. Buhrman co-organised the Fourth Workshop on Quantum Information Processing, Amsterdam, 2001. Peter Grünwald was co-organizer of the EURANDOM Workshop on Statistical Learning in Classification and

Model Selection, 2003, local co-chair of the 2001 COLT conference, 2001 in Amsterdam, and is on the steering committee of a 6th framework EU network of excellence PASCAL (on learning theory).

Utrecht: Van Leeuwen is a member of the editorial board of Springer Lecture Notes in CS, serves on many organising committees (currently MFCS 2003, European Symposium on Ambient Intelligence), and has a groundbreaking research collaboration on computation beyond the Turing limit with Wiedermann, Node 9.

Münster: Pohlers, Director of the Institute for Mathematical Logic and Foundations in Münster is very experienced, the recent Workshop in Proof Theory 2003 being organised on the occasion of his 60th birthday. He has edited a number of journals, is a member of the ASL Committee for Logic in Europe, and is chairing the program committee for Logic Colloquium 2004 in Turin.

Node 3: ATHENS, GREECE

Node 3 brings together a 6 teams (5 from Greece and one from Bulgaria) hoping to develop stronger links with other European research groups, and we are particularly looking forward to learning more from these very interesting research teams, with their very distinct and complementary expertise. Athens has offered to host an Annual Conference and/or a training event. Secondments to the Sofia node are planned. The node panel currently consists of Dimitracopoulos, Koletsos, Pheidas and Soskov.

Teams from Greece: The Inter-University Graduate Program in *Logic and Theory of Algorithms and Computation* is run by 6 Departments from 3 Universities (University of Athens, National Technical University of Athens and University of Patras), with 36 MSc and 4 PhD students, and involves most of the Athens researchers, including the highly experienced Y. Moschovakis. Moschovakis commenced his long and distinguished career at UCLA in 1964, with long, annual sojourns to Athens. Starting in 1997, he took an appointment in the Department of Mathematics at the University of Athens, where he regularly spends each Fall. There is also a Research Seminar in Logic and Algorithms (about 30 talks every year). There is strong involvement of the group in organising the Panhellenic Logic Symposium (a biennial international meeting, including at least 3 mini-courses directed to students), for instance the 2003 conference organising and scientific committees include Dimitracopoulos, Koletsos, Mytilineos, Pheidas, and Zachos. Members of the teams will be involved in the organisation of Logic Colloquium 2005, to be held in Athens.

Sofia: The Sofia group runs an MSc programme *Logic and Algorithms* with about 15 students. Soskov is currently Chairman of the Department of Mathematical Logic and its Applications at Sofia University. Professor Skordev has been associated with the group through much of its more recent history of research into logic and computability, playing an important role in organising a sequence of international conferences.

Node 4: BARCELONA, SPAIN

This is another large node, too rich in complementary expertise and experience to more than sketch, comprised of four teams from Spain and four from Portugal, and coordinated through the highly capable Barcelona team. Barcelona and San Sebastian would like to host the Annual Conference although Barcelona is already scheduled for ALT'2006 (see below). For schools Lisbon and Zaragoza should be added. Teams from Zaragoza and the University of Lisbon would like to host secondments. The node panel includes Atserias, Campagnolo, Fernandez-Combarro, Ferreira, Graca, Hermo, Mayordomo and Oitavem.

Teams from Spain: The node coordinator Atserias is very active (more than 15 scientific papers this century). Atserias and other senior researchers of the group are regularly involved in organising and programme committees of international conferences in theoretical computer science (ICALP, LICS, FOCS, MFCS, CCC, ALT, ...). Team members are involved in running postgraduate programmes and research seminars relevant to CiE in Barcelona, San Sebastian and Zaragoza. Zarazoza administers a research project founded by the Spanish government, "Modelado individualizado de secuencias simbolicas" (MOISES) that will last until November 2005, and involves PhD students in its organisation. Barcelona organized EUROCOLT'95 (European Conference on Computational Learning Theory), and their group has been proposed as a candidate to organizing ALT'2006 (Algorithmic Learning Theory). Barcelona was part of the COLORET HCM training network, for which it organized a highly successful workshop in 1997. Its local coordinator Balcázar is currently writing a book on computability, using his experience of providing courses for mathematicians.

Teams from Portugal: A number of members are part of CMAF (Centro de Matemtica e Aplicacoes Fundamentais) at the University of Lisbon. Ferreira is co-organiser of the CMAF sponsored winter school in proof theory in Braga (north of Portugal) in January, whose aim is to bring together mathematicians and computer scientists from Portugal (but also elsewhere) with interests in Logic. It is specially directed at graduate students. Ferreira has also been involved in the logic part of the MSc programme in mathematics in his department. Campagnolo is coordinator of the FCT/FEDER funded research project *Continuous Time Computation and Complexity* involving Francisco, Gouveia, Graca and Lourenco. He is involved in organising the Logic and Computation Seminar at IST. Kahle has been an organiser for a number of conferences, including the *Proof, Computation, Complexity* International workshop, 2002, in Tübingen.

Node 5: HEIDELBERG, GERMANY

The main centres in Node 5 are Heidelberg and Ulm, with participation from smaller teams at Berlin, Cottbus, Paderborn and Darmstadt. Heidelberg and Ulm are willing to host an Annual Conference or workshop. Secondments to Ulm are planned. The node panel currently includes Ambos-Spies, Köbler, Merkle (assistant coordinator), Otto, Schöning, Zheng and Ziegler.

