STARTPAGE

HUMAN RESOURCES AND MOBILITY (HRM) ACTIVITY

MARIE CURIE ACTIONS
Research Training Networks (RTNs)

PART B

CALCULEMUS-II

Systems for Computer-Supported Mathematical Knowledge Evolution

November 19, 2003

Project Acronym	CALCULEMUS-II
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Abstract The longterm goal of the CALCULEMUS interest group is to foster the all-embracing integration of symbolic reasoning into mathematical research, mathematics education, and formal methods in computer science. A new generation of mathematical software systems is currently under development that provides integrated computer-based support for most work tasks of a mathematician — including computation and reasoning as well as search in large mathematical data bases.

CALCULEMUS anticipates that in the long run these systems will change mathematical practice and that they will have a strong societal impact, not least in the sense that powerful infrastructure for mathematical research and education will become better accessible.

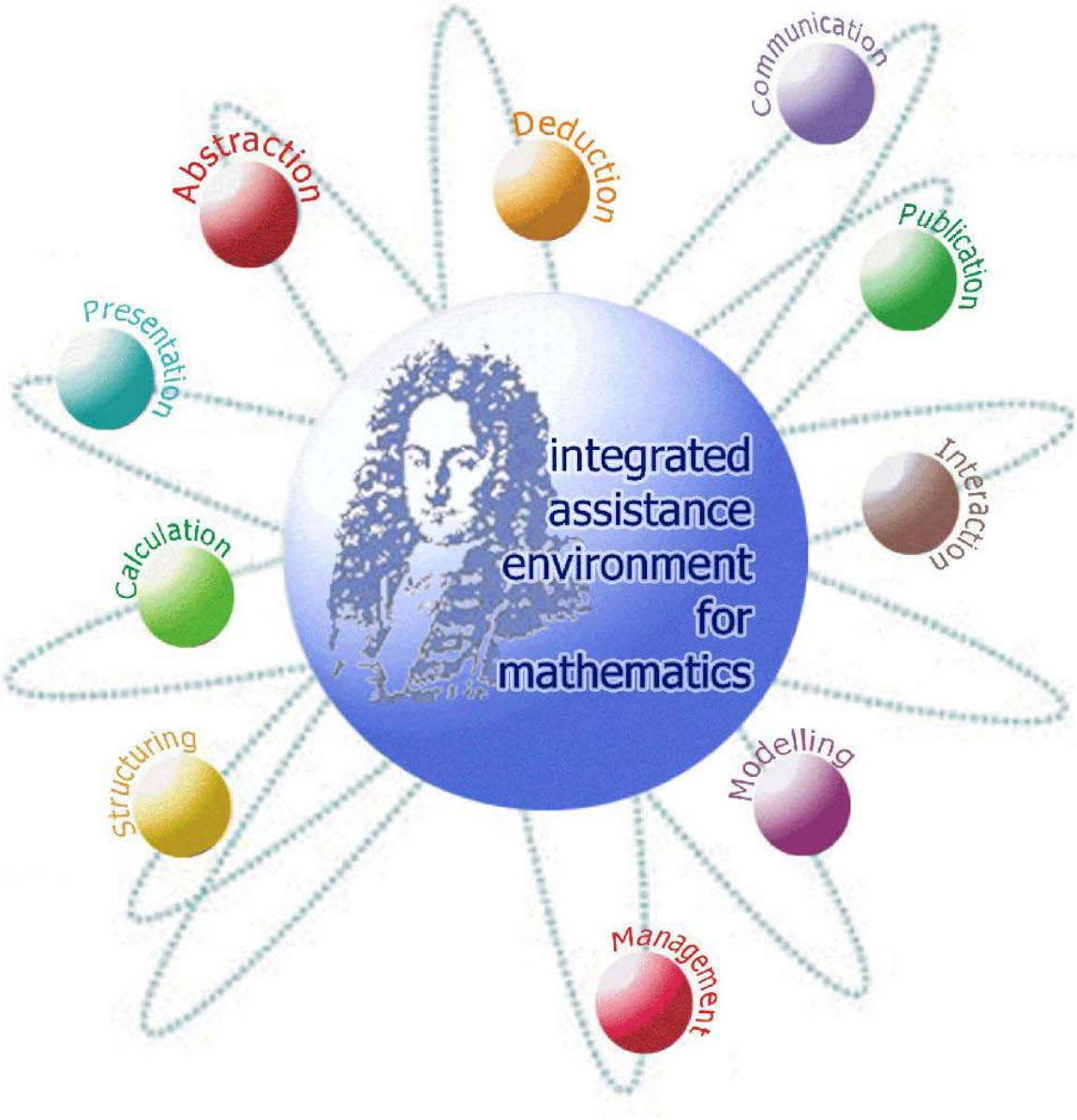
Mathematical reasoning systems have a strong impact on other fields, most notably in computer science for the verification of safety and security properties — and it is in these areas where a severe shortage of trained engineers exists.

CALCULEMUS-II will address this training and education problem via an integrated programme of distributed PhD supervision, post PhD training, industrial internships, international seminars, and lectures as well as an international CALCULEMUS Summer School.

The CALCULEMUS-II research depends on the expertise not only from the fields of computer algebra systems and deduction systems but also on fields such as artificial intelligence (in particular knowledge representation), knowledge bases, methodology of mathematics research and education, semantic web, and software engineering. The main sociological goal of CALCULEMUS-II therefore is to actively oppose the current fragmentation and separation of the relevant research areas of CALCULEMUS in academia and to build-up a fruitful training and career development environment for a new generation of young researchers that are interested to take on the CALCULEMUS challenge.

Part B

Scientific description of CALCULEMUS-II



B1 Scientific Quality of the Project

B1.1. CALCULEMUS-II Research Topic

Mathematics and its foundational field mathematical logic have seen several phases of lasting scientific development and change in its long history. While the last century provided the foundations and techniques for the mechanisation of symbolic reasoning, the vision of the CALCULEMUS interest group for the new millennium is to foster its all-embracing integration into mathematics research and education. To achieve this goal a new generation of mathematical software systems are currently under development that provide integrated computer-based support for most work tasks of a mathematician — including computation and reasoning and mathematical knowledge representation — as well as for formal methods in computer science.

CALCULEMUS anticipates that in the long run these systems will ultimately change mathematical practice and that they will have a strong societal impact, not least in the sense that powerful infrastructure for mathematical research and education will become better accessible. Computer supported mathematical reasoning tools and integrated assistance systems will have a strong impact in many theoretical fields such as safety and security verification of computer software and hardware, theoretical physics and chemistry and other related subjects. This new generation of interoperable mathematical assistance environments and mathematical software tools particularly contrasts the current situation characterized by partial and often non-interoperable solutions. Except for computer algebra systems these partial solutions have not yet reached sufficient acceptance and usage in mathematical practice.

The CALCULEMUS-II viewpoint is strongly bottom-up. Starting with existing techniques and tools of the partners for symbolic reasoning (deduction) and symbolic computation (computer algebra), CALCULEMUS-II will step by step improve their interoperability up to the realization of integrated systems. The envisaged systems will accommodate the evolutionary nature of mathematical research as they will support maintenance, retrieval and adjustment of mathematical developments (see also Figure 1). Research in CALCULEMUS-II is driven by practical needs of mathematical research and development and the related field of verification in computer science. CALCULEMUS-II will perform large use cases in selected fields of mathematics and computer science to control its research and will disseminate and distribute its results via conferences, seminars and industrial training.

CALCULEMUS-II will take up and improve the research pursued in the precursor research training network CALCULEMUS-I (see Section B8.1) addressing the integration of deduction systems (DS) and computer algebra systems (CAS) as a key issue to develop suitable mathematical assistance environments. CALCULEMUS-I revealed that the development of a single predominant theoretical approach for their integration is not possible and probably not even desirable. Hence the network had its emphasis on solutions for integration and inter-operation at the systems level. In CALCULEMUS-II we will build on these results and particularly focus on the theoretical and practical challenges raised in the context of interoperating mathematical specialist systems.

CALCULEMUS-II aims at *Computer-Supported Mathematical Knowledge Exploration* supporting an engineer working on mathematical problems in the improvement, the exploration, the distributed maintenance, the retrieval and the adjustment of mathematical theories. Most of the technical work involved in building up well-structured and re-usable mathematical knowledge should and can be automated. Interaction of the user should only be necessary — but then it is highly desirable — at crucial and "interesting" (eureka) steps of the evolutionary development process. The envisaged systems will support the full mathematical life-cycle allowing for a complementary top-down approach starting from existing pen and paper based mathematical practice to a computer supported solution.

The CALCULEMUS-II research depends on expertise not only from the fields of computer algebra and deduction systems but also from fields such as artificial intelligence (in particular knowledge representation), knowledge bases, methodology of mathematical research and education, semantic web, and software engineering. The main sociological goal of CALCULEMUS-II therefore is to actively oppose the current fragmentation and separation of the relevant research areas of CALCULEMUS in academia and to build-up a fruitful training and career development environment for a new generation of young researchers that are interested to take on the CALCULEMUS challenge.

The research and computer systems developed in CALCULEMUS-II will have an impact on society, anticipatedly first on the computer-based mathematics education sector and subsequently (with a new generation of mathematicians trained on these systems) also on mathematical research practice and on practical application of formal methods in computer science. This in particular is an area of severe shortage of trained personal and there are several "head hunting"-companies, which cannot fulfill the current demand in industry. Consequently a main goal of this network is to foster the immediate mutual knowledge exchange between CALCULEMUS-II research and these areas and to train as many qualified students, PhD and post PhD candidates as possible. The means to achieve this goal are (a) large applications and case studies in selected fields of mathematics, (b) early dissemination of results, and (c) secondments of young researchers in industry, e.g. at collaborating companies in the formal methods and e-learning sector.

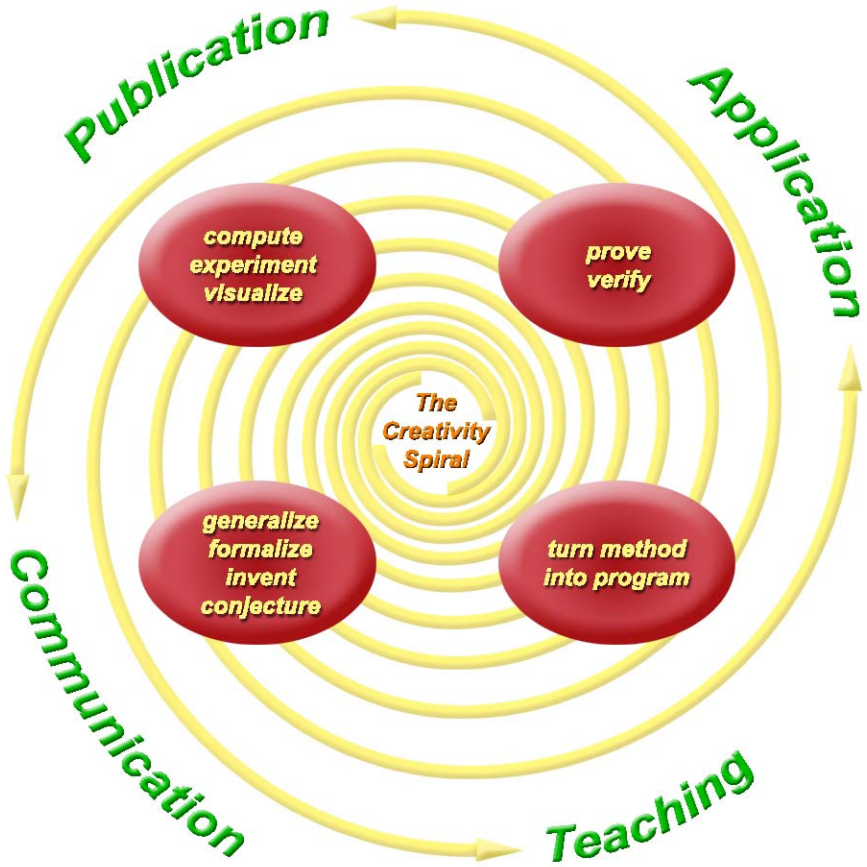


Figure 1: Mathematical Creativity Spiral; [Buchberger, 1995]

B1.2. Project Objectives

The overall **scientific project objective** of CALCULEMUS-II is to initiate and foster the systematic development of a new generation of mathematical assistance environments supporting the full mathematical life cycle as described in more detail in the objectives Sci 1 to Sci 6 below. The challenge in CALCULEMUS-II is to attack the scientific and technological gap between the targeted ideal mathematical assistance environments and the weaknesses and shortcomings of the current approaches. The CALCULEMUS-II methodology thereby is strongly bottom-up, starting from existing frameworks and systems (in particular those developed by the partners in CALCULEMUS-I) via their systematic extension and improved interoperability towards fully integrated solutions (see Figure 2 in Section B1.4).

The research and training in CALCULEMUS-II requires the combination of techniques and expertise from several areas. There is currently no single university (in Europe as well as worldwide) providing all the necessary expertise, background, and resources to ensure coverage of the heterogeneous spectrum of research aspects needed for CALCULEMUS-II. As a consequence, a high quality research training of prospective young researcher in this multidisciplinary area can currently only be achieved by joining forces in a research network.
The major **societal project objectives** of CALCULEMUS-II are:

Soc 1: The training of young researchers and the transfer of knowledge. CALCULEMUS research requires multidisciplinary background knowledge of the relevant fields which is currently hardly or only insufficiently taught at single universities. The training of students typically builds upon direct (one-to-one) student supervision as the introductory literature covering and structuring all relevant fields is not available. Even worse, interactive and automated theorem proving, i.e. two of the research fields addressed by the project, are currently rather diverting than consolidating in terms of pursued scientific approaches. This is one of the reasons why the scientific background of young researchers is usually those of the actual supervising group only. A very important function of the CALCULEMUS-II RTN is to attack and avoid the potential problems a very strong training focusing bears for our overall research goal: building complex and powerful mathematical assistance systems. Above all, this goal requires a good overview of the state-of-the-art in the heterogeneous research fields in order to combine and adapt the most promising individual approaches. Evidence for the impact and success of the CALCULEMUS training means is given by the numerous joint research results and joint applications of young researchers in the CALCULEMUS-I network (see section B8.1 and the CALCULEMUS-I Midterm Report documents [Ben03b, Ben03c, BH03]). Several PhD theses that do strongly benefit from and contribute to the joint CALCULEMUS initiative are in progress or have been already finished meanwhile (see Table 2 in Section B2.2).

Soc 2: The dissemination and exploitation of results in academia and industry. The systems, tools, and approaches developed in CALCULEMUS-II are targeting applications in (I) industry, (II) mathematics education, (III) mathematics research, and (IV) formal methods in computer science. A very important societal task therefore is to foster the immediate transition of CALCULEMUS results into these application directions. The formal and computer supported verification of safety and security properties is one of the areas where European research and developments are still dominant and this can have a dramatic impact on dependable and ultra-reliable software development - a niche where European software development companies could remain competitive against the low-cost countries such as India and nowadays mostly China. In order to achieve this goal we will have (Ia) industry secondmends of young researchers at collaborating companies, (Ib) a special workshop with industry involvement, (IIa) special training courses for high school teachers[1], and (IIb) university courses that actively employ our tools. A

[1]Such a course was already offered at the Autumn School in Pisa in CALCULEMUS-I and EU Comenius grants were available to support interested teachers. However, despite the networks advertisement effort and several strong expressions of interest for the event from German and European education ministries the number of concrete teacher registrations was unsatisfyingly low. In CALCULEMUS-II we will therefore change our strategy of encouraging teachers to participate in our network events and instead offer such courses at well frequented symposia and workshops for high school teachers.

lasting impact on mathematical research practice is not easily and quickly achievable; we want to initiate and foster it through education of a new generation of mathematicians with our systems (see IIb) but also by dissemination of our results in work task 4 where we propose to develop a selected field of mathematics completely with our tools.

Soc 3: The cross-fertilization and amalgamation of the involved research communities. The enlarged CALCULEMUS-II vision (far more than CALCULEMUS-I) requires the cooperation and (re-)union of different research communities. The CALCULEMUS community is the leading force in proposing such an integrated view and its research has had an increasingly stimulating effect on many related integrative research initiatives. A prominent example is the MKM[2] consortium which was initiated by researchers of the CALCULEMUS-I network[3]. MKM approaches the goal of revolutionizing computer-based mathematics in the new millennium by a complementary top-down approach starting from existing, mainly pen and paper based mathematical practice down to system support. (see [Buc01a, ABD03b]).
The detailed **scientific project objectives** are:

Sci 1: Interoperability and integration of systems for symbolic reasoning (deduction) and symbolic computation (computer algebra). The integration of deduction systems (DS) and computer algebra systems (CAS) has been addressed as a key issue for the development of better mathematical assistance environments in the precursor network CALCULEMUS-I. Although the developed integration techniques were successful in their own right, it became apparent that the increasing heterogeneity of approaches and tools at both sides of the spectrum between CASs and DSs require a more fine grained integration. However, designing a fully integrated system from scratch is not feasible given the manpower necessary for such a project (upto and exceeding 20 man years) and given the diffusion of expert knowledge. For that reason CALCULEMUS-II will focus on the theoretical and practical challenges raised in the context of interoperating mathematical specialist systems.

This work package will be important in order to achieve interoperability with the additional mathematical software tools addressed by research objective Sci 2 below. Moreover, although the results will be obtained for the domain of mathematics they should be transferable to the general problem of software interoperability and thus dealing with highly distributed knowledge. In detail we intend to address the following questions:

(I) **Interoperability:** What are the necessary prerequisites to achieve interoperability between computer algebra algorithms and deductive calculi?

(II) **Knowledge adaptivity:** How can systems and algorithms be implemented or extended such that they can dynamically adapt the behavior depending on the knowledge available from other components at a given time?

(III) **Knowledge certification:** What degree of explanation/certification is necessary to convince a software component/user of the appropriateness of a returned result (e.g. that something is a legitimate answer to a problem at hand)?

Sci 2: Frameworks and tools supporting the full mathematical life-cycle. While several individual support tools, such as computer algebra systems, nowadays play an important role in mathematics research and education it is nevertheless the case that the actual pragmatics of mathematics is still to be characterized as mainly pen and paper based. The reason is that there exists no system providing sufficiently integrated support for all the usual work phases of a mathematician from the initial conception and collection of ideas up to the final publication in a journal article. A successful integration of DSs and CASs (as proposed in Sci 1) will not automatically lead to mathematical assistance systems providing full integrated support, as this ultimate goal can only be achieved by a new and systematic build-up of mathematics from scratch using systematic, flexible, algorithmic tools such as characterized above. This is undoubtedly a long-term goal and the objective of CALCULEMUS-II is to initiate and strongly foster a respective development and to illustrate the benefits and its feasibility by large and novel case studies (see

[2] `http://monet.nag.co.uk/mkm/`
[3] The first MKM workshop was organized by Bruno Buchberger in 2001 at RISC Linz; see also [BC01].

Sci 4, Sci 5, and Sci 6). The concrete challenge of this objective is to systematically combine or extend the approaches and systems developed in Sci 1 by support tools that address evolution and modeling tasks as well as communication, maintenance, and publication aspects. Interoperability of the tools has to be guaranteed and a flexible interplay with distributed and shared mathematical knowledge bases is required.

Sci 3: Integration Infrastructure. Integrated mathematical assistance environments as proposed in Sci 2 require a powerful integration infrastructure (languages, protocols, semantic specifications, architectural schemata). CALCULEMUS-I contributed relevant infrastructure mainly for the integration of symbolic reasoning and symbolic computation. For CALCULEMUS-II this infrastructure support has to be opened up and improved w.r.t. additional tools as developed in Sci 2. We particularly want to investigate the suitability of approaches such as the (mathematical) semantic web and agent architectures. A major aim is to support open system architectures and intelligent modularization concepts in order to foster optimal exchange of tools and interaction also between different mathematical assistance environments and mathematical knowledge bases. A particular challenge is to provide respective communication means that cover the heterogeneous requirements in our enlarged setting. Another research aspect concerns the intelligent coordination of the heterogeneous tools: To which extent can intelligent coordination of tools be realized as part of the integration infrastructure and when is it better to guide coordination of tools directly by the reasoning engine of the mathematical assistance environments?