Heidelberg: The Heidelberg team (particularly Ambos-Spies, Merkle and Reimann) have great experience in hosting medium-sized meetings and a large number of visitors, regularly exchanging students and/or researchers with Amsterdam, Siena and Novosibirsk. They run many specialised lectures open to grad and PhD students, and a weekly seminar on current research. In recent years, the Heidelberg group has hosted three international workshops on areas relevant to CiE; researcher from the group have been co-organisers of a couple of Dagstuhl and Oberwolfach seminars. Merkle organized a Dagstuhl seminar with Vitanyi, and both are co-organizers of future TAI workshops on algorithmic information theory. Ambos-Spies is a member of the council of the ASL and editor of the Mathematical Logic Quarterly.

Ulm: The group is large and active, and has organised many international conferences, including complexity-related research workshops at the Dagstuhl conference center. They organise a weekly seminar on recent research. Schöning has authored a number of books on complexity-related topics, including *Logic for Computer Scientists*, Birkhäuser, 1999, and (with Pruim) *Gems of Theoretical Computer Science*, Springer, 1998.

Berlin: Köbler runs a research seminar on computational complexity in collaboration with Technische Universität Berlin and University of Hannover, and is involved with MSc courses in Computational Complexity and Cryptography. He is Principal Investigator (Germany) for a DST-DAAD funded project in complexity involving researchers from Berlin, Ulm, Aarhus and India.

Cottbus: Zheng is a very active researcher with more than publications related to CiE this century.

Darmstadt: Otto, just moved from Swansea to become Professor in Logic and Mathematical Foundations of Computer Science at Darmstadt, has involvement with a number of major conferences, either organising or speaking, including the 18th Annual IEEE Symposium on Logic in Computer Science (member of PC). He was an invited speaker and special session co-ordinator of the Special Symposium on the Unusual Effectiveness of Logic in Computer Science, 12th International Congress of LMPS, Oviedo, 2003 (with invited talks by CiE members Dawar and Kohlenbach). Keimel was Project Coordinator for a New Curriculum with an International Orientation Mathematics with Computer Science funded by DAAD, 1998-2002.

Paderborn: Ziegler is another very active researcher, with links to Brattka and computational physics.

Node 6: MUNICH, GERMANY

Node 6 brings together groups from Munich, Hagen and Siegen in Germany, together with Vienna, Austria, and Ljubljana, Slovenia. Munich and Hagen are willing to host a school or workshop. Secondments to Hagen are planned. The node panel consists of Bauer, Beckmann, Johannsen, Schwichtenberg, Spreen and Weihrauch.

Munich: Schwichtenberg, a distinguished researcher and experienced organiser, has just become head of his department, and is assisted in his node coordination role by Johannsen. The Munich team runs the Graduiertenkolleg "Logik in der Informatik" (GKLI), a PhD school with 8 students and 2 postdoctoral researchers, and runs a number of regular research seminars. They participate in the Sokrates programme, cooperating with Amsterdam (DeJongh). Schwichtenberg is one of the directors of the annual Marktoberdorf Summer School, an Advanced Study Institute of the NATO Science Committee, is an organizer of the semi-regular Oberwolfach meeting on Mathematical Logic, and serves on numerous organising and programme committees for international conferences. The Munich group organised CSL 2000, and two members (Schwichtenberg, Hofmann) are on the steering committee of the ICC workshop series.

Hagen: Members of the Hagen team, particularly Weihrauch and Brattka, have played a hugely important coordinating role via the *Computability and Complexity in Analysis* network, organising CCA meetings once a year since 1995, most recently CCA 2003 in Cincinnati, and CCA 2004, to be held in Wittenberg, Germany. They were also involved in organising tutorials on *Computability and Complexity in Analysis*, Feb. 2000 in

Hagen, Sep. 2002 in Wittenberg. Brattka has served on various programme committees (e.g., SOFSEM 2000, Milovy, Czech Republic).

Siegen: Spreen has wide interests and extensive research links, with more than ten publications this century. Since 2000 he has been an organiser of the biennial workshop on *Topology in Computer Science* at the Dagstuhl conference centre.

Vienna: The Vienna group organised Logic Colloquium 2001, as well as CSL and the ESSLLI summer school in 2003. Beckmann still has strong links with Münster, and has worked with Krajíček, supported by a Leopoldina-Fellowship.

Ljubljana: Bauer got his PhD at Carnegie Mellon in 2000, and has since developed some innovative collaborations within CCA and CiE (e.g., Escardo, Simpson).

Node 7: NOVOSIBIRSK, RUSSIA

Node 7 is very large, mainly consisting of researchers closely associated with the world-leading Novosibirsk and Kazan schools of Ershov, Goncharov and Arslanov, and having close links with many of the CiE participants via the COLORET and various INTAS projects. They specially strengthen the effort on objectives 3.2, 4.1. The researchers from St. Petersburg have less historical links with CiE, but are integral to objectives 4.2, 4.3. The node panel is being developed on the basis of Arslanov, Badaev, Bereznyuk (assistant coordinator), Goncharov, Matiyasevich and Omanadze.