Sci 4: Theory exploration in selected fields of mathematics. The development of the approaches, systems, and tools in CALCULEMUS-II will be guided, in parallel, by large case studies. While in CALCULEMUS-I individual and smaller (nevertheless challenging) case studies have been selected to evaluate the scientific and technological progress, the CALCULEMUS-II consortium is convinced that now is the time for the complete development of selected fields of mathematics. An objective of CALCULEMUS-II therefore is the selection of suitable fields and its systematic development in a mathematical assistance environment provided by the network.

To make the formalization more thorough we restrict the scope to two or three fields of mathematics. A key issue in the subsequent development is to find a reasonable compromise between the degree of heterogeneity of mathematical representations and the enforcement of representational uniformity. An efficient development strategy needs also experiments for proper assessment of how large a database of formal knowledge should be to allow practical formalization of selected mathematical theory.

The work will be divided into two stages:

(I) First, we want to reach the research frontier in selected fields of mathematics by developing a sufficiently rich database of computer checked mathematics to enable the formalization of at least some recently published mathematical papers.

(II) Second, we want to develop a virtually complete database for the selected fields of mathematics that would allow formalization of almost all published papers belonging to a particular field.

The result will be used for further machine processing: data mining, translation to other formats, and translation to natural languages. The database will be used also for educational purposes. We expect that this experiment will force the evolution of mathematical assistance systems, the increase of writability and readability of formalized texts, and development of new tools related to mathematical services such as search engines.

Sci 5: Industrial applications in computer mathematics. CALCULEMUS-II aims at a bidirectional knowledge transfer between academia and industry in form of industrial-strength case studies. This will be supported by industrial internships of selected young researchers of CALCULEMUS-II at industrial collaborators (see Section B3.3) with an expected bidirectional fertilization. Today, a typical situation is that industry is often not fully aware of the tools that are already available and which can provide solutions to their problems. In CALCULEMUS-I, for instance, there were several cases where young researchers were able (during their industry internship) to sketch novel problem solutions to the hosting industry partners based on tools (not

necessarily only those that were directly developed in CALCULEMUS-I) that were previously unknown to them.

The contributions of CALCULEMUS-II are at least threefold: (i) experience in combination of different support tools for reasoning and computing, (ii) methods and tools for mathematical/formal training of engineers and researchers, (iii) knowledge and research experience on interdisciplinary problem solving, mixing of exact and numeric computation or the investigation and development of computer-aided verification tools (*hybrid formal checkers*) based on model-checking, which incorporate reasoning over mathematical theories of increasing complexity. Instances of hybrid checkers can, for instance, be *equivalence checkers*, *bounded model checkers*, and *inductive invariant checkers*.

Sci 6: Computer-based e-learning in mathematics. The systems proposed in CALCULEMUS-II will in the long run have a lasting impact on the pragmatics of mathematics and its perception in society. To foster their usage in mathematics it is necessary to educate the next generation of mathematicians and engineers with our tools and our mathematical assistance environments. One project objective therefore is to integrate our mathematical assistance tools with the emerging computer-based e-learning systems and to employ them in mathematics and engineering education. Computer-based e-learning systems are increasingly used in university and high school education and combining them in the domain of mathematics with our mathematical assistance systems is thus a consequent step.

By the combined techniques for mathematical knowledge management (e.g., automated theorem proving, computer algebra, semantic web, artificial intelligence, and digitization tools) and by the joint effort of the strongest research groups in Europe and other continents, a new, much stronger and practical, version of "Bourbakism" will be created, the "Bourbakism of 21st century":

(I) it will put "computer and algorithms" into the center of mathematical research,

(II) it will be a frame for both algorithmic and non-algorithmic mathematics,

(III) it will enable mathematicians to build up various "views" of mathematics (i.e. various essentially different hierarchical roadmaps for building up mathematics) in short time (a couple of months) according to the personal preferences of research groups and to the various needs of mathematical applications in the frontiers of natural science as, for example, information technology, life sciences and nano-technology,

(IV) it will generate the various views with say 99% of automation and 1% of high-level human interaction and inspiration,

(V) it will build up these views with a high degree of correctness guarantee.

B1.3. Scientific Originality

The vision of computer-based mathematical assistance systems providing integrated support for all work phases of a mathematician has fascinated researchers in artificial intelligence, particularly the deduction systems area, and in mathematics for a long time. The dream of mechanizing mathematical (and general) reasoning dates back to Gottfried Wilhelm Leibniz in the 18th century. He conceived a *lingua characteristica* and a *calculus ratiocinator*, i.e., a most general framework to mechanize human reasoning, which was not least inspired by his own contributions to the mechanisation of simple arithmetical operations. In the beginning of the 20th century modern mathematical logic was born and important milestones were reached in the formalization of mathematics are Hilbert's program and the 20th century Bourbakism.

After the enthusiasm of the 50s and the 60s the deduction systems area increasingly fragmented into several subareas which all developed their specific approaches and systems similar to the Artificial Intelligence area in general. Today many of these subareas even have separate conferences. As a consequence the ambitious goal of integrated mathematical assistance environments was very weakly represented at these conferences and in the deduction systems community until the end of the 90s. It is only very recently that this trend is reversed, with the CALCULEMUS community being one of the driving forces of this movement.

The development of integrated mathematical assistance environments is a challenge that demands joining resources not only with respect to system and tool development but in particular with respect to research expertise and the training of young researchers. A join of resources at the system development level is pursued by most of the groups that have concentrated on the development of proof assistants for the last decade(s). Among others, they developed the systems NUPRL [ACE+00], COQ [Coq03], HOL [GM93], PVS [ORR+96],MIZAR [RT03], Isabelle [Pau94, NPW02], THEOREMA [Buc01b, Buc01c] and ΩMEGA [SBB+02, SBF+03]. Many of these systems are developed in cooperation between different universities and research institutes. An important move fostered by the CALCULEMUS community is to support cooperation and tool exchange also across these system boundaries and in addition to support a better joining of research expertise and training measures. In CALCULEMUS-I the focus thereby was on the integration of deduction systems and computer algebra systems, which is a key issue for the development of better mathematical assistance environments. In CALCULEMUS-II this scope will be widened in order to address further relevant research aspects.

Joining resources at the tool and component level is the aim of the very recent QPQ[4] initiative at Stanford University, USA, which proposes to build up a repository of deductive software tools. As it has been proposed in the CALCULEMUS-I network presentation at the first QPQ workshop in July 2003 (Miami, USA), a cooperation with the QPQ project could focus on the interoperability aspects (which are not addressed in QPQ but are at the heart of CALCULEMUS research) and, in the long run, semantical capability descriptions could be envisaged for the systems registering to QPQ.

In the following paragraphs we discuss the scientific originality of the project from different angles contrasting the deduction systems perspective above.

Computer Algebra Systems Perspective. Industrial research departments use CASs at the early stages of applications design, i.e. at a time when an erroneous answer can have (at least financial) severe consequences. But the computation can be very involved and time/memory consuming. Some computer algebra results can be obtained only by very intricate programs, which for example, drive and mix together mathematical operations and memory management. Thus, proving the correctness of such algorithms can be considered as mandatory. Often, this is just impossible, due to a lack of a clear semantics and of the substantial use of memory management tricks. A true answer to this problem needs several steps: The first one is to strengthen mathematical assistance environments, in order to describe algorithm specifications and to prove their mathematical properties. The second one is to extend such environments with semantical capabilities in order to trust program design. Then, efficiency can be increased by choice of data representation, program transformations, whose correctness can be asserted within the proof assistant. The challenge of this approach is to obtain efficiency of programs, while at the same time

[4] www.qpq.org

implementing complex algorithms in a completely trustworthy way. Some of the network partners (the FOC group at UPMC for example) have already some experience in this subject.

Formal Methods Perspective. Safety Standards for the development and assurance of high integrity industrial computer systems (process control, nuclear protection, fly-by-wire airplane systems, car engine management, etc.) require formal methods, that is, rigourous methods with a strong mathematical basis. Despite the fact that such methods have been available for at least a decade, they are still not widely used in industry, due to a lack of appropriate development tools and also to the lack of formal training of engineers. Contributions of CALCULEMUS-II are at least threefold: experience in the combination of different support tools for reasoning and computing, methods and tools for mathematical/formal training of engineers and researchers, knowledge and research experience on certain not yet fully developed subjects, for example mixing of exact and numeric computations. Some major challenge for CALCULEMUS-II is to provide improved support for the analysis of exact versus numeric computations for the verification of hardware circuits and hybrid systems. In order to deal with the growing complexity of these systems, verification tools are required to perform logical reasoning combined with mathematical reasoning over different kinds of mathematical theories.

A rather new but very promising application area is molecular biology. The introduction of formal methods for modeling biological systems allows to describe the systems in terms of languages other than numerical equations. For example, logical relations to describe the interactions between genes, by relying on object-oriented approaches, *etc.* The kind of analysis deeply depends on the particular method adopted and this permits, for example, to choose between different kinds of analyses for addressing laboratory experiments.

Mathematical Research Practice Perspective. Recently several research initiatives approach the goal of changing mathematical research practice from a different angle. Whereas CALCULEMUS-II is working bottom-up from existing tools and approaches some of these initiatives are starting from existing, mainly pen and paper based mathematical practice and try to gradually increase the amount of computer-based support. Prominent examples are EULER[5], MKMNet[6], MKM North America[7], Trial Solution[8], LIMES[9], and ERAM[10]. These complementary research projects, in particular MKMNet and MKM North America, provide opportunities for fruitful cooperation.

[5] http://www.emis.de/projects/EULER/
[6] http://monet.nag.co.uk/mkm/index.html
[7] http://imps.mcmaster.ca/na-mkm-2004/
[8] http://www.trial-solution.de/
[9] http://www.emis.de/projects/LIMES/description.html
[10] http://www.emis.de/projects/JFM/

B1.4. Research Method

CALCULEMUS-I has built up a research methodology and research structures that will be exploited and refined by novel impacts in CALCULEMUS-II. Our research methodology distinguishes between a horizontal and a vertical dimension. The challenge at the horizontal level is to overcome the technological fragmentation of the field in various approaches, systems, and tools. On the vertical axis the challenge is to support the transition from prototype developments and case studies to industrial strength systems and applications.

The overall technological approach on the horizontal level is bottom-up (see Figure 2) from existing tools towards integrated mathematical assistance environments. Thereby the careful selection and adaptation of individual tools as well as the systematic improvement of the interoperability of these tools is at the heart of CALCULEMUS-II research. This bottom-up strategy has been developed and successfully pursued in CALCULEMUS-I. It particularly supports early case studies, the monitoring of progress at a concrete level, and early industry involvement. Therefore the bottom-up approach is also very beneficial for the placement of CALCULEMUS PhD projects.

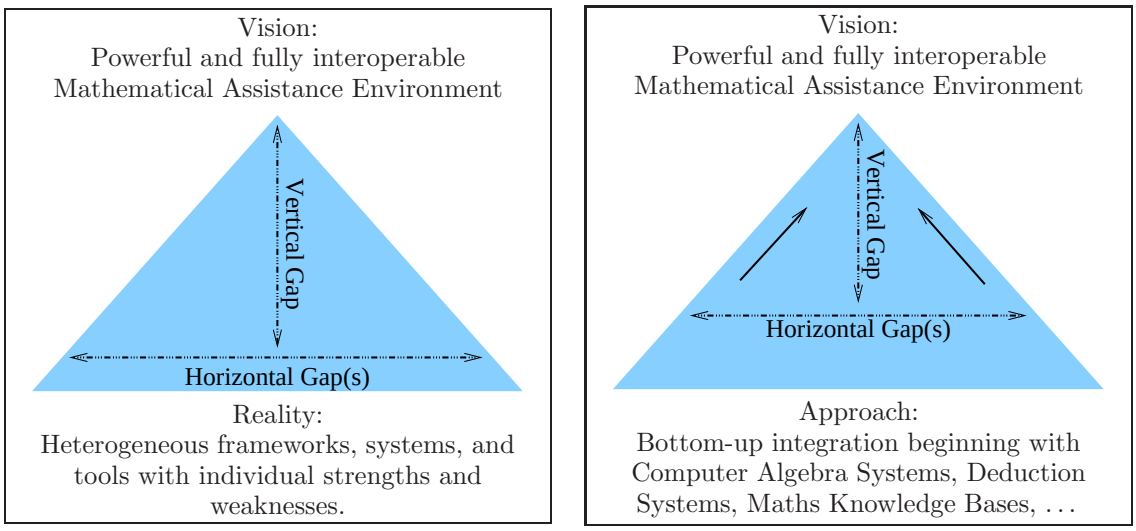


Figure 2: Methodological approach of CALCULEMUS-II

An important issue for each tool integration is whether an 'as-is-integration' is reasonable or whether a previous adaptation or even a complete redesign and reimplementation is required. Research on tool cooperation and interactively controlled tool coordination in the project will subsequently be supplemented by research on automated tool coordination.

Based on the creativity spiral (see Figure 1) as a model for the process of (formal) theory exploration, the network (RISC, Buchberger) has recently expanded this model towards the novel "four threads model" of formal theory exploration, see [Buc03b]. In this model, theory exploration is carried out within the following parallel threads of activity:

- The "theory thread" (object level): Stepwise build-up of the axioms, definitions, problems, propositions, and algorithms of the theory (following the creativity spiral).
- The "reasoning thread" (object level): Formal verification / refutation of the propositions and algorithms proposed in the theory thread.
- The "automated reasoners thread" (meta-level): Invention and implementation of automated reasoners that can support the activity in the reasoning thread.
- The "ideas thread": Presentation of fundamental ideas for generating reasonable and interesting axioms, definitions, problems, propositions, and algorithms in the theory thread. This presentation is given by axiom schemes, definition schemes, problem schemes, proposition schemes, and algorithms schemes, respectively.

Particular emphasis is given, in the four threads model, to the interplay between the object level and the meta level, notably to the possibility of expanding the "automated reasoners thread" while working on the "reasoning thread" and to expand the "ideas thread" by feeding the experience gained in the "theory thread" back to the "ideas thread". It is natural to consider these transitions from the object to the meta-level in the frame of presenting abstract schemes as categories and functors that map domains in categories to other domains in other categories. This gives also a natural link to the study of higher-order solving as pursued in the project [Ben03a].

The four threads model can serve both as a roadmap for comparing the capabilities of the various existing systems that aim at supporting mathematical theory exploration and will also serve as the fundamental research plan for the future expansion of systems of the CALCULEMUS-II network.

The expansion of our mathematical assistance systems will be driven and guided by large case studies; see project objective Sci 4. Within the last few years it has already been shown — by CALCULEMUS-I and other projects — that practical formalization of quite advanced mathematics is possible (e.g., in the proof assistants MIZAR, COQ, HOL, NUPRL, Isabelle). Now, the question arises whether complete formalization of at least a small field of mathematics is feasible. It is hard to overestimate all the advantages of having such a corpus of formal texts which thoroughly explores a selected field of mathematics.

The move in CALCULEMUS-II from individual, small size case studies towards a covering development of formalized mathematics in selected fields is an important example for our research strategy with respect to the vertical dimension mentioned in the beginning of this subsection.

We briefly mention some further relevant aspects:

Work-plan. The work-plan (see Section B1.5.) has been carefully designed so that each task requires techniques and expertise coming from different areas. Task forces comprising teams with complementary scientific specialty have been set up to tackle the tasks.

Networking. Effective management will be enacted by the coordinator and the Executive Committee to ensure a good coordination of the activities. Network workshops, task-force meetings, and supervision meetings will be held on a regular basis. At the network workshops the partners will assess the progress of the research activity and modify — when appropriate — the work-plan and the research effort devoted to the tasks.

Training. Visiting researchers will carry out the research activity by usually visiting at least two teams. The Training Committee will develop a general structure of the network's Career Development Plan scheme and instantiate it for each young researcher together with the hosting node. The Training Committee will also monitor the training progress. A training camp will be organized at the very beginning and the end of the network.

Industrial Exploitation. Selected young researchers of the network will go through in-house internship in one of several associated industrial companies. This will *(i)* ensure a contact of the trainees to actual applications, as well as *(ii)* establish a path of knowledge transfer from the network to industry (vertical axis).

With its bottom-up approach in integrating tools developed in the heterogenous landscape of approaches and systems the CALCULEMUS community has become a driving force for the bundling of resources across boundaries. Relevant scientific, technological and very important sociological structures have been built up in CALCULEMUS-I from which CALCULEMUS-II will profit from the very beginning. Thirteen leading European universities and research institutes in the area are forming the nodes of the network and their existing links to further academic and industrial collaborators are exploited in order to further broaden the partnership involvement and the impact of the network.

B1.5. Work Plan

The CALCULEMUS-II network consists of 13 research teams as listed in Table 1. In groups they will jointly work on the tasks described below. Thereby they will selectively collaborate with further academic and industrial partners as further explained in Section B3.3.

List of Tasks

Task 1: Interoperability and integration of systems for symbolic reasoning (deduction) and symbolic computation (computer algebra).
Task Leader: UBIR; Partners: USAAR, ITC-IRST/DIT, UNIJ, RISC, UKA, UBATH, UGE, TUE, IUB, UPMC

1.1 Support for interoperability and integration of knowledge exchange between different computer algebra and deduction systems.

1.2 Dynamic knowledge adaptation.

1.3 Automatic documentation, explanation, and certification of results.

Task 2: Frameworks and tools supporting the full mathematical life-cycle.
Task Leader: RISC; Partners: USAAR, UED, UWB, IUB, UNIJ

2.1 Models for the mathematical life-cycles.

2.2 Implementation of a few selected models.

2.3 Interaction between implementations of different models.

2.4 Major case studies of theory development in the various models.

Task 3: Integration Infrastructure.
Task Leader: IUB; Partners: USAAR, UED, ITC-IRST/DIT, UGE, UKA, TUE

3.1 Support for communication means (languages, protocols) to support the exchange of tools and interaction between mathematical assistance environments.

3.2 Development of open system architectures to support heterogeneous mathematical assistance environments.

Task 4: Theory exploration in selected fields of mathematics.
Task Leader: UWB; Partners: RISC, USAAR, UNIJ, UKA, UBIR, TUE, UPMC, UED

4.1 Selection of mathematical fields for subsequent formalization.

4.2 Preparation of a preliminary database to formalize selected exemplary articles in renowned mathematical journals.

4.3 Identification of additional facts to be included in accordance with previously collected results.

4.4 Preparation of virtually complete databases for selected fields of mathematics.

Task 5: Industrial applications in computer mathematics.
Task Leader: ITC-IRST/DIT; Partners: UBATH, UKA, UGE, UBIR, UPMC

5.1 Selection of a set of industrial-strength case studies

5.2 Application of the mathematical assistance environment in selected fields of mathematics and computer science

No.	Acronym	Network Node		Node Speciality	Tasks
1	USAAR (Coordinator)	Dr. Christoph Benzmüller Prof. Jörg Siekmann Saarland University Dr. Dieter Hutter DFKI GmbH Saarbrücken	DE	Deduction Systems Formal Methods	1,2,3,4,6,7
2	UED	Prof. Alan Bundy The University of Edinburgh	UK	Deduction Systems	2,3,4,7
3	UKA	Prof. Jacques Calmet Karlsruhe University	DE	Computer Algebra	1,3,4,5,7
4	RISC	Prof. Bruno Buchberger RISC-Linz	AT	Computer Algebra Deduction Systems	1,**2**,4,6,7
5	TUE	Prof. Arjeh Cohen Eindhoven University of Technology	NL	Computer Algebra E-Learning	1,3,4,**6**,7
6	UNIJ	Dr. Herman Geuvers University of Nijmegen	NL	Deduction Systems	1,2,4,7
7	ITC-IRST/DIT	Dr. Alessandro Cimatti Dr. Marco Bozzano ITC-IRST, Trento Dr. Roberto Sebastiani DIT, University of Trento	IT	Deduction Systems Formal Methods	1,3,**5**,7
8	UWB	Dr. Andrzej Trybulec University of Bialystok	PL	Mathematical Knowledge Bases Deduction Systems	2,**4**,6,7
9	UGE	Dr. Alessandro Armando Università degli Studi di Genova	IT	Deduction Systems	1,3,5,7
10	UBIR	Dr. Volker Sorge The University of Birmingham	UK	Deduction Systems	**1**,4,5,6,7
11	UBATH	Prof. James Davenport University of Bath	UK	Computer Algebra	1,5,6,7
12	UPMC	Prof. Thérèse Hardin Université Pierre et Marie Curie	FR	Deduction Systems Computer Algebra	1,4,5,6,7
13	IUB	Prof. Michael Kohlhase International University Bremen	DE	Mathematical Knowledge Management	1,2,**3**,6,7

Table 1: The research teams of the CALCULEMUS-II network.