The Novosibirsk and Kazan schools: Here we find some of the more distinguished figures of Russian mathematics. Ershov, hugely honoured both in Russia and abroad, Academician of the Russian Academy of Sciences, Director of the Sobolev Institute of Mathematics, continues to play a key role in the subject. For Node Coordinator Goncharov too, Corresponding member of the Russian Academy of Sciences, we can only hint at his experience and achievements — he is Dean of the Department of Mechanics and Mathematics in Novosibirsk, and in 2002 was elected to membership of the European Academy of Sciences. He has published more than 100 research works, and is co-editor (with Ershov et al) of the 2 volume *Handbook of Recursive Mathematics*. S.Goncharov was a member of program committees of many all-union and international conferences. He has supervised numerous doctoral students, co-organised many conferences in Russia, travels widely, and is in demand as a plenary speaker and programme committee member. Goncharov, Ershov, Morozov and Puzarenko have a joint DFG-RFFI project 2001-2003, involving CiE members Streicher, Keimel and Spreen. Arslanov is another key figure, corresponding member of the Tatarstan Academy of Science, head of his department in Kazan, the current owner of the historic desk of Lobachevsky. He has organised a number of major international meetings in Kazan, and been a frequent speaker and programme committee member at international conferences. He is a member of the ASL Committee for Logic in Europe.

St. Petersburg and the Steklov Institute: The name of Matiyasevich will, of course, be forever associated with the celebrated negative solution to Hilbert's Tenth Problem, which should not detract from the current work of his group at the distinguished Steklov Institute, where he is Head of Laboratory of Mathematical logic. He has much experience with international conferences, at all levels, is correspondent member of the Russian Academy of Sciences, and is on the editorial board of various journals.

Kazakhstan and Georgia: The team from Almaty was very active in the INTAS projects already mentioned, in particular organising a one-week workshop *Computability and Models*, 2002, under the aegis of the Kazakh National University. Omanadze is a fine researcher and an essential part of the project.

Node 8: OSLO, NORWAY

Scandinavia is served by Node 8, bringing together closely associated logic groups Oslo from Norway and Uppsala from Sweden, with the smaller, but important, Aarhus group from Denmark. There are also two individuals with research links to Oslo included, from Bergen and the Oslo University College (Kristiansen is an integrated member of the UiO-logic group). And Luleaa and Jens Blanck is closely associated with Uppsala. There is interest within the node, particularly from Aarhus, in hosting the Annual Conference or a school/workshop. Secondments to Uppsala and Aarhus are planned. The node panel currently contains Kohlenbach, Stoltenberg-Hansen and Normann, and others may be added appropriate to the node activities.

Norway: The coordinator Normann was Chairman of the Department of Mathematics, 1989–90, and 1996–2001 was on the Central University Committee for student complaints. He is currently Chairman of the committee for the Master Programme in mathematics. The Oslo team runs regular courses for master/PhD-students in topics related to the project, and organises a weekly seminar on Mathematical Logic. Both Uppsala and Oslo have organised the Scandinavian Logic Symposium at two locations. Normann and Stoltenberg-Hansen were organisers of the Mittag-Leffler year in Logic 2000-2001. One of its aims was to share knowledge with younger researchers. Normann was for ten years an editor of the *Annals of Pure and Applied Logic* and is on the programme committee for Logic Colloquium 2005 in Athens.

Uppsala: The group is involved with regular MSc courses in Domain Theory, Algorithm and Complexity Theory, Constructive Logic and Lambda Calculus, with around 15-20 students. There is a weekly Stockholm-Uppsala research seminar. Members of the group (particularly Stoltenberg-Hansen) were involved in organising the 9th International Congress of Logic, Methodology and Philosophy of Science, Uppsala, 1991. Stoltenberg-Hansen was the chair of the programme committee for the ASL European Meeting in Helsinki 2003. He was an invited lecturer at the Marktoberdorf Summer School in 1999 and 2001 and he is on the editorial board of the Journal of Logic and Algebraic Programming.

Aarhus: Kohlenbach is on the Board of the BRICS International PhDSchool in ComputerScience. His group organises the weekly BRICS Logic and Semantics Seminar. In 2002 Kohlenbach was conference chair of the 17th IEEE Symposium on Logic in Computer Science (LICS'2002) and member of the organizing committee of FloC'02 (held in Copenhagen). In 2003 he was a member of the scientific committee of the Workshop on Proof Theory and Algorithms held in Edinburgh, and a member of the organizing committee of the 18th IEEE Conference on Computational Complexity in Aarhus. Kohlenbach is a member of the Teaching Committee of his department.

Node 9: PRAGUE, CZECH REPUBLIC

The Node 9 participants are drawn from two closely-allied Prague based groups of high academic standing: Coordinator Jiri Wiedermann's world-leading computer science team at the Academy of Sciences of the Czech Republic, and that of the historic Charles University, led by A. Kučera. The Academy of Sciences, with ideal facilities for hosting meetings of up to 50 persons, plan to organise a workshop. Secondments of early-stage researchers to Charles University are envisaged. The node panel is Kučera, Wiedermann, and Žák (assistant coordinator).

Academy of Sciences: Krajíček organizes Fall schools of Logic and co-organized conferences on complexity with a special aim at postdocs (e.g. Edinburgh'01). He is on the ASL European Committee. J. Wiedermann is member of the Steering Committee of the Annual International Conference SOFSEM (Theory and Practice of Informatics) (XXXth Annual Conference in January 2004). Hájek is the head of the ERCIM working group on Soft computing, organising yearly workshops, and was Chair of the General Program Committee for the 12th International Congress of Logic Methodology and Philosophy of Science, Oviedo, 2003. The group organised or co-organised more than forty meetings in the last ten years, and are editors of various international journals, etc. (Pudlák is editor of the ASL Perspectives in Logic.)

Charles University: A. Kučera is very experienced in research and administration, and as head of his computer science department brings an important interdisciplinary influence to the project. He has a number of CiE links, including Heidelberg, Leeds, and Siena.

Node 10: SIENA, ITALY

Five exceptionally strong research groups including Florence, Padua, Siena, Turin and Udine come together in Node 10, and some of the more experienced organisers in the network are to be found here. Siena is willing to host an Annual Conference, and Padua and Florence will offer other training events. Secondments will involve Florence and Padua. The node panel involves Andretta, Cantini, Crosilla, Gianantonio, Sambin and Sorbi.

Siena: The node coordinator Sorbi is an internationally leading researcher, with many collaborations involving leaders in computability from Europe, the US, Russia and the Far East. He has great experience in organising meetings, training programmes and scientific visits, and serves on the CiE executive committee. He was the coordinator of the EU COLORET network *Complexity, Logic and Recursion Theory*, and its related PECO extension (Prague, Kazan, Novosibirsk); has been local coordinator of the INTAS project *Computability and Models*; and is currently the coordinator of the INTAS project *Computability in Hierarchies and Topological Spaces* (Siena, Siegen, Almaty, Novosibirsk). He is currently the head of the graduate school in Mathematical Logic and Theoretical Computer Science at the University of Siena. He has been on the program committee of many meetings, most recently Logic Colloquium 2002 in Münster, co-organising the Special Session in Computability Theory, and Logic Colloquium 2004 in Torino. Montagna has organized in Siena many of the AILA (Italian Association of Logic and Applications) meetings, specially directed to young researchers in logic. Montagna organised the international workshop *The Logic of Soft Computing*, Nov, 2003.

Florence: Cantini is Head of the Department of Philosophy which has a longstanding tradition in logic; he is member of the rectorial cttee. of Florence University supporting international research cooperation. The logic group organised the 1995 *Logic Methodology and Philosophy of Science* meeting (over 800 participants) and the international meeting *Operations, Sets and Types* (1998). Cantini and Minari have standing cooperation with IAM Bern: in particular, a joint CNR-SNS project (2001). Crescenzi is Director of the Degree programme in Computer Science. He has been italian representative in the bilateral CRUI project Germany - Italy (1998), unit coordinator in the SCOOP project funded by EU (1997) and responsible for several CNR (National Research Council) projects (2000-2002). Laura Crosilla has co-organised with Peter Schuster (Munich) the workshop *From Sets and Types to Topology and Analysis* (2003) Sponsored by Volskwagen Stiftung.

Padua: This is a very active and internationally regarded group, running a number of courses and seminars, and international meetings. They organised courses at ESSLLI 98 on formal topology and at ESSLLI 99 on basic logic. They organized the first (in !997) and the second (in 2002) Workshop on Formal Topology, and both have been very successful in increasing contact between various schools in constructive topology.

Turin: Odifreddi has a whole career now in popularising computability and logic, including books, newspaper articles and his own TV programme. Andretta is chairing the organising committee for Logic Colloquium 2004 in Torino (other committee members Marcone, Zambella).

Udine: Gianantonio is involved in the ESPRIT working group TYPES. Honsell leads the *Semantics and Logics of Programs* Research Group, and has been involved with organising numerous conferences (e.g., steering committees of ETAPS 2000, Berlin, ETAPS 2001, Genoa, and ETAPS 2002, Grenoble).

Node 11: SWANSEA, U.K.

Apart from the large group at the University of Wales at Swansea, Node 11 includes key researchers from Imperial College, London. Swansea would be willing to host and Annual Conference or smaller training activity. A secondment of an early-stage researcher to Imperial College is planned. The node panel currently is Berger (assistant coordinator), Edalat and Tucker.

Swansea: Tucker, the node coordinator, was Head of Computer Science Department, 1994-2002, and First Chair of the Physical Sciences Planning Group, University of Wales, Swansea. He is Chair of Steering Committee of IT Wales (1996-), this recently becoming a 1.4m EU funded industrial programme for ICT in Wales. Tucker was founder and first Chair of British Colloquium on Theoretical Computer Science for 1985-93, organiser of several colloquia and other meetings, including British Logic Colloquium, Gregynog, 1999. He has played an important role developing research links between mathematics and theoretical computer science. Berger administers the EPSRC funded research project *Domain-theoretic methods for program synthesis*, employing a research student and involving links to CiE centres Munich, Edinburgh, Imperial, Leeds, Manchester, Oslo and Uppsala. Setzer organises the programme of regular Computer Science Research Colloquia.

London: Smyth is one of the co-organisers (with Spreen) of the biennial Dagstuhl workshop on *Topology in Computer Science*. Edalat is leader of the Exact Computation research group at Imperial College. He was an invited speaker at ETAPS 2000 in Berlin.

B5. RELEVANCE TO THE OBJECTIVES OF THE ACTIVITY

Computability in the European context: In B1.1 we outlined the key role played by computability-related research in science and the wider context, pointing to the essentially interdisciplinary nature of recent developments in the area, on which we intend to build. In B2.2 we described what we called the *European dimension* to our project, explaining why there was a particular need for a specifically European development of research potential in this area. Aspects touched on included: (a) The exceptional contribution European researchers have made in the past, contrasted to the current dominance of North America in economic exploitation of expertise in computability, and the related migration of human resources; (b) The key role for CiE in pushing through a fundamental restructuring of core research, and European research infrastructure, within this important area; (c) Some specific ways in which CiE will help in developing European research potential, within a longer-term perspective of European enlargement.