Task 6: Computer-based e-learning in mathematics.
Task Leader: TUE; Partners: UWB, UBATH, USAAR, IUB, RISC, UPMC, UBIR

6.1 Integration of mathematical assistance environments in e-learning systems.

6.2 Application of mathematical assistance environments in mathematics education.

Task 7: Special training measures.
Task Leader: Training Committee; Partners: all

7.1 Organization of a CALCULEMUS School on mathematical assistance environments within the first 6 months of the project (to attract researchers, users etc.).

7.2 Organization of a second CALCULEMUS School on mathematical assistance environments within the last 6 months of the project (to disseminate results of CALCULEMUS-II).

7.3 Organization of Network Meetings and Midterm Review Meetings.

7.4 Organization of other workshops, tutorials, and training events with industry or teacher involvement.

Milestones and Deliverables

Milestone I [6]
Task 4: Mathematical fields are determined.
Task 7: First CALCULEMUS School has been organized; Lecture material and school report.

Milestone II [12]
All Tasks: Progress report.
Task 2: Complete descriptions of the life-cycle models of the individual task partners and specification of the necessary software tools based on the analysis of major case studies.
Task 6: An outline of courses using a mathematical assistance system..

Milestone III [24]
All Tasks: Mid-term report
Task 1: Prototypical Implementation of Task 1.1.
Task 2: Systematic comparison of the different models, identification of common features and distinctive features and specification of possible interfaces between the models.
Task 4: Demonstration of the database in 4.2.
Task 5: Industrial training I completed.
Task 6: A model for employing state of the art software for the e-learning environment.
Task 7: Material on special training measures.

Milestone IV [30]
Task 4: Identified facts of 4.3.
Task 2: Implementation of the various models by the individual task partners with joint work on the common tools.

Milestone V [36]
All Tasks: Progress report
Task 2: Implementation of the specified interfaces with the objective of realizing a globally accessible web-based theory exploration platform.
Task 3: Demonstrator of a web-services based interaction framework for mathematical assistant systems.

Milestone VI [48]
All Tasks: Final report
Task 1: Prototypical implementation of task 1.2 and 1.3.
Task 2: Realization of a few selected common case studies of theory exploration in all models

and of additional specific case studies of the task partners.
Task 3: Demonstration of an integration framework for mathematical assistant systems based on incremental communication and negotiation of joint domain representation.
Task 4: Demonstration of the virtually complete database in 4.4.
Task 5: Industrial training II completed.
Task 6: A pilot of an e-learning environment built on the foundations laid by the previous milestones of this task.
Task 7: Second CALCULEMUS School has been organized; lecture course material and school report. Material on further training measures.

The network will collaborate in the work and training programme with further academic and industrial partners as described in Section B3.3.

B2 Training and/or Transfer of Knowledge Activities

B2.1. Content and Quality of the Training and Transfer of Knowledge Programme

Content of Training

Training and transfer of knowledge in the network is organized along a horizontal and a vertical axis. While the horizontal axis enumerates the various domains of research activities, the vertical axis reflects the various stages in the transfer from basic research to industrial applications.

The Horizontal Training Axis. Concerning the horizontal axis CALCULEMUS provides an infrastructure to train young researchers in heterogeneous approaches, various systems, and tools pursued and developed at the individual partner sides. The goal thereby is to build up a new generation of researchers that will have a much broader scientific and technological background as it would be possible at an individual site only. Scientists trained in CALCULEMUS are expected to foster and guarantee a lasting impact of the network's vision to the involved and highly fragmented research fields (like, for instance, deduction systems) and to promote the proposed research and systems in industry. It will help to overcome the current situation in which PhD students often reach only a very deep specialization highly depending on their particular research environment. This positive impact of CALCULEMUS-I is already visible, for instance, in the deduction community and is steadily strengthened by measures such as joining the CALCULEMUS Symposia with the International Joint Conference of Automated Reasoning (IJCAR) in 2004, which will help to amplify the dissemination of results and visibility of CALCULEMUS.

The training is divided into three different application areas as addressed in Tasks 4, 5, and 6. The training programme of an early-stage researcher will typically cover only one of these application areas while experienced researchers are expected to develop deeper experience in multiple areas.

The joint work on the *Certification of solutions to permutation group problems* [CMPS03] by Arjeh Cohen (TUE), Scott Murray (TUE), Martin Pollet (USAAR), and Volker Sorge (UBIR) is a good and illustrating example on how the CALCULEMUS-I network currently exploits its complementarity along the horizontal training axis. Being a result of two early-stage researchers trained by USAAR, UBIR and TUE, USAAR provided the expertise in proof planning and the use of the ΩMEGA system, UBIR contributed the expertise in integrating computer algebra systems into proof planning, and UWB accounted for the expert knowledge on the mathematical domain and on the computer algebra side. None of the involved partners exhibited sufficient experience at its side to pursue this research on its own.

The main instruments for the training at the horizontal level are:

- Secondments of young researchers at individual nodes of the network and at industrial and academic collaborators; this includes local training measures at the nodes such as lectures, tutorials, seminars, group meetings, and other activities.
- CALCULEMUS schools organized at the very beginning and at the end of the funding period. (To get an impression on the outline of these schools we refer to material of the predecessor Autumn School in Pisa, 2002 which is available at (`www.eurice.de/calculemus/autumn-school/`) and [BE02a, BE02b, BE02c, ZB02])
- CALCULEMUS Symposia organized by the CALCULEMUS interest group.
- Network meetings like they were organized in CALCULEMUS-I in conjunction with other events in Siena (Italy) 2001, Genova (Italy) 2002, Marseilles (France) 2002, Pisa (Italy) 2002, Saarbrücken (Germany) 2003, and in Rome (Italy) 2003.
- Tutorials and workshops organized by subsets of the consortium and events organized by collaborating research initiatives such as listed in Table 8.

The Vertical Training Axis On the vertical axis the training is concerned with the systematic personal development of young researchers towards their intended career goals. The two main options for young researchers are to aim either at a career in industry or at a career in academia. Specialization to foundations, system and tool development, integration aspects, applications are further options on an orthogonal scale. Depending on the options different training instruments are appropriate. The vertical training axis also addresses the training of complementary skills.

The training instruments on the vertical axis include:

- Industry internships and industrial-strength case studies.
- Active involvement of experienced young researchers in the networks training events, e.g. by giving courses and tutorials or as technical organizers.
- Involvement of experienced young researchers in research management, for instance, as CALCULEMUS-II node manager.
- Involvement of young researchers at the local nodes in network independent management tasks or technical challenges.
- Courses at the CALCULEMUS schools addressing complementary skills (in addition, of course, to the scientific courses and tutorials); exemplary course proposals are:
  - European Project Office of Saarland University on *International Project Management*
  - Alan Bundy on *Good Research Practice at Pre- and Postdoc level.*
  - Bruno Buchberger on *Thinking, Speaking, Writing.*
  - Jörg Siekmann on *Research Management Skills.*
  - Andrew Adams on *Intellectual Property Rights.*
  - Woman's affairs office of Saarland University (Bärbel Miemietz) on *Management of Gender Issues (with discussion).*

In the CALCULEMUS-I network, for instance, the training of Corrado Giromini (Italy) from UGE illustrates the various stages on the vertical axis. At UGE he started his career in the area of integrating heterogeneous systems, broadened his background at USAAR and worked on techniques and case studies for the verification of hybrid systems at the DFKI. Next he was further trained at UED pursuing an industrial case study at Motorola, i.e., one of the CALCULEMUS-I industry partners. Afterwards he returned to USAAR to be trained as technical organizer of the CALCULEMUS Midterm Review meeting. Finally, Mr. Giromini was hired by industry.

Quality of the Training

As illustrated in Section B4.1, CALCULEMUS-II will establish a Training Committee which will guide and monitor all training efforts of the network. In order to achieve a uniform high standard in training, the Training Committee will issue binding guidelines for training activities during the initial phase of the project. During the project the individual network nodes will periodically report to the Training Committee on the training activities. Part of the Training Committee will be an ombudsperson who serves as a confidant for the trained researchers in case of conflicts with the accommodating node. To avoid institutional conflicts the ombudsperson should be neither the head nor the team manager of some node nor a coordinator. Part of the Training Committee will be also an equal opportunity commissioner to support and monitor an effective gender management (see section B6 for a detailed description of gender issues).

Individual Training. Researchers intending to make use of the training efforts of the network will contact the Training Committee. Together they will specify a global *Career Development Plan* identifying the areas of interest and the potential nodes to be visited based on the particular training needs according to the chosen options on the horizontal and vertical training axes.

Recruited researchers of the network will have an individual main advisor (who is usually the head of a node or a senior researcher). In cooperation, the researcher and his advisor will refine

the initial Career Development Plan with respect to the local training at the node. The advisor will monitor the progress of the young researcher, adapt the instruments if needed and report (if necessary) to the Training Committee.

The Training Committee will investigate the idea of an official CALCULEMUS-II PhD curriculum. The ideas include:

- Entry prerequisite: a master or equivalent degree (e.g. Diploma in Germany and Austria) in mathematics or computer science and a kind of a TOEFL (English test); will be checked by Training Committee.
- A PhD candidate is assigned to a main node as her permanent PhD study site and a main advisor; the candidate is assigned to a second advisor from some other node.
- The typical length of a PhD study is 3 to 4 years.
- The candidate spends, typically, approx. 60% of the entire period at her main node, approx. 20% at the node of the second advisor and 20% at other CALCULEMUS nodes.
- The individual Career Development Plan including the appropriate training instruments on both axes are defined by the two advisors, the Training Committee and the PhD candidate.
- The first year should also be devoted to getting acquainted with the research areas at the chosen node and the research areas in all CALCULEMUS nodes. (A booklet describing the research areas of all CALCULEMUS nodes would be necessary for this.) After the first year, the candidate should choose a concrete subject for the PhD thesis and a first and second advisor in agreement with the faculty at the node(s).
- Evaluation of the PhD theses should be standardized throughout the CALCULEMUS network.

Between UGE, UED, and the academic collaborator AC4 (see Section B3.3) there exists already an official joint PhD curriculum.

Global Training. There is a natural limit given by the budget restriction (65% for young researcher employment) for the possible training measures at the global network level. Because of the very good success of these measures, especially the CALCULEMUS Autumn School, in CALCULEMUS-I and the high need for such measures, we are planning to exploit the available networking money to a large extent for the organization of such events.

The major global Training measures include:

- (in months 1-6) CALCULEMUS School
- (approx. month 12) Network Meeting
- (approx. month 24) Midterm Review + Network Meeting
- (approx. month 36) Network Meeting
- (in month 42-48) CALCULEMUS School

The network also wants to exploit the CALCULEMUS symposia as a training measure and will organize further smaller workshops and tutorials (some of these will have industry or teacher involvement).

Gender aspects in the recruitment of young researchers will be addressed as outlined in Section B6.

A complete overview of the successful training measures of CALCULEMUS-I until the networks midterm review is given in [BH03][11]. These measures will be further improved in CALCULEMUS-II as illustrated above.

[11] http://www.ags.uni-sb.de/~chris/papers/MTR-report-short.pdf

B2.2. Impact of the Training and/or Transfer of Knowledge Programme

Industry and academia have a high and increasing need of scientist and engineers with the skills of the CALCULEMUS-II network. This holds for all of the three prospectus application directions of the systems developed and trained in the network; see the Tasks 4, 5, and 6. Industry has a high interest in the strongly expanding formal methods and despite the global economical crisis the shortage of highly qualified engineers in this area remained a problem over the last years (see also the accompanying letters of our industrial collaborators). Bio-informatics is a fast growing area and given the anticipated applicability and relevance of our research in this area new job opportunities for our researchers can be anticipated. In fact, the former CALCULEMUS-I young researcher and proposed CALCULEMUS-II academic collaborator Simon Colton meanwhile started an academic career in the Bio-informatics area. The e-learning sector is expected to have a high impact in the years ahead, both in an industrial and academic context. The network's contribution to mathematics research, e.g. the complete formal development of a selected field of mathematics with our systems, are of fundamental nature and are going to prepare a lasting change of mathematical research practice; some international journals are already discussing the idea of selective formal verification of submitted mathematical texts.

Within this broad spectrum of application directions CALCULEMUS-II early-stage researchers will typically concentrate on only one direction in their training. Together with their main supervisor and the networks Training Committee they will then determine their particular training focus and instantiate the networks frame Career Develop Plan, which includes secondments at well chosen partners or collaborators of the network – in CALCULEMUS-I many examples exist where up to 3-4 partners were directly involved in the training of single young researchers; see Table 2.

The training of experienced researchers — usually they are aiming at an academic career — at different sites of the network addresses the following aspects: (i) they gain a broader picture of the networks research with respect to all three application directions, (ii) they strengthen their focus in one direction, (iii) they improve their overall academic and research management skills, (vi) they strongly contribute to the dissemination of results and the international recognition of the network, e.g. by contributions to international journals and conferences, (v) they contribute to the knowledge transfer within the network by giving local courses at the single host nodes. An experienced researcher usually himself brings in a very specific network relevant expertise that is not optimally represented so far. This ensures a bidirectional enhancement of expertise between the network and the recruited experienced researcher. A good example is the CALCULEMUS-I recruitment of Stephan Schulz, the developer of the theorem prover E, which is a world leading system for first-order logic with equality. In his stay at UED, RISC, and ITC-IRST/DIT, he added to the network expertise in traditional first-order theorem proving and he was himself trained by the broader perspective the network takes on the deduction area in which systems such as E obtain the role of important tools employed within mathematical assistance environments.

The networks emphasis is on early-stage training because of the strong industrial and academic need of a new generation of scientist trained in CALCULEMUS-II topics. We are therefore proposing a 70% rate of early-stage researchers.

Through this new generation of researchers trained for the growing European (and international) job market in the application areas specified above the network will foster a quicker transition of basic research to industry. Direct transfer of knowledge is fostered by the selective industrial collaborations. At the academia side the network is the driving force in joining forces in the fragmented involved fields across Europe and the researchers of CALCULEMUS-I have already stimulated and initiated several further collaboration initiatives such as the before mentioned MKM community. The participating nations in the network gain from the enhanced research and training capacities and the very good networking that has been achieved; this particularly includes our partners and collaborators from less favored regions such as UWB, and the academic collaborators AC3 and AC5 (see Section B3.3).

Career prospects of the researchers in the network are very high. This holds for trained young researchers as well as for the scientific staff of the individual nodes, since they also strongly benefit from the enhanced networking possibilities guaranteed by the network. Career examples of CALCULEMUS-I young researchers are: Simon Colton is now lecturer at Imperial College, Silvio Ranise is scientist at INRIA Lorraine Nancy, Andrew Adams is lecturer in Reading. Examples

PhD Student	Nationality	Status	Training in CALCULEMUS-I at
Autexier, Serge	FR, DE	finished	USAAR, Autumn School
Aransay Azofra, Jesus M.	ES	ongoing	UKA, Autumn School
Colton, Simon	UK	finished	UED, UKA, USAAR, UBIR
Compagna, Luca	IT	ongoing	UGE, UED, (Industry in 2004)
Craciun Adrian	RO	ongoing	RISC, UED, Autumn School
Duncan, Hazel	UK	ongoing	UED, UWB, USAAR, Autumn School
Giero, Mariusz	PL	ongoing	UWB, TUE
Giromini, Corrado	IT	Industry	UGE, USAAR, UED, Industry, Autumn School
Pollet, Martin	DE	ongoing	USAAR, UBIR, TUE, Autumn School
McNeill, Fiona	UK	ongoing	UED, USAAR
Meier, Andreas	DE	finished	USAAR, UBIR, Industry, Autumn School
Zimmer, Jürgen	DE	ongoing	USAAR, UGE, UED, Industry, Autumn School

Table 2: Examples of PhD projects that contributed to and benefitted from CALCULEMUS-I

of CALCULEMUS-I senior researchers that made some further career steps are: Michael Kohlhase is now full professor at International University of Bremen, Christoph Benzmüller and Clemens Ballarin are assistant professors at Saarbrücken resp. Munich, Volker Sorge is lecturer at Birmingham University, Herman Geuvers is now professor at Nijmegen University. Industry contacts were, for instance, strengthened by Julian Richardson's (formerly UED) appointment at NASA, USA.

B2.3. Planned Recruitment of Early-Stage and Experienced Researchers

The total figures and the team-individual figures of early-stage and experienced researchers to be trained in CALCULEMUS-II are presented in Table 3.

	Early-stage and experienced researchers to be financed by the contract			Other professional research effort of 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)	Researchers likely to contribute (number of individuals)	Researchers likely to contribute (person months)
1. USAAR	35	10	45	8	80
2. UED	40	5	45	7	59
3. UKA	20	15	35	3	42
4. RISC	35	10	45	4	80
5. TUE	30	10	40	6	56
6. UNIJ	20	15	35	6	76
7. ITC-IRST/DIT	30	10	40	8	70
8. UWB	30	15	45	6	64
9. UGE	30	10	40	5	35
10. UBIR	20	15	35	4	52
11. UBATH	24	12	36	4	40
12. UPMC	24	12	36	8	58
13. IUB	20	15	35	3	37
Total	358	154	512	72	749

Table 3: Professional Research Effort (person-months)

Tables 4 and 5 present the names and person-months of researchers funded from other resources that will contribute to network.

Vacancies in the network will be published and advertised by making use of (i) the CALCULEMUS-I networks web-pages and information infrastructure (see Section B4.1), (ii) the recruitment infrastructure of the Commission, national bodies, and the networks partner universities, (iii) the specific woman's networks, and (iv) the information infrastructure (e-mail lists, etc.) built-up and employed for the 2002 CALCULEMUS-I Autumn School. Building on the great success of the 2002 CALCULEMUS-I Autumn School we particularly want to exploit the planned CALCULEMUS-II School at the very beginning of the proposed network period to recruit young researchers. Gender issues in the recruitment will be addressed by involvement and professional support of an equal opportunity commissioner as discussed in Section B6. Generally the balance between female and male students in computer science and mathematics varies strongly across European nations and the bias towards male students appears to be worse in Germany than for instance in the UK. The network will endeavour to reach the objective of at least 40% female recruitment (cf. section B6.1 for a detailed list of activities).

Some young researchers which have been recruited in CALCULEMUS-I will probably not be able to completely finish their training and their work (e.g. PhD thesis) until the end CALCULEMUS-I. These young researchers will immediately be available for further recruitment in CALCULEMUS-II. Since CALCULEMUS-II will ideally start immediately after CALCULEMUS-I expires a smooth transition from CALCULEMUS-I to CALCULEMUS-II can be realized. This way it should be possible to avoid the recruitment problem CALCULEMUS-I faced at its very beginning. CALCULEMUS-II recruitment will particularly benefit from the build-up of public perception of CALCULEMUS-I and the CALCULEMUS Autumn School. The initial recruitment problems in CALCULEMUS-I have been completely solved and some nodes have meanwhile completely used up their budget.

Site	Scientific Specialty	Main Researchers	Involvement		
			Main (person months)	=% (of 48 months)	Other (person months)
1. USAAR	DS, TD, SI	Chr. Benzmüller (C,M)	10	21	30
	CAS	Wolfram Decker	2	4	
	DS, TD, SI	Armin Fiedler	6	13	
	DS	Helmut Horacek	4	8	
	DS, FM, TD	Dieter Hutter (C)	8	17	
	DS, TD, CP	Erica Melis	6	13	
	CAS	Frank-Olaf Schreyer	2	4	
	DS, FM, SI	Jörg Siekmann (H)	2	4	
	DS, FM, SI	Werner Stephan	4	8	
	DS, TD	Claus-Peter Wirth	6	13	
2. UED	DS,FM,SI	Alan Bundy (H)	6	13	25
	FM, DS	Jacques Fleuriot	4	8	
	FM, DS	Paul Jackson	4	8	
	DS, SI	Roy McCasland (M)	6	13	
	FM, DS	Ewen Maclean	6	13	
	SI	Gordon Reid	4	8	
	FM, DS, SI	Alan Smaill	4	8	
3. UKA	CAS, FM, SI, CP	Jacques Calmet (H,M)	8	17	18
	CAS, FM	Regine Endsuleit	8	17	
	CAS, SI	Anusch Daemi	8	17	
4. RISC	CAS, DS, SI, CP	Bruno Buchberger (H)	8	17	52
	DS, SI	Tudor Jebelean	6	13	
	DS, TD	Teimuraz Kutsia	6	13	
	SI, TD, CP	Wolfg. Windsteiger (M)	8	17	
5. TUE	CAS	Andries E. Brouwer	4	8	20
	CAS, DS, SI, CP	Arjeh Cohen (H,M)	8	17	
	CAS, SI, CP	Hans Cuypers	8	17	
	FM, DS	Rob Nederpelt	4	8	
	TD, SI	Manfred Riem	8	17	
	CAS, SI, CP	Hans Sterk	4	8	
6. UNIJ	DS, CP	Herman Geuvers (H)	4	8	40
	DS	Henk Barendregt	4	8	
	DS, CP	Freek Wiedijk (M)	8	17	
	CAS	Wieb Bosma	4	8	
	DS, CP	Bas Spitters	8	17	
	DS	Dimitri Hendriks	8	17	
7. ITC-IRST/ DIT	DS, SI	Piergiorgio Bertoli	6	13	26
	FM, TD	Marco Bozzano (M)	8	17	
	SI, TD, FM	Alessandro Cimatti (H)	6	13	
	DS, FM	Fausto Giunchiglia	2	4	
	DS, FM, TD	Marco Pistore	6	13	
	DS, TD	Marco Roveri	6	13	
	DS, SI, FM	Roberto Sebastiani (M-DIT)	8	17	
	FM, DS	Paolo Traverso	2	4	

Table 4: The research teams 1-7 of the CALCULEMUS-II network.