We now expand on the benefits to be obtained from a European project of this nature. In doing this we must first briefly outline the nature of research in the area, including its specifically European aspects. We will then explain how the particular features of our project exactly address the existing developmental needs, and the wide-ranging benefits to be gained from that development.

Normal science and new developments: As Thomas Kuhn comments in *The structure of scientific revolutions* (Third edition, University of Chicago Press, 1996, p.37):

> ... a scientific community acquires ... a criterion for choosing problems that ... can be assumed to have solutions. To a great extent these are the only problems that the community will admit as scientific or encourage its members to undertake. ... One of the reasons why normal science seems to progress so rapidly is that its practitioners concentrate on problems that only their own lack of ingenuity should keep them from solving.

What is important about computability today is that there is now a serious focus on new computational paradigms. Normal science will certainly play a vital role in any radical new breakthrough, and identifiable problems will to a large extent structure our research activities. But any attempt to restrict research to a rigid agenda will be be ultimately counter-productive. As is now widely accepted, foresight committees and the like can only achieve so much. The really new developments — such as a better understanding of how physical systems may breach the Turing barrier, or practical breakthroughs in how computers deal with continuous systems — are less predictable, and depend on less convergent approaches to basic research, involving a more piecemeal development of concepts and concomitant discovery of missing ingredients. We believe the CiE research programme and its accompanying human resources to be focused at an appropriate level.

The positive and negative roles of fragmentation: From this perspective, fragmentation within a research area is a double-edged weapon. Just as innovation may depend on the coherence of disparate ingredients, and the sort of interdisciplinarity represented by CiE, it also depends on separate but interactive scientific activity. Most of the great scientific advances of the past were made by individuals, or very small groups, working in isolation, but benefitting in some crucial way from a wider context. Both fragmentation and interaction become essential to scientific progress. Large collaborative research teams may be physically necessary in certain areas of research, but for the theoretician can act as a negative constraint. They are not essential to a Newton, an Einstein, a Gödel or a Turing. We view the rich research infrastructure of CiE as a strength. Our plan is to realise its potential via the sort of activities and approaches to research, training and exchange of knowledge we have outlined above.

It is no mean feat to bring together some hundreds of researchers, the majority of them relatively young, based at over sixty-five universities in seventeen European countries, and form something coherent and meaningful. What makes it not just possible, but necessary to progress in the area, is the extent to which this distribution and richness of resources mirrors the scientific ingredients one can anticipate playing a role in the research. As we described earlier, not only is the achievement of our specific research objectives dependent on novel interactions, but would entail further interrelationships, some of which would only become clear in the course of the project, and which can be expected to tell us more about major underlying scientific issues. In our opinion, fragmentation in the area is less a problem for the *project*, more one for *European science* without such such a project. But rather than make negative projections based on a conception of a European science without CiE, let us list some things we hope and expect to flow from the full implementation of the proposal, appropriately linked to planned mechanisms for their achievement.

An appropriate infrastructure for research, training and transfer of knowledge at the European level: Whatever happens, Europe will continue to produce leading researchers in computability-related areas of mathematics, logic and computer science. But CiE will address certain retention issues, and the balance of research collaborations will be moved in favour of Europe. What is remarkable is that major figures in European computability, working on related problems, have for various reasons not worked together. The thought of Matiyasevich, Moschovakis and Paris, brought together for the first time at a CiE meeting, is just one intriguing image. For the young researcher at that meeting, there will be both memorable occasions, and challenging new ideas, to sustain motivation and feed into independent research. There may be the experience of presenting her work before such experts, in a supportive and encouraging atmosphere, and the possibility of following up an after-talk conversation with a research visit. Her thesis — taking our scenario further — is a good one, benefitting from expertise from opposite ends of Europe, taking in Russia too. As a result of links formed within the network, a long-standing open problem is solved, and network mechanisms for transfer of information produce both European exploitation of the new techniques, and an eventual permanent position for the young researcher. She does not need to move to the US to continue her research, and returns to Crete (in this instance). Her career is a long one, the breadth of knowledge acquired via the network, the confidence from being involved in its organisation, the enduring support of the research contacts made, all provide a platform from which to develop her career in new directions as initial interests wane and become worked out. The European research community is stronger, as are the scientific resources of a less-favoured region. Notice two key ingredients here: The complexity and complementarity of the scientific area, and the benefits delivered through linking and independent development; And the wide dispersal of expertise within the research community, with a consequent need for mechanisms for networking. Research in computability needs a scientifically inclusive strategy. What CiE does is to recognise the need to practically match this at the European level with a parallel approach to training, transfer of knowledge and management of resources.