Site	Scientific Specialty	Main Researchers	Involvement		
			Main (person months)	=% (of 48 months)	Other (person months)
8. UWB	CP,DS,FM,TD	Grzegorz Bancerek	8	17	30
	CP,DS,TD	Czeslaw Bylinski (M)	8	17	
	CP,DS,FM,TD	Artur Kornilowicz	4	8	
	CP,DS	Roman Matuszewski	2	4	
	CP,DS,TD	Andrzej Trybulec (H)	8	17	
	DS,TD	Anna Zalewska	4	8	
9. UGE	DS,FM,SI,TD	Alessandro Armando (H)	4	8	15
	DS,FM,SI,TD	Claudio Castellini (M)	8	17	
	DS	Mauro Di Manzo	4	8	
	DS,FM	Enrico Giunchiglia	2	4	
	DS, FM	Giorgio Delzanno	2	4	
10. UBIR	DS,SI,TD	Volker Sorge (H,M)	8	17	24
	DS,SI	Manfred Kerber	8	17	
	FM,TD	Behzad Borbar	6	13	
	TD,CP	Alan Sexton	6	13	
11. UBATH	CAS	James Davenport (H,M)	8	17	12
	DS	David Pym	4	8	
	CAS, TD	Russell Bradford	8	17	
	TD, SI	Julian Padget	8	17	
12. UPMC	DS, FM	David Delahaye	4	10	12
	DS, FM,SI	Damien Doligez	8	20	
	DS, FM , SI	Therese Hardin (H)	6	10	
	DS, FM	Mathieu Jaume	6	15	
	CAS	Valerie Menissier-Morain	6	15	
	DS, FM	Olivier Pons	4	10	
	CAS	Renaud Rioboo (M)	8	20	
	FM, SI	Pierre Weis	4	10	
13. IUB	DS, CP, TD, SI	Michael Kohlhase (H,M)	6	13	15
	DS, SI, TD	(N.N. postdoc)	8	17	
	SI, TD	(N.N. grad. student)	8	17	

Table 5: The research teams 8-13 of the CALCULEMUS-II network. The tables make use of the following abbreviations: In the column *Main Researchers* we use **C** for *Coordinator*, **H** for *Head of Node*, and **M** for *Team Manager*. These roles are defined in Section B4.1. In column *Scientific Speciality* we use **DS** for *Deduction Systems*, **CAS** for *Computer Algebra Systems*, **FM** for *Formal Methods*, **TD** for *Tool Development*, **SI** for *System Integration*, **CP** for *Content Provider (Knowledge Bases)*

Recruitment in CALCULEMUS-II will furthermore benefit from the modified eligibility criteria; for instance, qualified candidates in CALCULEMUS-I from non-eligible countries in the fifth framework will now become eligible: the additional EU grant the network received for supporting (network independent) participants of the 2002 Autumn School in Pisa attracted several highly qualified students from eastern European countries which were unfortunately not eligible.

The length of an appointment will range from three months to three years. It may strongly vary, for instance between those young researchers who are already employed from network independent funds of a network partner side and who make use of CALCULEMUS in order to get additional training for a few months at another partner side, and those young researchers who will be recruited for a complete PhD project fully funded by CALCULEMUS.

The systems we develop also provide means to improve equal opportunities for disabled persons, see also Section B6. We want to further strengthen this by encouraging applications from disabled young researchers and, e.g., improvements in our distant learning concepts for this purpose.

B3 Training and/or Transfer of Knowledge Activities

B3.1. Collective Expertise of the Network Teams

The thirteen research teams of the CALCULEMUS-II network displayed in Table 1 combine different, world leading expertise in the spectrum of computer algebra, deduction system, formal methods, and mathematical knowledge bases. The network composition comprises all partner nodes of CALCULEMUS-I (with TUE and UNIJ now being separate research teams; before they jointly formed the team TUE). The three new research teams IUB, UBATH, and UPMC were selected in a competitive selection process by the Executive Committee of CALCULEMUS-I. A goal thereby was to strengthen the computer algebra expertise (James Davenport at UBATH and Therese Hardin and Renaud Rioboo at UPMC were thus elected) and the mathematical knowledge base competence (Michael Kohlhase, one of the initiators of CALCULEMUS-I who is now Professor at IUB, got elected).

The thirteen network nodes will cooperate with further academic and industrial collaborators; they are listed in Tables 6 and 7 in Section B3.3. The majority of this additional collaborators has a very strong link, for instance, based on existing projects, to one or more of the proper network nodes. This was also the reason why the initially planned network structure for CALCULEMUS-II did include the collaborators AC1, AC2, AC3, AC4, AC5, AC6, and AC13 (with AC3 and AC5 being located in less-favored regions) as proper subnodes of UED, UKA, UWB, UGE, IUB, UBATH, and UBIR respectively. Since we were advised by our current CALCULEMUS-I EU officer that such a subnode structure is not foreseen and eligible for RTNs in the sixth framework we include them now only as academic collaborators.

The research teams with their senior researchers are summarized in Tables 4 and 5 in Section B2.3. Those tables contain further information, such as scientific specialization and the researchers involvement in the networks work programme in person months and percentage of full time employment. The last column ('Others') in those tables summarizes the involvement (in person months) of further staff in the project; this includes the nodes young researchers.

USAAR **Saarland University, Germany (Benzmüller, Hutter, Siekmann)**

Research and Training Experience Computer Science Institute at the Saarland University is rated as the best department with respect to research in Germany and among the top five internationally. Its research in representing, proving and processing mathematical knowledge is internationally well-known. The ΩMEGA group has studied automated theorem proving, knowledge-based proof planning, and mathematical knowledge representation for over 20 years. The ΩMEGA project is part of the collaborative research center *Resource-adaptive Cognitive Processes (SFB 378)* at Saarland University, and has strong ties with the DFKI group and the Max-Planck Institute for Computer Science in Saarbrücken.

At Saarland University the research groups of Prof. Siekmann are typically offering each semester about 4-6 lectures and seminars in artificial intelligence, deduction systems, formal methods, and multi-agent systems. In CALCULEMUS-I USAAR together with UKA organized the CALCULEMUS Autumn School as well as several smaller workshops and courses together with other project partners. USAAR hosted 8 young researchers and was involved in three industry internships.

Role in CALCULEMUS The ΩMEGA system is a mathematical assistent environment with a broad scope and it will be used as a base environment for the integration and employment of the tools developed in Task 2. ΩMEGA research currently addresses proof planning, traditional theorem proving in first-order and higher-order logic, human-oriented user interfaces with natural language capabilities, distributed and agent-based architectures, representation and learning of proof guidance knowledge, communication infrastructure, interfaces, and transformation mechanisms supporting the integration of external specialist reasoners. Integration of computer algebra systems (Task 1) in proof planning is supported by SAPPER, a transformation tool that translate computations into verifiable proof objects. MathWeb-sb, which originates from ΩMEGA and is now widely used in and outside the CALCULEMUS-network, is an integration infrastructure (Task 3) that is now further developed at USAAR and UED. ΩMEGA is one of the main clients of the MathWeb-sb through which it accesses its different system modules, calls the external specialist reasoners, and interoperates with the mathematical knowledge base MBASE; thereby OMDOC is used as communication means. The connection from ΩMEGA to MBASE is via the MAYA management of change tool (Task 2) developed at DFKI. In collaboration with THEOREMA at RISC the ΩMEGA system will be employed in a larger case study in Analysis (Task 4). As a system that is integrated to the e-learning environment ACTIVEMATH and the natural language based tutorial dialog system under development in the SFB 378 ΩMEGA will be employed in computer-based e-learning in mathematics (Task 6).

Linkages As CALCULEMUS-I coordinator USAAR has further tightened its links to all network partners and together with UKA the CALCULEMUS Autumn School has been organized. The collaboration with UBIR (M. Kerber and V. Sorge at UBIR are former members of USAAR), which also employs the ΩMEGA system, addresses: integration of CAS and DS via proof planning, the agent-based suggestion mechanism ΩANTS, learning of proof guidance knowledge, and the adequate representation of mathematical objects. Under the leadership of IUB (M. Kohlhase at IUB is a former member of USAAR) USAAR contributes to the development of MBASE and OMDOC; via MBASE the ΩMEGA system has access to the MIZAR system developed at UWB. Together with UGE and UED, USAAR investigated applications in formal methods. With UED the MathWeb-sb system is developed and proof planning is studied; applications of proof planning are also pursued in cooperation with UWB. With RISC an THEOREMA-ΩMEGA workshop series has been started in April this this year. To UBATH a link has been established in MKM.

Researchers and Research Infrastructure The main researchers at USAAR and DFKI are: Dr. C. Benzmüller, Prof. Wolfram Decker (Mathematics Dep.), Dr. A. Fiedler, Dr. H. Horacek, Dr. D. Hutter, Dr. E. Melis, Prof. Frank-Olaf Schreyer (Mathematics Dep.), Prof. J. Siekmann, Dr. Werner Stephan, Dr. C.P. Wirth. The young researchers are: S. Autexier, S. Hussain, A. Meier, M. Obaid, M. Pollet, F. Theiss, D. Tsovaltzis, Dr. B. Quoc Vo, M. Wagner, J. Zimmer.

Two most significant CALCULEMUS**-relevant publications:** [SBF+03, MPS02]

UED **The University of Edinburgh, Scotland (Bundy)**

Research and Training Experience The Mathematical Reasoning Group at the University of Edinburgh forms part of the School of Informatics, which recently received a top rating in the university-wide research assessment. The main research contribution of the group has been in the field of automated reasoning, contributing to understanding of the structure of proof in applicable domains such as software and hardware verification.

Lecture courses in Automated Reasoning and Research Methodology are offered to students by members of the group as well as diverse Artificial Intelligence and Knowledge Representation courses. Regular tutorials and supervisions are arranged for students and researchers, offered by more senior members of the group. The research environment is vibrant and collaborative enhanced in particular by a variety of seminar series aimed at both experienced researchers and PhD students who are starting out.

Role in CALCULEMUS The Edinburgh node of the CALCULEMUS network has been involved in a number of projects, lending its expertise particularly in the areas of Proof-Planning and Automated Theory Formation. Young visiting researchers from other nodes in the CALCULEMUS network have collaborated with the Mathematical Reasoning Group by combining the systems developed at Edinburgh with those from their node.

The λ *Clam* proof-planner, developed at Edinburgh, is a tool for automating mathematical proof by abstracting the proof-steps at the object level and working at a meta-level. In particular, annotated reasoning is used to help reason about the progress of a proof. This annotated reasoning is referred to commonly as *rippling*. The mathematical reasoning group has applied rippling and proof-planning to a number of different domains, including induction, ordinal arithmetic and non-standard analysis. During the course of the Calculemus program, λ *Clam* has both enhanced and been enhanced by other systems such as the MathWeb software bus.

Automated Theory Formation is provided by the HR system developed by Simon Colton. A set of production rules is devised by which conjectures can be made in different mathematical theories. The Calculemus network has allowed this to be extended by connecting HR to theorem provers, allowing more benchmarks to be automatically created for Automated Theorem Provers. Also, HR has been connected to the MathWeb Software Bus so that many other theorem provers and computer algebra systems can be made use of.

UED will closely cooperate with Simon Colton who is now at Imperial College, London.

Linkages The Edinburgh node of the CALCULEMUS network has worked with the University of Saarland in connecting both HR and λ *Clam* to the MathWeb Software Bus, and has had fruitful links with Genoa, Bialystok, Linz and Karlsruhe. Edinburgh has been jointly responsible for two industrial internships with a major electronics company who benefitted from expertise in formal systems.

Researchers and Research Infrastructure The Mathematical Reasoning group was initially set up by Professor Alan Bundy and now comprises a research team of four lecturers: Professor Alan Bundy, Dr. Alan Smaill, Dr. Paul Jackson and Dr. Jacques Fleuriot; three researchers: Dr. Roy McCasland, Gordon Reid and Ewen Maclean; and ten full time PhD students. The whole research group will be actively encouraged to take part in the CALCULEMUS-II project.

Two most significant CALCULEMUS-relevant publications: [CS02, BJ02]

UKA **University of Karlsruhe, Germany (Calmet)**

Research and Training Experience J. Calmet is active in Computer Algebra (CA) since the foundation of the field. He did organized the first European conference in 1982. He is co-founder of the journal AAECC (Applicable Algebra in Engineering, Communication and Computing). He did either found or establish conferences such as the pioneering Marseilles conferences in the 1970s, the Rhine Workshop on CA or the AISC (Artificial Intelligence and Symbolic Computation) conference. Among the former master or doctoral students some names are today well-known university professors: D. Lugiez (France) or C. Schuermann (Yale, USA) in the former case, H. Comon (France), G. Bittencourt (Brazil), F. Ulmer (France) or O. Tjandra (Canada) in the latter case. Two former doctoral students have started their own company (J. Schü and P. Kullmann) while another one (K. Homann) seems to be very successful at Siemens. This list is not exhaustive. This illustrate that although labeled Computer Algebra, the research activity of the group is fully anchored in Computer Science. This group has been among the very first ones to define mathematical knowledge (a first paper in 1984 and a major one in 1990 at a knowledge conference) and to investigate the coupling of CA and deduction already around 1994. Software systems for knowledge representation (MANTRA), for formal specification (FORMAL) and for a mediator query system (KOMET) have been designed. At the origin UKA together with USAAR developed ideas that led to CALCULEMUS well before it was accepted as a RTN.

Role in CALCULEMUS The role in CALCULEMUS-II will build on what has been done in CALCULEMUS-I. UKA will extend it to some facets that belong more to CS than to applied mathematics. The task centered on protocol and software bus will evolve into a multi-agent system approach making thus full use of the knowledge gained when designing and implementing KOMET. This will offer an opening on the management of heterogeneous mathematical knowledge. A goal is to provide a frame to enlarge the integration capabilities beyond pure deduction and symbolic computation. To extend OMSCS (Open Mechanized Symbolic Computation Service) to arithmetics requires to investigate how to define "theories" in arithmetics but also to refine the investigation of the concept of proofs calling on arithmetic routines. This is a renewed research area. We will investigate problems dealing with security issues. On one side, we rely on agent systems that need to be secured to permit their routine use. On the other side, security protocols although apparently of a similar nature are in fact a different facet of security that could be merged with the former one. A new frontier for computation and proof problems is algebraic and differential topology. We plan to investigate how to design decision and proof methods in these domains. Two application areas are to prove that differential system can be solved and to construct solutions when they exist.

Linkages Contacts exist for several years, under different forms, with the three new nodes UBATH, PARIS-VI, and IUB. Unrelated to the RTN CALCULEMUS-I, links did or do exist with existing nodes to conduct joint work (ITC-IRST, UGE), to organize conferences (RISC, TUE), in editorial boards of journals (RISC, UBATH), in program committees of conferences (RISC, TUE, PARIS-VI, UGE) or even in doctoral student exchange outside CALCULEMUS-I. CALCULEMUS-I started from two consortiums being led respectively by USAAR and by UKA originating from the deduction and the computer algebra communities. UBIR is a node in another European project on a fully different topic to be submitted shortly. It is coordinated by UKA. In CALCULEMUS-I the joint organization with USAAR of the Autumn School reinforced the links with all of the existing nodes. The link to UED was strong since two YVRs came to Karlsruhe for 3 and 6 months.

Researchers and Research Infrastructure The principal researchers at UKA taking part in CALCULEMUS-II are Prof. Jacques Calmet and Regine Endsuleit. Other members of the group are young doctoral students.

Two most significant CALCULEMUS-relevant publications: [CBK01, BCGH99]

RISC **RISC, Linz, Austria (Buchberger)**

Research and Training Experience The Research Institute for Symbolic Computation (RISC) of the Johannes Kepler University Linz was founded in 1987 by Professor B. Buchberger with the objective of pursuing research, graduate teaching and industrial cooperations in the field of symbolic computation. The main research achievements of the Theorema Group within RISC, led by Professor Buchberger, are

- the invention and development of the theory of Groebner bases that turned out to have applications in almost all areas of computer algebra, e.g. algebraic geometry, combinatorics, invariant theory, constraint Solving, geometrical theorem proving, integer programming etc.
- and the design, foundation and implementation of the Theorema software system for computer-supporting the entire life cycle of mathematical theory exploration with an emphasis on automated reasoning.

Hence, the research experience and goals of the Theorema Group at RISC strongly coincide with and anticipated the general philosophy and objectives of the Calculemus Group of which the Theorema Group was a founding member.

RISC also established an international PhD program specializing in symbolic computation whose objectives overlap with the later YVR program within the Calculemus project. In the RISC PhD program, permanently, approximately 25 international PhD students are enrolled of which 5 to 8 are related to the Theorema project.

Role in CALCULEMUS In the frame of CALCULEMUS-I, RISC was task leader for tasks 2.2 (CASs with enhanced reasoning power) and 3.1 (Automated support to writing mathematical publications) and, in addition, participated in tasks 1.1 (Construction of mathematical frameworks) and 1.2 (Definition of mathematical service).

The Theorema system is being developed at RISC in the frame of the Theorema project, which has been initiated by B. Buchberger in 1994. In its current version, Theorema is designed as an add-on package to the well-known computer-algebra system Mathematica. Theorema aims to computer-support the entire life-cycle of mathematical theory exploration in a united framework. The system already offerers a simple and intuitive interface for specifying and structuring mathematical theories using the language of higher order predicate logic and for computing using executable formulae, as well as several automated provers for general and specific domains: These features qualify the Theorema system for formalizing large areas of mathematics in order to gain the acceptance among mathematicians.

Linkages In May 2003, a series of ΩMEGA-Theorema-workshops has been initiated with its first meeting in Hagenberg May 24-27. The next meeting between RISC and USAAR is planned for early 2004, having the formalization of basic Analysis (see Task 4) as a common topic. Connections to UED are tightening through exchange of YVR. In the period 09/2003-12/2003 A. Craciun (RISC) is visiting UED, in the period 10/2003-12/2003 D. Winterstein (UED) is visiting RISC. A. Trybulec (UWB) taught an online MIZAR-course to the members of the Theorema group. This will be helpful for future cooperations in formalizing larger areas of mathematics. Links to many of the groups in CALCULEMUS-II are given by the common engagement in MKM.

Researchers and Research Infrastructure Currently, the Theorema group consists of 8-10 researchers. Among the Theorema group, the following personnel will mainly concentrate on CALCULEMUS-II-relevant issues: Prof. Dr. Bruno Buchberger (head of node), Dr. Tudor Jebelean, Dr. Teimuraz Kutsia, Dr. Wolfgang Windsteiger (team manager), M.Sc. Adrian Craciun, M.Sc. Camelia Kocsis, M.Sc. Laura Kovacs, M.Sc. Florina Piroi, M.Sc. Nikolaj Popov.

Two most significant CALCULEMUS-relevant publications: [BDJ+01, Buc03a].

TUE **Eindhoven University of Technology, Netherlands (Cohen)**

Research and Training Experience The Department of Mathematics and Computer Science at the "Technische Universiteit Eindhoven"(TU/e) hosts RIACA, the Research Institute for Applications of Computer Algebra, which plays a pivotal role in the development of mathematics on computer.

The RIACA research team performs research on Discrete Mathematics, Computer Algebra and its applications and is one of the main contributors to the OpenMath standard. Results in the past include software packages for Algebra and Discrete Mathematics for Lie theory, for non-commutative algebra, for codes, and for graphs. Also, the group has produced several interfaces mathematical software, and Interactive Algebra Lecture Notes (published by Springer Verlag). The group has extensive teaching experience (on under- and postgraduate level) in their respective specialties. It is currently a member of the Calculemus project (RTN1-1999-00301), the OpenMath Thematic Network (IST-2000-28719) and the Monet project (IST-2001-34145).

Role in CALCULEMUS Integration of systems (Task 1). Frameworks and tools supporting the full mathematical life cycle (Task 2). Industrial applications in computer mathematics (Task 5). Semantically rich languages for the communication of mathematics, queries, and services, and e-Teaching (Task 6).

Linkages There is a good collaboration with USAAR (Martin Pollet) and UBIR (V. Sorge), on the field of verification of permutation group results, in which we also employ the ΩMEGA system.

With the members of the CALCULEMUS project we address issues like the integration of CAS and DS via proof planning, the interaction with the MONET project, learning of proof guidance knowledge, and the adequate representation of mathematical objects.

A.M. Cohen (TUE), M. Kohlhase (IUB) and J.H. Davenport are leading members of the OpenMath Society. They have exchanged programs and ideas around OpenMath and OmDoc.

With UNIJ collaboration takes place on several levels: joint computer algebra, interchange of proof theory ideas, and a joint PhD. project.

In a collaboration with UGE a C++ library for OpenMath is in the make.

Both UBATH and TUE participate in the MONET project.

From January 2004 on, USAAR and TUE will be joint in the FP6 project LeActiveMath, coordinated by DFKI.

Researchers and Research Infrastructure People: Prof. Dr. A. E. Brouwer (Discrete math. and Unix), Prof. Dr. A. M. Cohen (Discrete math., Computer algebra, Inter. math. docs), Dr. H. Cuypers (Discrete Math., Inter. math. docs.), Dr. H. Sterk (Algebra, Mathematical education, Inter. math. docs.), Dr. R. Nederpelt (Theorem proving, Proof checking, Type theory) M. Riem (XML-Java & Technical assistance), E. Reinaldo Barreiro (PhD. student).

Two most significant CALCULEMUS-relevant publications: [Coh01, CMPS03]

UNIJ **University of Nijmegen, Netherlands (Barendregt)**

Research and Training Experience The Foundations group of the Department of Computer Science at Nijmegen has as a major research theme "Formalizing Mathematics". The concrete aim is make formalizing of known mathematics of the same degree of easiness as writing it up in LaTeX. This should lead to a computer system that could be called a "mathematical assistant". To contribute to this aim, we work on the following issues: (1) Foundations: what are and what should be the logical and practical foundations of such a system. (2) Libraries: how to actually make a (large) coherent library of formalized mathematics. (3) Tools: create the appropriate automation and notation tools, specific to the field of mathematics one is working with. (4) Interface: create a general purpose (system independent) "Math Mode" that allows declarative proofs, ideally combined with the advantages of tactic-based (procedural) proving. (5) Algorithms: formalize and prove mathematical algorithms correct; combine Proof Assistants with Computer Algebra systems in a "skeptical" way, by asking "witnesses" from the CA system that can be checked in the PA.

Members of the Foundations group are active users of the proof assistants Coq, MIZAR and HOL-light and they have a lot of experience in type theory, which forms the foundational basis of Coq. Recently the group has started to develop C-CoRN, the Constructive Coq Repository at Nijmegen, a library of formalized algebra and analysis. The aim of C-CoRN is to experiment with libraries of formalized mathematics, but also to study the relation between conceptual mathematics (proofs) and computational mathematics (algorithms).

We cooperate with other research groups in the following projects: Calculemus I (as a subnode of TUE), Mowgli (Mathematics on the Web, Get it by Logic and Interfaces, EU-IST-FET project, with a.o. USAAR, TUE), Types (EU Working group, with a.o. UWB).

Role in CALCULEMUS Task 1: We want to study and use the combination of CA and DS in a "skeptical way": the DS (in our case we would say a Proof Assistant, PA) would consult the CA for "witnesses" that the DS can check.

Task 2: In our development of C-CoRN, we also study documentation and tools for documenting formalized mathematics. We also study different "proof styles" to bring proof assistants closer to mathematicians.

Task 4: We want to further explore constructive analysis, especially from the point of view of the underlying mathematical algorithms. As part of this we study the formalization of various (computational) representations of 'exact' real numbers.

Task 5: From C-CoRN we want to generate a set of course notes for undergraduate algebra and analysis which is based on the formalized mathematics.

Linkages We cooperate with TUE, UWB, USAAR on various of the above mentioned topics. See also the list of EU projects above.

Researchers and Research Infrastructure The list of researchers involved in CALCULEMUS-II at UNIJ includes Herman Geuvers (Assoc. Prof.), Henk Barendregt (Full Prof.), Freek Wiedijk, Bas Spitters, Dimitri Hendriks. In addition the following PhD. students will contribute to the project: Luis Cruz-Filipe, Milad Niqui, Jasper Stein, Iris Loeb, Lionel Mamane.

Two most significant CALCULEMUS-relevant publications: [Wie03, GPWZ02]

ITC-IRST/DIT **ITC-IRST and DIT, Trento, Italy (Cimatti)**

Research and Training Experience The Center for Scientific and Technological Research (ITC-IRST) is an internationally recognized research center conducting research in the areas of Information Technologies, Microsystems, and Physical Chemistry of Surfaces and Interfaces. The members of ITC-IRST involved in this project are from the Automated Reasoning Systems (SRA) division, currently consisting of about 40 people, who have been actively working in the field of formal verification since 1990, in the development of techniques and tools for automated deduction and model checking. One of the main objectives of SRA is technology transfer of formal verification techniques within industrial projects, where a solid experience has been built during many years of activity. Model checking techniques have been applied to the design and verification of safety critical system.

The Department of Information Technology (DIT) of University of Trento consists on 33 among full, associate and assistant professors with permanent positions, and a relevant number of other personnel. The members of the DIT team has a great expertise in formal methods and in SAT procedures and their application, and have given tutorials on SAT tools and integrated decision procedures to major international conferences and schools. DIT organizes with the collaboration of ITC-IRST the *International ICT Graduate School* for PhD students, hosting about one hundred PhD students, which would be a natural source of Young Visiting Researches for other nodes.

Jointly with the group of prof. Clarke at CMU and with UGE, ITC-IRST/DIT has developed NuSMV, an open architecture for model checking. Furthermore, ITC-IRST/DIT has been active in the development of formal verification techniques based on decision procedures for propositional satisfiability (SAT). ITC-IRST/DIT team members have contributed to the CALCULEMUS Autumn School with a course on model checking and the NuSMV tool. ITC-IRST/DIT team members have organized 1997, 1999 and 2001 editions of Calculemus! symposiums, and have co-edited the Journal of Symbolic Computation, Special Issue on the Integration of Automated Reasoning and Computer Algebra Systems.

The number of YVRs hosted and trained in CALCULEMUS-I is 4, plus 3 other YVRs appointed.

Role in CALCULEMUS ITC-IRST/DIT team has developed MathSAT, a decision procedures for combinations of boolean and mathematical propositions, based on the tight integration of a SAT procedure with a set of mathematical deciders for theories of increasing expressive power. The existence of such procedure has opened the possibility to solve problems arising from real-world domains. In particular, we have addressed and are currently addressing the development of verification tools (model checkers) for complex real-world systems and protocols, in particular for timed and hybrid systems and for RTL circuit designs.

For ITC-IRST/DIT, the main goal of the research inside CALCULEMUS will be the development of a new generation of *hybrid formal checkers*, that is, computer-aided verification tools which are capable to perform reasoning on hybrid theories (involving, e.g. equality, linear and non-linear arithmetic over integer or real numbers, uninterpreted functions). Application fields are verification of hardware circuits, verification of industrial hybrid systems, modeling and analysis of biological systems.

Linkages ITC-IRST/DIT has a long tradition of scientific collaboration with UGE node on decision procedures and formal methods. During CALCULEMUS-I it has had many interactions and collaborations also with UWB, UED, RISC, and USAAR nodes. ITC-IRST/DIT has very strong connections with many international research centers. Among them, it has a scientific collaboration on topics related with hybrid formal checking with Intel Israel, which would be a natural place for stages for YVRs.

Researchers and Research Infrastructure The principal researchers at ITC-IRST and DIT are Dr. P. Bertoli (ITC-IRST, Expert Researcher), Dr. M. Bozzano (ITC-IRST, Expert Researcher), Dr. A. Cimatti (ITC-IRST, Expert Researcher), Dr. F. Giunchiglia (DIT, Full Professor), Dr. M. Pistore (DIT, Assoc. Professor), Dr. M. Roveri (ITC-IRST, Expert Researcher), Dr. R. Sebastiani (DIT, Ass. Professor). Dr. P. Traverso (ITC-IRST, Expert Researcher). The young researchers are V. Kirov (PhD student) and S. Tonetta (PhD student).

Two most significant CALCULEMUS**-relevant publications:** [ABC+02, ACKS02]

UWB **University of Bialystok, Poland (Trybulec)**

Research and Training Experience For three decades the MIZAR Group led by Andrzej Trybulec at the University of Bialystok (Institute of Computer Science) has been developing a proof checking system MIZAR with input language close to the informal mathematical language. The main achievement of the group is the Mizar Mathematical Library (`http://mizar.org/mml/`), a huge repository of computer checked mathematics, recognized as the largest library of that kind in the world. It is the result of a collaboration with more than 140 authors from 10 countries.

MIZAR is the name of both the formal language for writing mathematical papers, and the proof checker. That system is based on classical logic and Fitch-Jaśkowski system of composite logic (conditional proofs). MIZAR is distributed as freeware (`http://mizar.org/`). Apart from the verifier the system consists of programs for reviewing submitted articles, managing the library, MIZAR query, and software for publishing the journal *Formalized Mathematics*. Currently (November 2003) the size of the Mizar Mathematical Library (MML) is about 57 MB, the library contains 798 articles, 39199 proved theorems and 6797 definitions. Since 1990 the journal *Formalized Mathematics* (ISSN 1426-2630) has been published (paper, and electronic version `http://mizar.org/fm/`). It consists of abstracts of MIZAR articles translated to English.

We have many years of experience in using the MIZAR system for teaching purposes (compare [MT85, Szc87, Zal87]). In September, 2002 UWB contributed to the CALCULEMUS Autumn School providing a course on Mizar Mathematical Library. Additionally, several MIZAR courses were conducted via the Internet.

Role in CALCULEMUS UWB will provide the network with the corpus of verified mathematics - the Mizar Mathematical Library database. The MIZAR system will be available for e-learning in mathematics (Task 6) using our long-term experience in Computer Aided Instruction. That experience is based on numerous BS, MS, and PhD theses written in MIZAR language concerning different fields of mathematics and computer science, since the end of 1980s.

Our group will also share the experience with well developed techniques of proof-planning used in MIZAR, available also in HOL, Isar and COQ. The library of MIZAR articles can serve as a basis for a case study on complete formalization of selected fields of mathematics (Task 4). MML can also provide an extensive source of input (hints, new proof tactics) for theorem provers.

Andrzej Trybulec is a CALCULEMUS trustee. Members of MIZAR Group have contributed to CALCULEMUS conferences.

Josef Urban from Charles University in Prague visited UWB as CALCULEMUS young visiting researcher. He developed Mizar Problems for Theorem Proving (MPTP), Mizar Proof Advisor (MPA), Mizar Mode for Emacs, and worked on XML formats and export from MIZAR to TPTP and TSTP libraries.

Linkages UWB closely cooperates with UNIJ in preparation of "MIZAR Mode for COQ" and in parallel formalization of a proof of FTA. IUB has developed MBASE system which now has access to the MIZAR library. With USAAR applications of proof planning are also pursued. A link to UBATH and to UBIR has been established in MKM Consortium. Similarly, a link to PARIS-VI has been established in TYPES Consortium. Artur Korniłowicz from UWB has spent one year at ITC-IRST, his visit resulted in common publications (SAT). With UED we have collaboration concerning data mining. The collaboration with RISC refers to automated support to writing mathematical publications, and in 2002 we organized a course on MIZAR via Internet. With UKA we collaborate in challenging mathematical problems.

Researchers and Research Infrastructure Dr. Andrzej Trybulec, Dr. Grzegorz Bancerek, Dr. Czesław Byliński, Dr. Artur Korniłowicz, Dr. Roman Matuszewski, Dr. Anna Zalewska, Mariusz Giero, Adam Grabowski, Robert Milewski, Adam Naumowicz, Krzysztof Retel.

Two most significant CALCULEMUS**-relevant publications:** [RT03, BR02]

UGE **Università degli Studi di Genova, Italy (Armando)**

Research and Training Experience The Artificial Intelligence Laboratory (AI-Lab) of DIST (Department of Information, Computers and Systems Science) at the University of Genova is a young, dynamic reality in the scenario of Automated Reasoning in Italy. Staff in the laboratory offer a number of advanced courses whose topics range from artificial intelligence to databases and and software engineering.

Research at the AI-Lab focuses on both practical and theoretical aspects of automated reasoning with a special emphasis of applications. Considerable experience has been matured in the development of automated reasoning techniques and tools supporting the automatic analysis of security and/or safety critical systems such as security protocols and hardware designs.

The group has been involved in several national and international research projects (including CALCULEMUS-I). Dr. Alessandro Armando is coordinating a project for the co-tutoring of PhD students in a network of European Research Institutions. He is also coordinator of the EU-funded project "Automated Validation of Internet Security Protocols and Applications" (AVISPA) IST-2001-39252, and he has served in the program committee of a number of international conferences, among which IJCAR, IJCAI and FroCoS. He has also contributed to the CALCULEMUS Autumn School in Pisa with a course on Integration of Decision Procedures in Automated Reasoning.

Role in CALCULEMUS The role of UGE in CALCULEMUS-II will be focused on the development and integration of automated reasoning techniques as well as on their application to a number of problems of great practical importance such as the validation of security protocols and the model-checking of software. This will be done by identifying a set of mathematical domains useful for the purpose and by developing techniques supporting the automatic reasoning and/or management of knowledge within such mathematical domains. Prototypes will be developed to assess the effectiveness of the proposed techniques. UGE is already developing and maintaining a tool for automated reasoning on disjunctive temporal problems (TSAT++, `http://www.mrg.dist.unige.it/~drwho/Tsat`) as well as a model-checker for security protocols (SATMC, `http://www.mrg.dist.unige.it/~compa/satmc`).

UGE will also benefit from the collaboration with INRIA Lorraine (Dr. Silvio Ranise, Dr. Michaël Rusinowitch).

Linkages The AI-Lab is in close contact with a number of universities, research institutions and hi-tech companies, among which Stanford University (California, US), the ETHZ (Technical High School) in Zürich and Siemens AG (München, Germany). Among the CALCULEMUS-II participants, the laboratory has strong links with ITC-IRST/DIT, the School of Informatics at Edinburgh (UK), INRIA Lorraine (France) and USAAR.

Researchers and Research Infrastructure Main researchers at AI-Lab (UGE) for CALCULEMUS are Dr. A. Armando, Dr. C. Castellini, Dr. G. Delzanno, Prof. M. Di Manzo and Prof. E. Giunchiglia. In addition, the following PhD students will contribute to the project: L. Compagna, P. Ganty and J. Mantovani.

The two most significant CALCULEMUS**-relevant publications:** [AB01, ARR03]

UBIR **The University of Birmingham, England (Sorge)**

Research and Training Experience The School of Computer Science is a research led department with strong activities in the area of reasoning and verification. It hosts inter alia the Midlands e-Science Centre. It has developed strengths in theorem proving and model checking. In the area of automated reasoning we have investigated approaches to the integration of system, agent-based theorem proving, proof planning, theory exploration, machine learning, and the mechanisation of three-valued logics.

By the end of CALCULEMUS-I the School will have hosted 4 Young Visiting Researchers. The Birmingham group has mainly contributed by developing an approach to a sound integration of computer algebra into proof planning, by carrying out several large scale case studies to show the effectiveness of this integration and by developing new and more effective representations for mathematical objects. Manfred Kerber and Volker Sorge were main organizers of the CALCULEMUS symposia 2000 in St Andrews and 2002 in Marseille, respectively. They are editors of separate special issues of the "Journal of Symbolic Computation" on "Computer Algebra and Mechanized Reasoning" and they have contributed a course; on partiality and a tutorial on ΩMEGA to the CALCULEMUS Autumn School.

The Birmingham team has been joined recently by Alan Sexton and Behzad Bordbar. Alan Sexton is interested in the application of database technology to non-standard areas such as mathematical knowledge. He brings in his expertise on indexing of highly structured data. He was an organiser of the 1999 conference on Data Bases in Birmingham. Behzad Bordbar works on the quality of services and is interested in applying systems developed in CALCULEMUS to industrially relevant problems. His current interests include software engineering and Unified Modeling Language (UML). In particular, he is interested in developing specification, design and verification techniques for distributed systems. He has been involved in various European and EPSRC/UK research projects.

Role in CALCULEMUS UBIR will be task leader of task 1 and will collaborate with Paul Cairns, University College London.

Linkages The group has traditionally strong links with USAAR, as two of the principal investigators were leading members of the ΩMEGA group. Further collaboration, the continuing development of the ΩMEGA system and hosting Martin Pollet and Andreas Meier as Young Visiting Researchers have further intensified these links. The YVR were also involved in a joint case study with TUE and USAAR on certifying solutions to permutation group problems and in work on the classification of finite algebraic structures done in collaboration with Simon Colton from Imperial College. We have a regular exchange of scientific ideas with USAAR, UGE, and UED in the workshop series CIAO and are currently intensifying the link to UED with work on classification of prime submodules and Zariski Spaces. We also have a longstanding collaboration with Michael Kohlhase (IUB) related to the common development of the ΩMEGA system. Additional links exists via the MKM consortium with UBATH, UPMC, and UWB.

Researchers and Research Infrastructure The principal researchers at UBIR are Dr. Volker Sorge, Dr. Manfred Kerber, Dr. Behzad Borbar, Mr. Alan Sexton, and Dr. Paul Cairns (University College London). The young researchers are Mr. Richard Swinbank, Mr. Athanasios Staikopoulos, and Mr. Jeremy Gow.

Two most significant CALCULEMUS-relevant publications: [JKP02, MPS02]

UBATH **University of Bath, England (Davenport)**

Research and Training Experience The University of Bath is a major science and technology University of England, ranking in the top 12 of over 120 Universities in Britain. It has strong expertise in Mathematics and Computing, with 5 or 5* ratings in all areas of mathematics.

Prof. James Davenport is Hebron & Medlock Professor of Information Technology and University Director of Information Technology, and works on computer algebra systems. He is one of the original authors of the Axiom system and has designed type systems for knowledge representation in computer algebra systems. He has been a Royal Society Industrial Fellow and has been awarded with the Ontario Research Chair in Computer Algebra. He is Editor-in-Chief of the London Mathematical Society's Journal of Computation and Mathematics, and on the Editorial Board of the Journal of Symbolic Computation, and was Treasurer of the European Mathematical Trust.

Prof. Davenport is Project Chair of the European OpenMath Project and its successor Thematic Network, with responsibilities for aligning OpenMath and MathML, producing Content Dictionaries and supervised a Reduce-based OpenMath/MathML translator. He chaired the University's Working party on Mediated Learning Environments, and spearheads the University's e-Learning initiatives. He is coordinating the University's response to the European Union's Framework Six initiative.

Prof. David J. Pym is a Professor of Logic & Computation at Bath and a Royal Society Industry Fellow at Hewlett-Packard Laboratories, Bristol. His research focuses an computational logic, proof search and the philosophy of mathematics.

Role in CALCULEMUS The role of UBATH will be to supply expertise in computer algebra and deduction systems. With its good connections to industry and the mathematical publishing world, UBATH will foster the dissemination and diffusion of the network's results in the corporate world. The work on the OPENMATH content dictionaries gives a sound basis for many of the representation and integration activities in the network.

Linkages Even though UBATH is a newcomer to the CALCULEMUS network, it has long-standing contacts to many of the network partners through the OPENMATH and MKM networks. Most significantly among these is the collaboration with IUB node on content dictionaries and knowledge representation.