Long-term projections: We have already touched on some of the long-term benefits to be expected from a Europe-wide initiative in this area, such as the retention of leading researchers, the extending of research careers beyond the initial first few years, and the consolidation of research excellence in less-favoured European centres. There are a number of others. One can expect to get many young participants in CiE meetings and training activities from outside the network, and even the subject, attracted by the quality of the training and the higher profile that CiE gives computability related issues. These can be expected to feed a growth in the number of researchers entering the area. A side-effect of interdisciplinarity is improved communication, beyond that mentioned in relation to our website and external relations initiatives: there is a new need to think through and express the *reasons* for doing a piece of research, and a pressure to interpret specialised work to the interested non-specialist. This will impact favourably on both the quality of training and the wider assimilation and application of the results of the research. Implicit in all of this is an improved *level* of research, both in terms of output and quality. This, and the higher profile of computability and theoretical computer science within mathematics and computing departments will feed through into a consolidation and growth of permanent positions in the field. As the EC is well aware, interdisciplinary research, despite its wider relevance, often loses out in the competition for posts, unless properly flagged and funded.

Computability in Europe — the need for research, training and transfer of knowledge, and the road to growth: According to Einstein (*Out of My Later Years*, Philosophical Library, 1950, p.54):

> When we say that we understand a group of natural phenomena, we mean that we have found a constructive theory which embraces them.

Science since the time of Newton, at least, has been largely based on the identification and mathematical description of algorithmic content in the Universe. The advent of the computer makes a whole range of theoretical issues concerning computability and constructibility of pressing relevance. A European response to such challenges is both important to the general development of the scientific area, and basic to the scientific culture on which European developments in relation to the computer will depend. The assimilation of theoretical concepts and constructs from logic and computability have already played an important part in the computing revolution of the last century. This period of rapid advance is not yet over. It is important that Europe continues to occupy a leading position in theoretical developments related to computability and its applications. If this is to happen, the sort of practical steps advocated in this proposal, the basic mechanisms outlined for the support of research, training and the transfer of computability-related knowledge, will be a valuable step in the right direction.

B6. ADDED VALUE TO THE COMMUNITY

The wider contribution to European development: The precise form of the benefits of basic research are largely unpredictable. Sometimes there are no immediate benefits beyond the relevant scientific field. In this context, the appearance of the first stored-program computers at the universities of Cambridge, Manchester and Pennsylvania, not much more than ten years after Turing's discovery of his Universal Machine, must count as quick returns. By way of contrast, it took around thirty years for Hilbert spaces to assume their essential role in quantum theory. (Coincidentally, the mathematician John von Neumann was a key figure in both of these progressions from pure mathematical theory to physical reality.)

Despite this, we can make some increasingly safe projections. There is growing evidence from many different sources, both scientific and theoretical, that not all physical systems can be framed within the standard model of computability. And just as the challenge to the standard model is an interdisciplinary one, so is the developing understanding of how this can be. Our first prediction is that progress towards harnessing this conceptual revolution will depend on diverse forces, and ones which are sufficiently focused on the possibilities opening out. And that CiE has the human resources and focus to qualify Europe, once again, for a leading role in the new science. Secondly, it is unlikely that the new computing revolution will be carried through without an understanding of its theoretical content. It is also reasonable to expect (prediction three) that whatever the results of the research, its content will feed via the training and exchange of knowledge programme into the wider scientific and social context. Researchers trained in the areas of the project are in demand from many industrial, financial and professional employers. While this is a drain on the basic research, there are already plenty of examples of wider added value to European research and development, particularly to computing and software concerns, and to the general level of understanding of new concepts related to computability and its applications. Logic and computability theory has already conceptually underpinned progress in computer design and programming to an extent unrecognised within mainstream mathematics, and often forgotten by its indirect beneficiaries. Its role has always been an interdisciplinary one, fitting uncomfortably within conventional academic structures. The safest prediction is that a large body of high quality research will result from the collaborations planned, and that much of this will have direct consequences in mathematics, computer science and (e.g., the work on exact real-number computation) in more practically relevant contexts.

Community cohesion, integration, and the role of Less-Favoured Regions and Associated States: There has already been some important steps towards integration and cohesion through earlier initiatives, such as COLORET, the EU-Twinning Project "Proof and computation" and the INTAS projects. These supported links involving researchers from Oslo and the Czech Republic, as well as from various third countries with an as yet less developed involvement with the EU (e.g., Russia, Kazakhstan and Georgia). Within CiE, Athens and Swansea (from Less-Favoured Regions) now play important role as full participants, with special expertise in relation to a number of research objectives. Both are expected to play a full part in the training and network activities, having offered to host conferences and workshops. Crete (part of the Athens node) has special experience in hosting Euro-conferences, and will also be encouraged to play an active role in hosting such events. There is also new participation from the Sofia team in Bulgaria (a Candidate Country), as part of the Athens node, and they will also play role in hosting training activities and in the secondments of young researchers. They have a very experienced team of researchers, and we are delighted to welcome them into the European research community. Other Less-Favoured regions represented include the ALgarve and Oviedo from the Barcelona node, with existing links to CiE participants (and between Oviedo and Morozov in Novosibirsk), and Cottbus (with research links to Hagen, Leeds and various other CiE participants). Although Charles University has long-standing links with Leeds, Siena, Heidelberg and other participants in earlier networks, the main participation from the Prague node (Candidate Country Czech Republic) is new, despite a number of less formal research links. Again, the participation of Prague is a key one, and they will participate in all the activities. The Norway (Associated State) participation is an old one, but brings in new researchers, and promises some particularly important interactions with new participants from CS. We also have new participation from Slovenia (Candidate Country), which is another scientifically significant one.