Researchers and Research Infrastructure James Davenport and David Pym are the principal researchers of the UBATH research team. They will be supported by Russell Bradford and Julian Padget, who are mainly responsible for tool development at the UBATH node.

Two most significant CALCULEMUS**-relevant publications:** [ABD03a, Dav02]

UPMC **Université Paris VI, France (Hardin)**

Research and Training Experience With around 300 members, the Laboratoire d'Informatique de Paris 6 (LIP6) is one of the most important computer science research laboratories in France. LIP6 covers almost all areas of computer science from computer architecture and networks to distributed systems and artificial intelligence. Started in 1998, the FoC projet is a joint effort of the Computer Algebra group and of the Proofs and Semantics group of LIP6. Its aim is to build a certified environment to design mathematical libraries. FoC provides a language with a unified framework which enables to write both specifications, programs and proofs that these programs meet their specifications. It may thus be viewed as a language for general use.

In its current state FoC provides a compiler from FoC sources towards Ocaml sources which enable programs to run efficiently. The compiler also produces Coq sources which reflect both programs and their specifications. A first distribution of the language and of a computer algebra library it provides has been done in July 2003. The efficiency of the code is comparable to that of the best computer algebra systems. Recently the compiler has been extended to produce MathML documentation for the library. An OMDOC version is planned in the very near future.

Role in CALCULEMUS T. Hardin and R. Rioboo are CALCULEMUS trustees and chaired the CALCULEMUS 2003 conference in Rome. FoC members have contributed to various CALCULEMUS conferences since 1999.

Linkages Along the times researchers joined the FoC project which is now distributed across different sites. In particular the computer science research group (CEDRIC) of CNAM (Conservatoire National des Arts et Métiers) and INRIA (Institut National de recherche en Informatique et Automatique) have researchers involved in FoC.

The project also has collaboration with mathematicians from the Effective Mathematics community. In particular with D. Duval of Institut de Mathématiques Appliquées Grenoble (IMAG) and H. Lombardi of Université de Franche Comté. The project has also very strong links with C. Kirchner of INRIA Lorraine and G. Dowek of École Polytechnique inside the Modulogic research effort on software safety.

Researchers and Research Infrastructure The principal researchers for FoC are T. Hardin (LIP6), Renaud Rioboo (LIP6), M. Jaume (LIP6), V. Menissier-Morain (LIP6), D. Doligez (INRIA), P. Weis (INRIA), O. Pons (CNAM), D. Delahaye (CNAM). Several young researchers (phd/postdoc) are also involved in the project.

The FoC group will provide a certified library for real algebraic numbers and sub-resultant computations (task 4). FoC will also continue its efforts on open mathematical documents (task 1). Recent FoC developments within Modulogic will enable us to consider industrial secure applications (task 5).

The team will benefit from the organizational infrastructures of LIP6 which has been present in many European Projects. Being a major computer science laboratory, LIP6 has experience in the management of academic and industrial contracts. The project itself has already been in the MKM EU FP5 project and involved in many collaborations with other institutions.

Two most significant CALCULEMUS-relevant publications: [PD02, BHR01]

IUB **International University Bremen, Germany (Kohlhase)**

Research and Training Experience The International University Bremen is a newly founded private university modeled after the Anglo-Saxon model for higher education institutions. Michael Kohlhase has been a group leader of the ΩMEGA project in the years 1996-2000. He is one of the co-founders of the CALCULEMUS-I Network and has served as its initial coordinator until he became an Associate Professor and Heisenberg stipend at Carnegie Mellon University in the years 2000-2003.

Michael Kohlhase is the lead developer of the OMDOC format for content-based mathematical knowledge management. This XML-based representation format extends the OPENMATH and MathML standards by an infrastructure for mathematical statements and theories, leading to an integrated framework for representing and manipulating mathematical knowledge. The format is used in a variety of projects ranging from formal mathematics (e.g. the MIZAR, PVS, and NUPRL systems) to e-learning systems like the ACTIVEMATH. The MBASE, a mathematical knowledge base system based on the OMDOC format is developed in cooperation with the USAAR node.

Michael Kohlhase is a member of the executive committee of the OPENMATH society, the MathML Working Group at W3C, a trustee of the Conference of Automated Deduction (CADE) and a general editor of the QPQ journal of deductive software components.

Role in CALCULEMUS The IUB node supplies the CALCULEMUS network with expertise in automated reasoning, mathematical knowledge representation, content-based e-learning techniques, and Internet standards for mathematics and the semantic web. IUB will collaborate in: **(Task 1)** Michael Kohlhase has been involved in resurrecting the ANALYTICA II system, a theorem proving system for 19^{th} century mathematics implemented on top of the MATHEMATICA system and probably features the tightest interaction of CAS and DS techniques currently on the market. **(Task 2)** In the MBASE mathematical knowledge base we intend to study the collaborative management of distributed mathematical knowledge, based on a structured difference management approach. **(Task 3)** IUB is the task leader of this task, and contributes experience in interoperation by protocols. **(Task 6)** The OMDOC format has been used as a basis for several e-learning systems in mathematics and computer science. We want to explore, how theory-morphisms can be used to foster re-usability of structured course materials and user-adaptability by exploiting the formal relationships between the induced mathematical domain theories.

Linkages IUB and has strong ties with almost all of the CALCULEMUS partners, most prominently USAAR (collaboration on MBASE, OMDOC, and ACTIVEMATH) UWB (collaboration on an OMDOC interface for MIZAR), TUE, UBATH, on OPENMATH development and system interoperability, and finally UBIR and UED on deduction systems and proof planning.

IUB also brings excellent contacts to North American research groups involved in CALCULEMUS-type research: the automated deduction group at Carnegie Mellon University (Co-PI on Project "Logosphere"), and the Open Learning Initiative (Co-PI on Project "Course Capsules") there, the NUPRL group at Cornell, (cooperation on formal digital libraries), the PVS project at SRI International (dito), Yale University (dito), and finally the Connexions project at Rice University (collaboration on a content-based e-learning repository system).

Researchers and Research Infrastructure The principal researcher of the IUB partner is Prof. Dr. M. Kohlhase, who has moved to IUB in September 2003. The research group will initially consist of himself, a post-doc researcher, and a pre-doc researcher, which will be funded by the university. Negotiations with two researchers from deduction systems and knowledge representation are under way, but not finalized. We expect the individuals to start early in 2004.

The research group is currently involved in building up a competence center on e-learning together with the IUB Information and Resource Center (IRC, Diann Rusch-Feja), the IUB vice-president Prof. Dr. Raymond Wells (mathematics), and the Alfred Wegener Institute at Bremerhaven (AWI), and the Connexions Project at Rice University. The techniques to be employed there (OMDOC, MBASE,...) are strongly related to the knowledge representation techniques in CALCULEMUS and we will profit from the infrastructure of this center, once it is operational.

Two most significant CALCULEMUS-relevant publications: [Koh03, KF01]

B3.2. Intensity and Quality of Networking

The strong networking activities of the current CALCULEMUS-I network as described in [BH03] will be further strengthened in CALCULEMUS-II. The concrete measures include: the CALCULEMUS schools, the symposia, the network meetings, task force meetings, smaller workshops and tutorials, and the exchange of senior and young researchers. Furthermore we will exploit other events organized by research initiatives and projects our network nodes are involved in or collaborating with. Examples of such events are displayed in Table 8 in Section B5. The good networking in CALCULEMUS-I lead to an excellent joint publication record; see Tables 10 and 13 in Section B8 and the publications referenced in [Ben03b, Ben03c].

Generally the organisation of CALCULEMUS-II networking measures and progress monitoring are controlled by the Executive Committee resp. Training Committee and the coordinator. Task force meetings are organized by the task force leaders and smaller workshops and tutorials by the heads or team managers of the participating nodes. The coordinator together with the Financial Committee in all cases will control the imposed financial budget issues.

UWB, a partner node from a less favored region has been successfully integrated in CALCULEMUS-I. In consequence, the node gathered experience needed to participate in other European projects like TYPES and the Euro-American consortium MKMNet, initiated mainly by researchers from CALCULEMUS. In this case, participation in CALCULEMUS helped gaining better knowledge of European administration policies and breaking the psychological barrier preventing nodes from less favored regions from joining European structures. This experience fostered a European Regional Development Grant of about 4 Million Euro which UWB received in 2003 to build a new department building and a computer center. Thanks to CALCULEMUS, the mathematical knowledge base MIZAR developed at UWB, which is the world's biggest collection of formalized mathematics, has been made available, for instance, via OMDoc and MBASE, in the current network to all partners in the network. UWB is furthermore involved in joint case studies and will be organising the next Mathematical Knowledge Management conference in 2004. UWB, which is one of the small nodes in CALCULEMUS-I with limited funding, will become one of the driving forces (task leader of Task 4) and big nodes in CALCULEMUS-II.

CALCULEMUS-II wants to integrate further partners from less favored regions; the initial strategy was to associate AC3 and AC5 (see Section B3.3) as subnodes of other experienced network partners. However, since a subnode construction is not foreseen by the EU for RTNs in FP6 (see also discussion in Section B3.3) and since the network already consists of thirteen elected partner nodes we were forced to mention them as academic collaborators only.[12]

Another measure to better integrate less favored regions is to attract young researchers and lecturers ,e.g. from eastern European countries, to participate and contribute to the CALCULEMUS-II schools. Cooperations with partners from less favored regions can thereby be initiated. Such a strategy, supported by additional students and teacher participation grants, has already been successfully applied for the CALCULEMUS-I Autumn School. Unfortunately the FP5 recruitment constraints did then not allow the network to host some of the highly qualified students as young researchers in CALCULEMUS-I.

CALCULEMUS-I is already actively opposing the unfortunate fragmentation and separation of the relevant research areas. CALCULEMUS-II will strengthen this initiative and foster further international collaborations.

[12] Therefore we would welcome if the EU could revise their abolishment of the initially intended CALCULEMUS-II subnode structure as described in Section B3.3 in case of funding.

B3.3. Relevance of Partnerships Composition

The network composition of CALCULEMUS-I was already motivated by the need to join the heterogenous research, training, and system development capacities and capabilities of leading universities that share the vision of integrated mathematical assistance systems but which are approaching the goal from very different scientific angles.

The extension of partnership composition of CALCULEMUS-II with respect to CALCULEMUS-I has been exhaustively discussed among the CALCULEMUS-I partners and the enlarged composition was then decided in a formal vote; in this vote a target of twelve network nodes was envisaged in order to keep the network at a manageable size. As a result several highly qualified, motivated, and interested research teams could not be taken into account in the composition of the thirteen nodes. Since a subnode construction is not foreseen by the commission, we are aiming at integrating these research teams as academic collaborators as well as possible with respect to the commissions rules. However, a subnode solution would guarantee a better visibility and would have strengthened their identification with the network.

One goal in the extension was to reach a better balance between teams from the computer algebra area and teams from the deduction systems area. Furthermore we wanted to support the new aspects in the scientific programme (exploration of mathematics).

Academic Collaborators The collaborating individual research teams are listed in Table 6. Most of these teams have very close existing links and joint projects with some of the thirteen network nodes; some of these research teams are headed by former CALCULEMUS-I researchers (e.g. Dr. Colton, Dr. Ranise, Dr. Ballarin) which have very active links to their former affiliations.

AC1	Dr. Simon Colton, Imperial College, London, UK Speciality: Theory Exploration; Existing collaborations: UED, UBIR, USAAR
AC2	Prof. Julio Rubio-Garcia, Universidad de la Rioja, Rioja, ES Speciality: Computer Algebra; Existing collaborations: UKA
AC3	Prof. Petr Stepanek, Charles University Prague, Praha, CZ Speciality: Mathematics; Existing collaborations: UWB
AC4	Dr. Silvio Ranise and Dr. Michael Rusinowitch. INRIA Lorraine, Nancy, FR Speciality: Deduction Systems; Existing collaborations: UGE
AC5	Prof. Christoph Kreitz, Universität Potsdam, Potsdam, DE Speciality: Mathematical Assistance Systems; Existing collaborations: IUB, USAAR
AC6	Dr. Andrew Adams, The University of Reading, UK Speciality: Deduction Systems; Existing collaborations: UBATH, USAAR
AC7	Prof. Ursula Martin, Queen Mary University of London, UK Speciality: Computer Algebra
AC8	Dr. Clemens Ballarin and Prof. Tobias Nipkow, Technical University Munich, Munich, DE Speciality: Deduction, Computer Algebra; Existing collaborations: UKA
AC9	Prof. Bernd Krieg-Brueckner, Bremen University, Bremen, DE Speciality: Formal Methods; Existing collaborations: USAAR, UWB
AC10	Dr. Joris von der Hoeven, Université Paris-Sud, Orsay Cedex, FR Speciality: Computer Algebra, User Interfaces; Existing collaborations: USAAR
AC11	Prof. Andrea Asperti, University Bologna, Bologna, IT Speciality: Mathematical Knowledge Bases; Existing collaborations: TUE, USAAR
AC12	Prof. Dr. Wolfram Koepf, AG Computational Mathematics, Universität Kassel, DE Speciality: Computer Algebra and Maths Education
AC13	AC13 Dr. Paul Cairns, University College London, UK Speciality: Mathematical Knowledge Management and Interfaces; Existing collaborations: UBIR, USAAR

Table 6: The academic collaborators of the network.

The academic collaborators will be involved at a scientific level as well as at the training level. For this we want to invite them to regularly actively participate at network meetings and at training events (in particular at the planned CALCULEMUS schools). They furthermore may send selected students to other network partners or may host students for secondments in selected cases.

Industrial Collaborators The network will cooperate in particular in Task 5 with industrial collaborators in order to guarantee an early mutual scientific stimulation between the new approaches and systems developed and studied in the network and concrete industrial or near-industrial application scenarios. Positive examples for such a mutual stimulation exists in the current CALCULEMUS-I network. The concrete proposal is to send selected students to the proposed partners for some training visits after they have gained some experience within the network. A requirement for industry internships is that an interesting collaboration context (e.g. industrial case study) has been identified and clearly specified between the CALCULEMUS-II partner node, the industrial collaborator, the visiting student, and the CALCULEMUS-II Training Committee. During these visits the students remain under contract and supervision of their home network node and the CALCULEMUS-II Training Committee.

A very close link exists, for instance, to Dr. Richardson at NASA is a former researcher and doctoral student of UED. The network will regularly invite their industrial collaborators to participate at network meetings and at training events. The industrial collaborators are listed in Table 7; we mention them directly in this proposal since potential topics for case studies, i.e. student internships, are already clearly identified. Some of the network nodes have active links to further potential collaborators; their potential involvement in the network will be discussed in case interesting case studies and interested young researchers can be identified during the networks work programme.

The network is collaborating with European and North American industrial collaborators; the involvement of the latter is motivated by already existing contacts and their very active role in our field of interest.

IC1	Escher Technologies Ltd., Mallard House, Hillside Road, Ash Vale, Aldershot GU12 5BJ United Kingdom, `http://www.eschertech.com/`, Contact: Dr. David Crocker
IC2	Lemma 1, 31A Chain Street, Reading, Berkshire, RG1 2HX, UK, `http://www.lemma-one.com/`, Contact: Dr. R.D. Arthan
IC3	NASA Ames Research Center, M/S 269-2, Moffett Field, CA 94035-1000, USA, `http://www.riacs.edu/`, Contact: Dr. Julian Richardson
IC4	Intel Corporation, JF1-13, 2111 NE 25th Avenue, Hillsboro, OR 97124, USA, `http://www.intel.com/`, Contact: Dr. John Harrison
IC5	ANSALDO TRASPORTI, Via Nuova delle Brecce, 260 80147, Napoli, Italy. Contact: Pietro Marmo
IC6	SRI International, Computer Science Laboratory, 333 Ravenswood Avenue, Menlo Park, CA 94025, USA, `http://www.csl.sri.com/users/ruess/`, Contact: Dr. Harald Ruess

Table 7: The industrial collaborators of the network.

Existing collaborations amongst the network nodes and the academic and industrial collaborators The structure of the CALCULEMUS-II network builds upon and extends many existing collaborations and projects between the partners. Table 8 contains only part of them and further information is provided in the *Linkages* paragraphs of the node descriptions in Section B3.1. Examples of joint system development and joint case studies are given in Tables 11 and 12.

B4 Management and Feasibility

B4.1. Proposed Management and Organisational Structure

The proposed organisation and management of the CALCULEMUS-II network evolved from the successful structures of CALCULEMUS-I.

The network consists of 13 research teams composed of researchers of leading European universities in the field. Some of these teams have internal collaborations with other universities or research institutes. These internal collaborations result from already existing scientific cooperations between these partners. The network proposes to exploit this way of existing collaborations also in the context of CALCULEMUS-II.

The organigram in Figure 3 gives an overview on the overall structure of the proposed network.

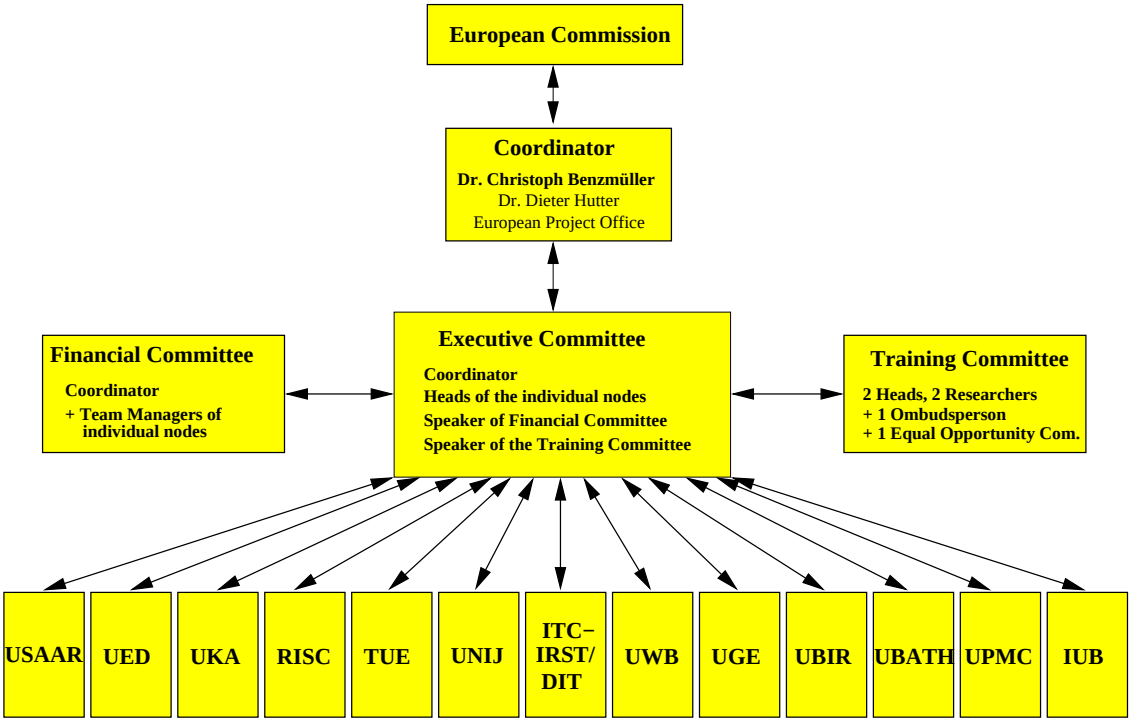


Figure 3: Organigram of the network

Coordinator The network will be coordinated by the USAAR team at Saarland University (Christoph Benzmüller) and the DFKI (Dieter Hutter) in Saarbrücken; the administrative and financial coordination will rest with the European Project Office of Saarland University, Saarbrücken. This team was fully effective w.r.t. to the coordination of CALCULEMUS-I.

The coordinator will represent the network to the EU officials and report to the Executive Committee. His role is to implement (execute) the decisions of the Executive Committee and to take minor decisions between the periodical convention of the Executive Committee. The coordinator is responsible for managing the global budget intended for the organization of event based activities.

Executive Committee Ultimate control of the network rests upon the *Executive Committee* consisting of one representative for each team, the coordinator and the speakers of the Budget and Training Committee. The head of each research team is usually also the representative of his team in the Executive Committee (exceptions are possible if good reasons exists). The Executive Committee is chaired by the coordinator and is responsible for defining the policy and for taking major decisions on the proposed network.

A kick-off meeting of the Executive Committee will take place as soon as possible after the network is granted. Subject of this meeting will be to to discuss and further refine the network policy, the recruitment strategy, and the scientific work plan, to decide on the chairs of the committees, and to decide on the chairs, scientific content and overall organisation of the first CALCULEMUS-II School to be held at the very beginning of the network.

Training Committee The Training Committee consists of two heads, two main researchers and an *ombudsperson*. The ombudsperson will be elected by the trained researchers and is usually a main researcher who is neither a head nor a team manager. The tasks of the Training Committee comprises

- to outline, specify and organize the global training measures of the network (e.g. CALCULEMUS School),
- to instantiate the networks frame for a Career Development Plan for each individual young researcher,
- to monitor the progress of individual training at individual nodes, and
- to settle disputes between trained researchers and their hosting nodes (ombudsperson).

The Training Committee is a body that did not exists in CALCULEMUS-I so far. It will be set up at the very beginning of the network (before the official start).

Financial Committee The Financial Committee consists of the coordinator and four team managers elected by the Executive Committee. The Financial Committee controls the global budget intended for the organization of central events and reports to the Executive Committee. It will work out plans to resolve upcoming payment problems. If the Financial Committee cannot agree on a common plan it will report alternatives to the Executive Committee which will finally make a decision.

Based on the experience of CALCULEMUS-I we propose that a central budget is maintained for the organisation of global training measures such as the CALCULEMUS School. The reason for this suggestion is the avoidable hassle and work load the solution in our Network causes for the coordinator and event organizers (in the CALCULEMUS-I network this budget was distributed over the partner nodes).

Research Team Organisation and Team Managers The head of each team is supported by his local administration infrastructure (secretary and administration unit of the university) and in particular by a *team manager*. A team manager has to be announced by each team at the very beginning of the CALCULEMUS-II network. They will be the contact persons for the coordinator with respect to minor scientific and organisational aspects and all technical aspects. Their responsibilities in particular include:

- to technically supervise the young visiting researchers,
- to provide and distribute information on essential peculiarities and organisational issues for young researchers visiting their team,
- mediate between the team researchers, young researchers and the coordinator,
- to assist the head of the research team in administrative and financial issues,
- to maintain the network communication infrastructure (CVS) and the research team webpages at their site,
- to keep track together with the head of important network milestones and internal deadlines, and
- to control and assist the technical aspects for the preparation of network reports and other documents.

Candidates for team managers are the experienced researchers at each site or the post-doctoral young researchers employed by the network. In the latter case an additional training aspect is provided (management of EU research network teams), however, it will be only an option in case the candidate is already sufficiently experienced in the CALCULEMUS context. The internal organisational structure of the research teams is not further constrained and the organisation and coordination of internal collaborator construction is completely under responsibility of the research teams.

Communication and Interaction Infrastructure The main communication means of the CALCULEMUS-II Network are:

- e-mail lists as they are already existing in CALCULEMUS Network.
- web-sites:
  - The network main web-page (`www.eurice.de/calculemus/`) provides various scientific, administrative, and internal information. It furthermore links to the locally maintained individual network web-sites of the different research teams.
  - The individual network web-sites of the different research teams provide an overview on their particular research tasks and their internal organisational structure.
  - Further task related web-sites provide information on the actual research progress.
  - A Concurrent Version Control System repository maintained by the coordinator at USAAR will provide access to different important network data and documents; e.g. the url `www.ags.uni-sb.de/~chris/calculemus-cvs/` provides a web-based access to the respective current data accumulated in CALCULEMUS-I. This CVS repository stores data such as the network reports, the bibliography of the research teams in bib-format, talks, publications, figures and tables, information material, etc.
- common database: Particularly the CVS repository at USAAR turns out as a very useful tool. CVS supports the *direct* joint development of documents such as the CALCULEMUS Network Report [Ben03c] and this proposal; for this purpose it has proved far more flexible and useful than information exchange solely via e-mail or web-pages.

Intellectual property issues that may arise will be addressed in the Unified Consortium Contract.

B4.2. Management Know-How and Experience of Network Coordinator

The network will be coordinated by Dr. Christoph Benzmüller at Saarland University, Saarbrücken and Dr. Dieter Hutter at the DFKI, Saarbrücken. Prof. Jörg Siekmann will provide further support. The administrative and financial project management will be carried out by the European Project Office. Saarland University's European Project Office is a professional unit dedicated to the management and administration of the University's EU-funded projects.

The working group of Prof. Jörg Siekmann at USAAR and DFKI is very experienced in managing research projects in the complete spectrum from basic research to industrial applications. The accumulated yearly budget of the research projects of the AG Siekmann at USAAR/DFKI is approx. 3-5 Million €. For instance, the group is a founder and the coordinator of the CALCULEMUS-I network and Jörg Siekmann is the chairman of the DFG Collaborative Research Centre on *Resource adaptive cognitive processes* at Saarland University.

The DFKI is member (and in some cases also coordinator) of various networks of excellence like for instance Elsnet (Language and Speech), Planet II (AI Planning), OntoWeb (Ontologies for knowledge management and e-commerce), i3net (intelligent information interfaces), AgentLink 1+2 and AgentCities (Agentbased Computing) and CompulogNet + CologNet (Computational Logic). AgentCities.NET (other actual EU-projects: SAID, AgentCities.RTD, Eutist.Ami, MOWGLI, MKMNet).

We provide some further details on the coordinator team:

- Dr. Christoph Benzmüller has studied Computer Science and Artificial Intelligence at Saarland University and at CMU, Pittsburgh, USA and he received his PhD in 1999 at Saarland University. He has been working as postdoctoral research fellow in the research groups of Dr. Manfred Kerber in Birmingham and Prof. Alan Bundy in Edinburgh. In 2001 Dr. Benzmüller joined again Saarland University as Assistant Professor (Hochschulassistent) and is since then heading the ΩMEGA group of Prof. Jörg Siekmann and coordinating the CALCULEMUS-I research training network. He is furthermore principal investigator of two projects in the interdisciplinary collaborative research centre SFB 378 at Saarland University on *Ressource-adaptive cognitive processes.*

- Dr. Dieter Hutter has studied Computer Science and received his PhD in 1991 at the University of Karlsruhe. In 1991 he joined the Saarland University to head the VSE project (development of a tool for formal software development). In 1993 he moved to the DFKI GmbH, was a EPSRC-visiting fellow of the University of Edinburgh (A. Bundy) in 1997, became a DFKI research fellow in 2000 and is now a principle researcher at the DFKI. He headed numerous projects in the areas of deduction (inductive theorem proving), formal methods (reuse, management of change) and security (security policies, information flow) at the DFKI.

- Prof. Jörg Siekmann is the head of several research groups working in artificial intelligence at Saarland University and at DFKI in Saarbrücken. He is a professor in the department of computer science and a director at the DFKI. Currently he is the chairman of the collaborative research centre *Resource-adaptive cognitive Processes* (SFB 378) of the German Science Foundation (DFG). He is the co-chairman of the network of excellence on computational logic (CoLog Net) and vice president of the international federation on computational logic (IFCoLog). His main research interests are Artificial Intelligence, Automated Reasoning, Multiagent Systems and e-Learning in mathematics.

- Saarland University's European Project Office is a professional unit dedicated to the management and administration of the University's EU-funded projects. Founded in 1999, it has steadily increased its activities and is currently involved in around 30 FP5 projects and 13 FP6 projects under negotiation, several of which it supports in coordination. Its experienced staff has an excellent track record in supporting the University's scientists in proposal submission and project execution and its contribution is being favorably recognized in many proposal evaluations and project reviews. Role: The European Project Office will support the CALCULEMUS consortium in the management of the project (administrative, legal, financial and organisational aspects of the project) in close cooperation with the coordinator. It

will contribute to the monitoring of the project work and dissemination of its results and to the quality and knowledge management for the project. Furthermore the European Project Office will be charged with the check of eligibility of research fellow candidates according to the rules of the European Commission.

This team is currently successfully coordinating the CALCULEMUS-I Research Training Network and can thus rely on its experience but also employ the already existing and well functioning coordination structure and infrastructure. Amongst the CALCULEMUS-I events that were organized by this team are particularly the CALCULEMUS Autumn School in Pisa in 2002 and the Network Review Meeting in 2003 at the DFKI in Saarbrücken.

B4.3. Management Know-How and Experience of Network Teams

UED The Mathematical Reasoning Group has had a wealth of experience managing projects which involve many universities. The primary source of funding to the group has been the "Rolling Grant" from the Engineering and Physical Sciences Research Council. This Grant has required management of funds and preparation of reports and papers. The group has experience in organising conferences and workshops such CIAO, which is a collaboration between the University of Genoa, Saarland University and Edinburgh. Edinburgh has accommodated many Young Visiting Researchers from the CALCULEMUS Network and beyond and organising at least weekly seminars.

UKA UKA is involved in the management of research projects in many forms and for many years. We limit the presentation to the research group of Jacques Calmet. The list of projects managed by the other professors at the IAKS, Profs. T. Beth, H.-H. Nagel and R. Vollmar, is much too long to be given here. It is enough to say that within IAKS, T. Beth is leading the EISS institute (European Institute on System Security). Thus, the list is limited to the management of a research group with its own resources and people. Among the projects that have been coordinated, one may cite international collaborative projects (France-USA or Germany-Brazil research projects) including an INTAS project (on involutive bases from 2000 to 2002). UKA has been partner in CALCULEMUS and in a previous European project called STEM (Sustained development). It has been part of the different versions of the network of excellence "AgentLink". It has been asked to join the network of excellence in Computational Logic "CologNet". Numerous collaborative research projects at the national level (France then Germany).

The management know-how also include the foundation 14 years ago, and management since as editor-in-chief, of a scientific journal (AAECC, Springer-Verlag). It also includes the foundation of several conferences (alone or in collaboration): Marseille conferences on application of computer algebra (CA) in theoretical physics (early 1970s), first European conference on CA (Eurocal 1982), Rhine Workshop on CA, AISC (Artificial Intelligence and Symbolic Computation) as well as chairing and organizing several major conferences in the domain of Computer Algebra from SIGSAM in 1972 in Marseilles to DISCO in 1996 in Karlsruhe.

UKA is involved in the preparation of a few consortiums for projects to be submitted to FP6. Two will have been submitted when this proposal is submitted. They are called PRE-FLOOD (Action: Improving Risk Management) and GIFT (NEST/ADVENTURE). UKA coordinates GIFT.

RISC RISC is one of the leading research and technology-transfer institutions in the field of IT-Technology in Austria. Since the early nineties, RISC founded the Softwarepark Hagenberg, founded the Software Competence Center Hagenberg in the frame of the federal Kplus-program, founded the Polytechnical College for Software Engineering, founded the Conference Center Hagenberg, and was one of the founding members of RICAM (Radon Institute for Computational and Applied Mathematics, part of the Austrian Academy of the Sciences) in Linz, Austria. Currently, RISC is also working for initiating, with Austrian seed money, an IT-park in Timisoara, West Romania.

Professor Buchberger of RISC designed and founded the Journal of Symbolic Computation in 1985 as editor-in-chief, which internationally shaped the area of symbolic computation as a central research area in the intersection between mathematics and computer science.

RISC designed, initiated (1982) and built-up an international PhD program specializing in symbolic computation entertaining permanently approximately 25 international PhD students. This program became a model for similar programs at other European, North American and Japanese PhD programs, e.g. at North Carolina State University, University of Waterloo, and University of Tsukuba.

RISC was a founding member and co-initiator of CALCULEMUS (HPRN-CT-2000-00102) and MKM (IST-2001- 37057). RISC is also a partner in the OpenMath Thematic Network (IST-2000-28719) and organizer of a couple of other EU-projects like INTAS, COASTER, and MOST. RISC is leading partner in the "Spezialforschungsbereich Numerical and Symbolical Scientic Computing" (SFB F013 of the Austrian National Science Foundation FWF).

TUE The team at TUE has a long experience in projects related to computer algebra and interactive mathematical documents. This experience dates back to the beginning of the nineties, when RIACA came into existence. RIACA has coordinated the first big network of computer algebra centers in Europe, leading the CAIN network.

In order to be trained in computer algebra and the management of interactive mathematical documents, several students completed internships at RIACA.

RIACA's activities related to OpenMath involved a large amount of coordination and management. RIACA has been actively involved in many national and European projects, notably, the OpenMath ESPRIT project, the OpenMath Thematic Network (IST-2000-28719), and the Monet project (IST-2001-34145). The production of Algebra Interactive is an outgrowth of RIACA's collaboration with Springer Verlag, Heidelberg, in the OpenMath ESPRIT project.

In this context, several workshops have been organized, and joint reports have been written.

UNIJ The Foundations team at the UNIJ has a lot of experience in participating in national and EU projects. At present we participate in the CALCULEMUS-I network, as a sub-site of TUE and in the EU-IST-FET project MOWGLI, with USAAR, TUE (as a sub-site of UNIJ), INRIA (F), Bologna (I) and Berlin (D). We have just finished cooperation in the Types Working Group. UNIJ organised one of the annual Types Workshops of this working group. This working group may be continued as an EU-IST Coordinated Action, the proposal for which has been co-authored by Geuvers, who is a member of the Types Steering Committee. Finally we are part of the MKMNet application for a Network of Excellence.

ITC-IRST/DIT has a long experience in both participating and coordinating both research and technology transfer projects. In particular, the ITC-IRST team has a well-consolidated experience with EC-funded projects, among them we mention ESACS (G4RD-CT 2000-00361), DATAGRID (IST-2000-25182), AGENTLINK II(IST-1999-29003), PLANET II (IST-2000-29656), and many others. The DIT team has also a wide experience with national projects funded by MIUR, ASI, FIRB and local government (e.g., SACSO, EDAMOK, KLASE), and organizes an Indian-Italian network for students exchange.

As an institution, ITC-IRST has a long experience of both participating and coordinating both research and technology transfer projects, and has also an experienced administrative structure. The complete list of 5FP EC projects in which the whole ITC-IRST is involved is CALCULEMUS (HPRN-CT-2000-00102), NESPOLE! (IST-1999-11562), M-PIRO (IST-1999-10982), RENAISSANCE (IST-1999-12163), ECHO (IST-1999-11994), AH2000 (HPCF-CT-1999-00204), CLASS (IST-1999-12611), CORETEX (IST-1999-11876), PRESTO (IST-1999-20013), PRIMAVERA (IST-1999-20408), ILSIMS (IST-1999-20199), CORALROM (IST-2000-26228), ESACS (G4RD-CT 2000-00361), HARMONISE (IST-2000-29329), DIETORECS (IST-2000-29474), FAME (IST-2000-28323), DATAGRID (IST-2000-25182), VICO (IST-2000-25426), AGENTLINK II (IST-1999-29003), PLANET II(IST-2000-29656), HAHAcronym (IST-2000-30039), HOMEY (IST-2001-32434), IMPULSE (IST-2001-32061).

ITC-IRST/DIT team members have a consolidated experience in the organization of major conferences, including Sixth International Conference on Principles of Knowledge Representation and Reasoning (KR'98), the 1999 Federated Logic Conference (FLOC'99), 13Th International Conference on Automated Planning & Scheduling 2003 (ECAPS'03). One member will be the General Chair of the International Joint Conference of Artificial Intelligence in 2005.

DIT organizes with the collaboration of ITC-IRST the *International ICT Graduate School* for PhD students, hosting about one hundred PhD student, which would be a natural source of Young Visiting Researches for other nodes.

UWB has considerable experience with coordinating research in long-term projects. For 30 years we have been developing the MIZAR system. This task includes among other things: coordination of the system implementation process, collaboration with more than a hundred authors of MIZAR articles, and also scientific exchange.

- In years 1986 – 1991 we coordinated Central Research Project granted by Polish Ministry

of Science "Logical Systems and Algorithms for Computer Testing Correctness of Proofs". It required coordination of a big network of scientific teams from 12 Polish Universities.

- UWB organized the following conferences:
  - "QED Workshop II", Warsaw, 1995, `http://www-unix.mcs.anl.gov/qed/index.html`
  - "Computer Reconstruction of the Technology of Mathematics", Bialystok, 1998.
- We have been coordinating and maintaining the process of submission of new articles into MIZAR Mathematical Library (MML) and also distributing the MIZAR software.
- We organize MIZAR training courses for foreign participants.
- Since 1990 we have been publishing the journal *Formalized Mathematics*, ISBN 1426-2630.
- We have participated in a series of foreign scientific grants: Office of Naval Research (N00014-95-1-1336, N00014-97-1-0777), NATO (CRG 951368), FP5 (IST-2001-37057, IST-2001-35447, IST-1999-29001), and grants founded by Polish Committee for Scientific Research (8 T11C 018 12, 4 T11C 039 24).
- We established SUM (the Association of MIZAR Users, `http://mizar.org/sum/`) with the aim of popularizing, propagating and promoting the MIZAR language. The Association is the holder of all copyrights on the MIZAR system and MML. The Japanese Circle of SUM publishes the journal *Mechanized Mathematics and Its Applications*, ISSN 1345-82722.

UWB employs well-qualified administrative staff responsible for organizing research, scientific exchange, and financial service.

UGE The AI-Lab at the University of Genova (Italy) is currently involved in several national and EU-funded projects such as CALCULEMUS-I (HPRN-CT-2000-00102), the EU-funded project AVISS (IST-2000-26410). Moreover the group is the coordinating node of the EU-funded project "Automated Validation of Internet Security Protocols and Applications" (AVISPA) IST-2001-39252, of a national project on a related topic and of a project for the internationalisation of PhD programs. The group leader, Dr. A. Armando, is member of the Steering Committees of the "First Order Theorem Proving" and of the "Frontiers of Combining Systems" Workshop Series as well as of the "International Joint Conference on Automated Reasoning" (IJCAR). He has been program committee member of a number of international workshops and conferences and program chair of the 4th International Workshop on Frontiers of Combining Systems (FroCoS 2002).

The laboratory will benefit from the administrative support of DIST, which has a long record of international projects (more than 70 EU-funded projects since 1984).

UBIR The Automated Reasoning Group at the University of Birmingham has been involved in the CALCULEMUS-I network (HPRN-CT-2000-00102) as well as the MKM-Net on Mathematical Knowledge Management (IST-2001-37057). The members of the group held several EPSRC/UK projects over the years and several applications relating to the work of the group are currently underway. By the end of CALCULEMUS-I the School will have hosted 4 Young Visiting Researchers.

The group is supported in the administration of all research projects by the administrative and clerical staff of the School of Computer Science and the financial office of the University of Birmingham. Both units have a vast experience in dealing with European projects of various sorts on various levels. While the administrative staff of the School usually deals with the day to day issues of the project management and gives pastoral support to the Young Visiting Researchers, the financial office is concerned with the contractual and financial issues of the project.

UBATH The Department of Computer Science at UBATH has been involved in EU-funded projects since 1986, has coordinated several EU projects. Most recently VIM: A Virtual Multicomputer for Symbolic Applications (CHRX-CT93-040) and Platform for Animation and Virtual Reality (ERBFMRX-CT96-0036) and the Mathematical Knowledge Management Network (IST-2001-37057). Prof. Davenport has also chaired two EU projects. In Prof. Davenport, the University of Bath provides the Editor-in-Chief of the London Mathematical Society's Journal of Computation and Mathematics: a fully refereed electronic journal, with a full-text search engine.

UPMC As a leading research institution, Université Pierre et Marie Curie (UPMC) has a long experience in participating and coordinating research and technology transfer projects. It also has experienced administrative staff managing many EC projects. The Laboratoire d'Informatique de Paris 6 (LIP6) is the main computer science research department of UPMC and its 300 researchers deal with all parts of computer science from Computer Architecture to Artificial Intelligence. LIP6 is involved in a dozen of EC projects. The FoC project has been initiated by the Computer Algebra (CALFOR) and Sémantique preuves et Implantations (SPI) teams of LIP6. The FoC project has now many national collaborations and is currently involved in FP5 IST-08-8-1B MKMnet project.

IUB Prof. Michael Kohlhase has been involved in various EU projects, he is one of the co-founders of the CALCULEMUS consortium and has served as the initial coordinator of the CALCULEMUS-I training network. IUB is a node in the OPENMATH thematic network (IST-2000-29719).

B5 Relevance to the Objectives of the Activity

The CALCULEMUS community is a driving force in reverting the increasing fragmentation in the research communities addressed by the work programme. Our vision of future mathematical assistance systems proposes a common frame for the integration of the heterogenous tools with complementary strength developed in the niches of these research communities. As illustrated in Figure 4 the enterprise can be seen as a challenging puzzle where some of the puzzle pieces are not even correctly shaped or known yet.