Gender issues and the involvement of women: It is doubtful whether any mathematically related proposal can point to a satisfactory situation as regards the involvement of women researchers, particularly at senior levels. We are lucky in having particular teams which involve strong researchers who are women. Women researchers have been involved in preparing input to this proposal from nodes 1, 3, 4, 6 and 10, and some of these are already involved with node panels. In section B2.3 we described how we would take steps to optimise the recruitment of women as early-stage and experienced researchers, including the utilisation of the informational and support resources of the organisation *European Women in Mathematics*. Our proactive approach here would be in the context of a growing university-level range of measures. For instance, all institutions active in the Amsterdam node not only have policies to encourage female researchers to take up academic careers, but are also active in programmes to finance special permanent positions for young female researchers and promotions to higher level positions for more senior female researchers (the NWO programs MEERVOUD and ASPASIA for the Dutch institutions and the MWF program "Gender Mainstreaming" for the University of Münster). Similar frameworks exist throughout the network, and female researchers from CiE can expect the full support of the institutions via such measures. We will make the most of these opportunities. We are serious about this, and do expect to have an impact.

Enhancing the research environment for computability in Europe, and improved European competitiveness: We add here to our remarks in B2.2 in regard to the enhanced research environment, retention of researchers, and increased competitiveness.

A young researcher into computability requires motivation, self-esteem, opportunities to develop knowledge and technical competence, and to collaborate with researchers with complementary knowledge. S/he specially needs pride in being part of a meaningful ongoing scientific enterprise. And, of course, needs employment. What CiE can give the researcher is a role in a supportive European-wide *community* of like-minded researchers, containing high a high level of complementarity of expertise, which directly addresses all of these requirements, except that of providing long-term employment. Relevant to the latter, CiE will equip its young researchers to make the most of their opportunities for pursuing a research career. This will not just be through the specific training in research and complementary skills provided, but through the raised profile, interactiveness and relevance of the subject area. A university department will be able to read the signs provided by CiE activities that the researcher comes from a field of research which can deliver the sort of international visibility, links with other research areas, and funding, which qualifies it to contribute scientifically and financially to its global success. Increased European competitiveness will derive from the consequent retention of our best researchers, and the improved quality and focus of the research. Since computability is integral to so many fields of activity, this enhanced competitiveness will feed through to the economic level.

Synergies and the wider structuring effects: In sections B1.3 and B1.4 we tried to give some impression of the many links within the scientific area and between the approaches of researchers from different backgrounds, and how we would attempt to develop these links. We are frustratingly aware that in the space available we have had to suppress much technical detail, and have given a very incomplete picture of the extent of the connectionism and related dynamics within the subject. These links are the basis upon which we aim to build structural reform of the research area. This is a process which has already started, mainly through earlier funding through COLORET and the various INTAS projects mentioned earlier. This new network goes far beyond anything seen previously, and involves a depth of interdisciplinarity which will have consequences for the field, and for related parts of European science (see below). The consolidation of such a closely integrated body of research and researchers will provide a basis for a long-term integration of training and research resources, and a platform from which to develop other initiatives, with new funding, aimed at enhancing cohesion and combatting fragmentation in this important area. This is why we have called our project *Computability in Europe*. Although the research itself is important, and could be captured by a title such as *Computability in an Extended Context*, it is the restructuring which is our primary aim, and which is a precondition for the full exploitation and development of the human resources brought to bear. And while we cannot claim to include *every* leading researcher in the area, the team gathered together here is remarkably comprehensive, containing world-leaders related to all the research objectives, and more than worthy of the project title.

Added to those effects we have already outlined in relation to the network participants and the outcomes to their research, there are expected to be more wide-reaching developments. As we have already noted, there are a number of research developments and special European factors which give CiE a special world-role. There is a need for a new hegemony within computability-related research, involving a return to a more basic engagement with science, the humanities, and social and economic issues. Within CiE we expect the emergent new ways of working to develop into an interactive research framework which does not threaten the autonomy of different approaches, whether they be theoretical or more based on particular applications. This will provide a platform for greater inclusivity at all levels, and a widening of the interdisciplinary and synergetic benefits.

Coordination with regional, national and international activities: Most relevant to us are the many national programmes, and other international programmes such as INTAS, from which we intend to seek additional funding for our Third-Country participants. Space does not allow us to describe in detail here the extensive involvement of our participants in these complementary activities at all levels, or the considerable extent to which these will inevitably augment the work of CiE.

B7. INDICATIVE FINANCIAL INFORMATION

A number of assumptions relating to the marital status, academic origins and periods of employment of the fellows have had to be made — which impact on the the costs related to employment and the exact figures for such things as the monthly living allowance, monthly contribution to participation expenses, career exploration allowance, travel allowance, etc. — and this has been done in a way which will give us a reasonable level of flexibility in the actual circumstances of the project. For instance, we have based our budget computation on the assumption that all researchers are hired on the basis of a regular contract. We expect that the choice between salary and stipendiary contracts will depend on the appointed fellow and that moving a contract from salary to stipendiary will allow us to increase the number of person-months available to the fellow. Similarly, in the subdivisions of the allocations of person-months planned for particular nodes, we have allowed for a number of shorter visits. This is partly based on our earlier reasoning as to the benefits and demand for shorter visits from our own large pool of research students, taking into account the nature of the scientific area and the fact that 36 months is insufficient in most of Europe for a full PhD course. But it is also to allow us flexibility to satisfy the needs of the young researchers in the particular circumstances prevailing.

In relation to the expenses for the CiE network for activities not related to the appointment of early-stage and experienced researchers, we have allowed just under 22% of the total budget (A in the table below) for the network's event-based training programme, and for the participation of the members of the separate teams in network training and research activities. The figures in column (A) are, of course, related to the costs of employment relating to the separate nodes, with some minimal adjustments, and as described in part B4.1, the exact allocations may be varied during the course of the project, with the agreement of the Panel of Coordinators, to compensate particular teams for extra local costs associated with our training schools, workshops, and conferences. On the basis of plans received from the individual teams, we assume the organisation of approximately four training schools/workshops per year, occasionally in association with a major non-CiE international conference with CiE organisational involvement, at an approximate cost of 12,500 Euros each, including the costs associated with the participation of international experts, and those of the young researchers involved. We have allocated up to 20,000 Euros for each of our four Annual Conferences. We would also hope to contribute 10,000 Euros to the Novosibirsk node to facilitate their participation in the training and research activities of the network. These costs adds up to approximately 11% of the total budget.

Just under 1% (26,027 Euros) of the total budget has been allocated to the nodes for expenses associated with exchange of information (such as setting up and maintaining the network's webserver) and materials, and for such things as the appointments process (see column (B) in the table below). Also, just under 3% (78,162 Euros) is needed for the general management costs of the project, including the financial and administrative coordination of the network at global and local levels, with a number of particular costs such as eligibility checks, contacts with the European Commission, day-to-day financial monitoring and management, cost and project reporting, contract management and organisational costs associated with meetings. There will be a one-off cost of 9,000 Euros for the provision of a webserver for the network. This will be essential to the coordination and exchange of information within the network. The 10% overhead of the direct costs for the project will be allocated to the teams approximately in proportion to their part of the total budget.

The table on the next page summarises our breakdown of costs for activities not related to the appointment of early-stage and experienced researchers. The numbers are indicative and based on the calculation that the 212 person-months of early-stage researcher appointments will cost 845,205 Euros, the 162 person-months of experienced researcher appointments will cost 856,703 Euros, giving a total of the 374 person-months of appointments, costing a total 1,701,908 Euros. This last figure amounts to 65.36% of the total budget of 2,604,059 Euros, got by adding the costs related to appointments to those (A+B = 594,508 Euros in the table below) for the research, training and transfer of knowledge expenses, plus those (78,162 Euros) for management (C in the table below), plus the 9,000 Euros for equipment (D in the table), plus the 220,481 Euros overheads.

Indicative financial information on the network project (excluding expenses related to the recruitment of early-stage and experienced researchers				
Network Team No.	Contributions to the research/ training / transfer of knowledge expenses (Euro)		Management activities (including audit certification) (Euro)	Other types of expenses / specific conditions (Euro)
	(A)	(B)	(C)	(D)
1. Leeds	78,052	3,870	11,528	9,000
2. Amsterdam	64,150	1,733	6,018	0
3. Athens	44,577	2,105	6,233	0
4. Barcelona	51,124	2,566	7,616	0
5. Heidelberg	55,440	2,600	7,728	0
6. Munich	62,856	2,945	8,743	0
7. Novosibirsk	0	0	0	0
8. Oslo	62,015	2,936	8,738	0
9. Prague	41,282	1,947	5,758	0
10. Siena	64,631	3,220	9,577	0
11. Swansea	44,354	2,105	6,223	0
Totals:	568,481	26,027	78,162	9,000

B8. PREVIOUS PROPOSALS AND CONTRACTS

The present proposal is not based on a network already financed in the frame of the FP4 Training and Mobility of Researchers, FP5 Improving Human Potential or FP6 Human Resources and Mobility programmes. Some of the proposed participants (a small proportion of those from less than half of the proposed nodes) were involved in the FP4 Training and Mobility of Researchers Network COLORET (contract number CHRXCT930415, 1993–96). Of the ten research objectives of the current proposal, two (objectives 2 and 4.1) concern research topics touched on in the earlier project.

There is no other known source of community support currently provided or expected to be provided for training and transfer of knowledge within the same or similar fields. However, it should be noted that two of the nodes in the proposed network, Leeds and Munich, have connections to Marie Curie Host Fellowships for Early Stage Research Training (EST) proposal "Mathematical Logic and Applications", recently agreed for funding, and coordinated by Prof. H.D. Macpherson from the University of Leeds. The relationship of this relatively small-scale project to the proposed network is expected to be entirely complementary, the funding being used to fund a small number of PhD students from the whole of logic, some of these being hosted at a non-CiE institution.

B9. OTHER ISSUES

A. There are no ethical or safety issues associated with the subject of the proposal.

Does the research in this proposal raise sensitive ethical questions related to:	**YES**	**NO**
Human beings		NO
Human biological samples		NO
Personal data (whether identified by samples or not)		NO
Genetic information		NO
Animals		NO

B. We confirm that the research presented in this proposal does not involve any of the following:

- Research activity aimed at human cloning for reproductive purposes;
- Research activity intended to modify the genetic heritage of human beings which could make such changes heritable;
- Research activity intended to create human embryos solely for the purpose of research or for the purpose of stem cell procurement, including by means of somatic cell nuclear transfer;
- Research involving the use of human embryos or embryonic stem cells.

ENDPAGE

HUMAN RESOURCES AND MOBILITY (HRM) ACTIVITIES

MARIE CURIE ACTIONS

Research Training Networks (RTNs)

PART B

CiE