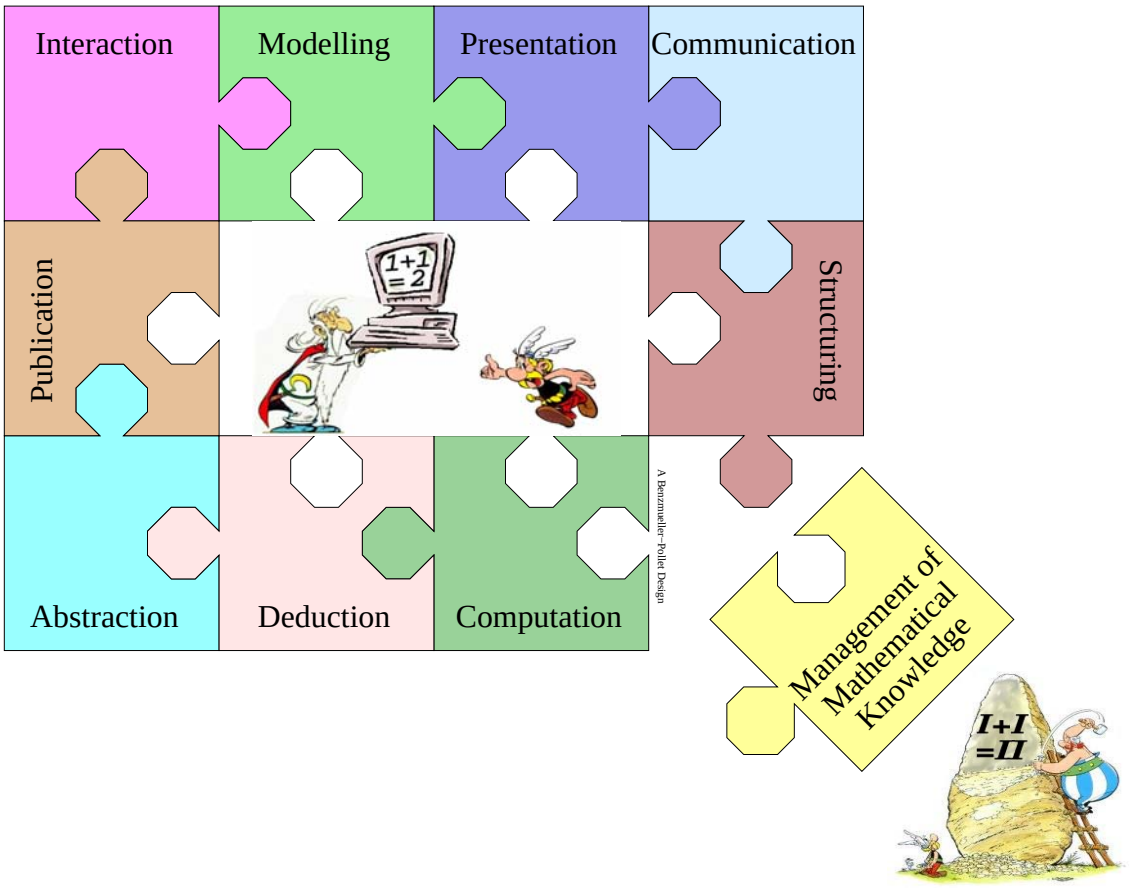


Figure 4: Integrated mathematical assistance environment as a puzzle challenge

The transition from ancient pen and paper representation of mathematical knowledge to digitalized and finally semantically represented representations (puzzle piece in lower left corner) is thereby a key issue. With increasingly rich knowledge bases of formalized mathematics being available the integrated mathematical assistance environments we propose will gain on impact and success.

The CALCULEMUS-II network even more than CALCULEMUS-I takes on the challenge to integrate the involved research niches and the focus thereby is on the education aspect: our research field needs a generation of new young researchers that have both, deep expertise in one or a few niches and at the same time a good overview on the complex puzzle challenge as a whole. The latter aspect is unfortunately not adequately represented (anymore) in the training measures and conferences of the fragmented research communities, and the focus is often on isolated tool development only (this is for instance the case for some of the systems participating in the yearly CASC competition at CADE conference). The situation is thus similar to that of the AI field as a whole and as it was criticized by Nils Nilsson (Kumagai Professor at Stanford, USA) in his speech at IJCAI 2003 where he received the IJCAI Research Excellence Award.

CALCULEMUS-II therefore proposes training structures and means that add an important complementary dimension to the sophisticated training means already provided in each of the niches. With CALCULEMUS-II Europe will further improve its leading role in our field even though CALCULEMUS researchers also fostered the MKM initiative which again fostered MKM North America.

The CALCULEMUS-I and CALCULEMUS-II research programmes are defined with the aim to subsequently increase the join of resources — not only in terms of joint case studies (see also Table 12) but in particular with respect joint system development and tool exchange (see Table 11). This clearly fosters long-term and durable collaborations for the future which are often not easily revertible. Many examples for smaller projects that concentrate on very specific aspects of joint research and tool development have been fostered; examples are given in Table 8.

CALCULEMUS **Interest Group and Symposia** (`http://www.calculemus.net/`) Involved: all partner nodes, many of the collaborators
CALCULEMUS**-I network** (`http://www.eurice.de/calculemus/`) Involved: ten partner nodes, many of the collaborators
MKMNet FP5 Network (`http://monet.nag.co.uk/mkm/index.html`) Involved: UBATH, UBIR, UPMC, USAAR, RISC, UWB, AC11
MKM Symposia (`http://www.cs.unibo.it/MKM03/`) Involved: majority of the partners, many of the collaborators
MONET EU IST project, (`http://monet.nag.co.uk/cocoon/monet/index.html`) Involved: TUE, UBATH
Workshop on Mathematics on the Semantic Web organised by TUE in May 2003, (`www.win.tue.nl/dw/monet/`) Involved: all partners
MoWGLI EU IST project, (`http://www.mowgli.cs.unibo.it/`) Involved: AC11, USAAR, TUE
Types EU IST project, (`http://www.dur.ac.uk/TYPES/`) Involved: UNIJ, UWB
CLAM-INKA-OMRS Workshops (`http://www.dfki.de/CIAO-2003/`) Involved: UED, USAAR, UGE, UBIR, ITC-IRST/DIT
Theorema-ΩMEGAWorkshops (`http://www.ags.uni-sb.de/~omega/workshops/TheoremaOmega03/`) Involved: RISC, USAAR
Accredited joint PhD program Involved: UGE, AC4, UED
EPSRC grant A MathWEB Service for PVS Involved: AC6, USAAR
2K* Symposium Annual event since 1995, (`http://peano.mrg.dist.unige.it/2Kstar/2003/`) Involved: ITC-IRST/DIT, UGE
Working group Graph isomorphism Involved: TUE, UBIR, USAAR

Table 8: Examples of existing collaborations and projects.

B6 Added Value to the Community

The 2503rd Council Meeting *Education, Youth and Culture* in Brussels, 5 and 6 May 2003, 8430/03 (Presse 114) states that: "In the area of mathematics, science and technology the European Union needs an adequate output of scientific specialists in order to become the most dynamic and competitive knowledge-based economy in the world. The need for more scientific specialists is underlined by the conclusion of the Barcelona European Council (2002) that overall spending on R&D and innovation in the union should be increased with the aim of approaching 3% of GDP by 2010". The report suggests that "Therefore, the total number of graduates in mathematics, science and technology in the European Union should increase by at least 15% by 2010 while at the same time the level of gender imbalance should decrease".

The above quotation is in particular relevant in the area of software development and computer science in general. While Europe has by and large lost its competitive edge in computer hardware, the development of highly specialized software is still vital in Europe. As most of the current low level software developments are now carried out in India and more recently in China, high quality and in particular ultra dependable software is still an important and strongly growing sector of the software market where Europe is dominant, albeit with a severe labor shortage.

The research topic and training programme of the CALCULEMUS-II network is addressing this objective at its core in two aspects:

Firstly, CALCULEMUS-II research combines mathematics, computer science, and modern web-based information technology and the ultimative goals are novel, dynamic, and knowledge-based assistance environments for the verification of safety and security properties of soft- and hardware components, for mathematics research and education, and its industrial applications. In the long-run CALCULEMUS-II aims at a lasting change of mathematical practice, not least in the sense that powerful computer- and knowledge-based infrastructure for mathematics research and education will become better accessible.

Secondly, the CALCULEMUS-II training network will train and educate a new generation of scientists in the range of computer-supported mathematics, computer science and knowledge-based technologies. As implemented by the options in the networks vertical training axis our young researchers may choose between training measures that are directed towards a career in academia or industry.

Our knowledge- and web-based integrated mathematical assistance environments are intended to foster novel approaches in education technology. Some of our systems are coupled with E-learning environments and are already applied at university level mathematics education (see also Task 6). E-learning has been identified as a promising means, for instance, to address gender issues and, in particular, to address equalization of opportunities for persons with disabilities.

In our network we already exploit our systems to address equalization of opportunities for persons with disabilities: some students (mostly distant learning) at UWB are taught by using the MIZAR system by e-mail. It started with a student who is deaf and meanwhile there are six such students.

The aim of our network is to overcome educational, sociological and technological boundaries and to join resources in order to tackle the CALCULEMUS challenge of building integrated mathematical assistance systems. Thereby we contribute to the improvement of the cohesion of the European Union on different levels, ranging from technological aspects such as joint system development and application to joint PhD curricula between universities of different nationality.

B6.1 Management of Gender Equality

Any strategy aiming at a wider participation of women in the field of mathematics, science and technology in the European Research Area has to take into account the main reasons for the existing gender imbalance in this field which are:

First, girls and boys still follow traditional ideas of alleged typically female and typically male professions and qualities, when they select subjects at school and also at university level; mathematics, science and technology do not count as typically female neither for children nor for their teachers and parents. Second, traditional gender roles keep on existing and especially

women still experience enormous difficulties to reconcile a working and scientific career with family / household life and often feel forced to decide whether to become mother or scientist.

The focus of the CALCULEMUS-II programme lies on research and training in the field of mathematics. The involved mathematicians and other scientists are by no means experts in the field of gender equality management. They are nevertheless interested in gender activities and want to integrate an effective gender management into the programme in order to gain the most qualified young researchers be they male or female. The measures to decrease the gender imbalance proposed in this section have therefore been elaborated in cooperation with Bärbel Miemietz, the head of the woman's affairs office at Saarland University; she is interested in consulting the Network in this respect.

The following overall measures to increase the gender balance are planned:

- The coordinator will guarantee a gender main-streaming management, which means that the gender perspective is integrated in every decision to be taken.
- Gender disaggregated statistics are run on researchers and collaborators. The statistics will be available on the network's main web-page and the annual report will contain gendered data on the persons involved.
- The language of the programme is intended to be gender neutral (e.g. ombudsperson instead of ombudsman). All first names in all documents are written in full form.
- A training course / information event will be organised at the beginning of the network (e.g. at the first CALCULEMUS-II School). The aim is to raise the awareness of gender issues in the Network and to discuss possible measures and instruments to decrease the gender imbalance at the partners sides. The event will also include a discussion on the situation of women in the very different countries involved in the CALCULEMUS-II network.

The following measures are planned to increase the participation rates and to enable and to encourage women to apply for positions:

- Any position to be filled in the CALCULEMUS-II network will be announced — additionally — also through specific womens' networks existing e.g. in Germany for the commissioners of womens' affairs at universities (BuKoF - Bundeskonferenz der Hochschulfrauenbeaufragten) and for different kinds of science / technology (e.g. FiNuT - Frauen in Naturwissenschaft und Technik; Deutscher Ingenieurinnenbund).
- Any woman who applies for a position in the network will be invited for a presentation, irrespective of her concrete profile, as long as she has high ranking certificates in one of the associated fields. If not appropriate for the announced position, a prospect to work with any of the project partners will be looked for. At least she will be encouraged to complete scientific education and to stay in connection with the CALCULEMUS-II network.
- If possible / if wanted a contact with a female professor should be offered to young women researchers in order to establish a mentoring relation.

To facilitate the reconciliation of work within the programme with family life and especially with the raising of children the following measures are taken:

- Women are generally encouraged in staff interviews to continue their career in mathematics at any rate, even if they plan to have children and to concentrate on family life.
- Additionally (future) fathers are encouraged to share the parental leave with (future) mothers within or not within the programme.
- The members of the CALCULEMUS-II network support all kind of activities that are meant to improve the childcare facilities at their home universities, institutions and so on.
- The nodes and the collaborators provide opportunities to keep or nurse children in urgent and unexpected cases of childcare need at work.

- It is taken into account that flexibility of working time, part-time work and working at home should be guaranteed.

The partners and collaborators of CALCULEMUS-II take part in local activities supposed to increase the interest of girls in mathematics, science and technology (e.g. the so-called "Girls' day" in Germany). They encourage young women researchers to become a mentor for women students or even school girls.

The network partners and collaborators are open for gender studies and allow researchers with e.g. a sociological, psychological or historical background to conduct field research in gender studies (e.g. in the field of history of women in mathematics) and in gender specific didactics.

B7 Indicative Financial Information

Network Team	Contribution to the research/training/transfer of knowledge expenses		Management activities (including audit certification)	Other types of expenses/ specific conditions
	(A)	(B)	(C)	(D)
1. USAAR	336147.00	45000	190000	0
2. UED	18147.15	0	6000	0
3. UKA	14114.45	0	0	0
4. RISC	18147.15	0	0	0
5. TUE	16130.80	0	0	0
6. UNIJ	14114.45	0	0	0
7. ITC-IRST/DIT	16130.80	0	0	0
8. UWB	18147.15	0	0	0
9. UGE	16130.80	0	0	0
10. UBIR	14114.45	0	6000	0
11. UBATH	14114.45	0	6000	0
12. UPMC	14516.15	0	0	0
13. IUB	14114.45	0	0	0
Totals	524069.25	45000	208000	0

Table 9: Indicative financial information on the network project in €

The expenses of the CALCULEMUS-II-network for activities not related to the appointment of early-stage and experienced researchers we plan to allocate are as follows: 7.6% of the total budget will be allocated to the networks event based training program. This budget will partly be used to invite international experts and to cover expenses of young participants to workshops, symposia and the CALCULEMUS Schools ($2 \times 50,000$€). The Autumn School 2002 in Pisa was already very successful in the CALCULEMUS-I project (`http://www.eurice.de/calculemus/autumn-school/getting_started.html`). They will take place for about 10-14 days. During these schools the research fellows have the opportunity to present their work and discuss it with other researchers. Furthermore the budget envisaged for these schools covers also the funds to invite experts with international reputation on the relevant fields of research. The topics of the training sessions will particularly address scientific knowledge generated within the network, but will also cover research management, international project management as well as business career development. Supplementing the CALCULEMUS schools there will be a large variety of workshops nationally and locally organised by CALCULEMUS-II members ($6 \times 7,000$€). These workshops will be smaller and organised also between the partner institutions. They will focus on a clearly defined subject. Furthermore it is planned to organize an invited talk once a year to the CALCULEMUS Symposia ($4 \times 5,500$€) as well as three Network meetings ($3 \times 18,000$€) where all partner institutions should participate to organize and monitor the further project development. The budget envisaged for the training activities will be allocated to the network coordinator. Another part of the budget will be used to enable our young researchers to participate in other workshops organised within the network (100,000€). This budget will be managed by the coordinator (USAAR) in Saarbrücken. Another 1.5% (45,000€) of the total budget will also be allocated to the coordinator for maintaining the webpages and databases, and for items such as costs for publications and exchange of information and materials. 6.9% (208,000€) will be required for the management (including the audit certification) of the whole project and will be thus assigned to the coordinator who will be supported by the European Project office of Saarland University. This budget will be used for the administrative and financial coordination of the network including activities such as contacts with the European Commission, day-to-day financial monitoring and management,

cost and project reporting, contract management and organisation of schools and the network meetings. About 6.7% of the budget will be allocated to the different teams according to Table 9. This will cover expenses of secondments between teams and for the participation of team members in networking training activities. The 10% overhead of the direct costs for the proposal will be allocated to the teams proportional to their part of the total budget. The numbers in the table are indicative and based on the calculation that the 512 person months of appointments will cost 1,950,000€ (to 65% of the total budget). With 569,069€ for research/training and transfer of knowledge expenses (A+B in Table 9), 208,000€ for management (C in Table 9) and 272,706€ for overhead, this adds up to a total budget of 2,999,776€.

B8 Previous Proposals and Contracts

B8.1 Predecessor Project: CALCULEMUS-I

Network Acrynym: CALCULEMUS

Contract Number: HPRN-CT-2000-00102

Contract Period: 01/09/2000-31/08/04

The present proposal is based on and extends the current CALCULEMUS-I network financed in the frame of the FP 5 Human Potential Programme. CALCULEMUS-II is intended to start a few months after CALCULEMUS-I expires such that a smooth transition is guaranteed. The main research objective of the CALCULEMUS-I network was to foster the integration of deduction systems and computer algebra systems both at a conceptual and at a practical level. Since its start in September 2000, CALCULEMUS-I has contributed to the convergence of DSs and CASs through its research on unifying frameworks for encoding and on combining computation and deduction, the identification of the architectural requirements for a new generation of reasoning systems and the prototypical implementation and application.

The extensive research activities of the CALCULEMUS-I network is visible not least in the list of publications of the network within the first 30 months period. Table 10 provides an overview on these publications. Joint publications are those with at least two authors with affiliations from different network nodes, most authors range high resp. very high on the international cite-seer index.

	Joint Publications	All Publications
Refereed Papers		
- Journals	7	22
- Proceedings/Books	33	54
Technical Reports	4	13
PhD Thesis		3[a]
Others		4
Total	44	96

[a]This are only the PhD thesis from young researchers that were directly employed in the network. Further PhD theses (approx. 10) have been finished within the period by students which benefitted from the network but which were not directly employed.

Table 10: Publications in CALCULEMUS-I from 8/2000 until 2/2003

Its productivity is furthermore shown in its various network activities. CALCULEMUS organized the following international events: annual CALCULEMUS Symposia (2000 in St. Andrews, Scotland, 2001 in Siena, Italy, and 2002 in Marseilles, France) and the CALCULEMUS Autumn School 2002 in Pisa, Italy. Table 13 summarizes the proceedings resulting from these meetings.

CALCULEMUS-I aims at the integration of DS and CAS. As a consequence joint efforts of the network were spent in the development and enhancement of existing computer algebra systems and deduction systems by turning them into open systems capable of using and providing mathematical services. CALCULEMUS-I investigated both, the enhancement of Computer Algebra Systems by reasoning power as well as the enhancement of Deductive Systems by computation power.

Table 11 illustrates the joint system developments of the CALCULEMUS-I partners. It illustrates the impact of the research training network in joining forces. Especially the decision to jointly develop and employ systems and tools stimulates lasting and durable collaborations.

These systems are evaluated and tested with the help of application scenarios given in Table 12. Some of these examples were done either by single partner nodes or in collaboration between different nodes.

The network's high dissemination activity is also illustrated by the various proceedings edited by network researchers and supported by the network. An overview is provided in Table 13.

System, Language, Software	Developed/used at the following nodes
OMDOC	USAAR,UBIR,UED,UWB, UPMC
MathWeb	USAAR,UBIR,UGE,UED, UPMC
ΩMEGA	USAAR,UBIR
MIZAR	UWB,TUE
MathSat	ITC-IRST/DIT,UWB
TSAT++	UGE
COQ	TUE,UNIJ, UPMC

Table 11: Joint system development and application in CALCULEMUS-I

Application	performed by the following nodes
Exact real arithmetics	UPMC
Irrationality of $\sqrt{2}$	TUE,USAAR,UWB,RISC
Exploration of Residue Classes	USAAR,UBIR,UED
Permutation Groups	USAAR,UBIR,TUE
Zariski Spaces	UBIR,UED
Hybrid Systems	USAAR,UGE,UED, ITC-IRST/DIT
Correct Functions in MAPLE	UKA,UED,UGE
Formal Analysis of Security Protocols	UED,UGE,ITC-IRST/DIT
Model Checking for Real-Time Systems	ITC-IRST/DIT,UWB,UGE
Temporal Reasoning	ITC-IRST/DIT,UGE

Table 12: Joint applications and case studies in CALCULEMUS-I

B8.2 Other Projects

Two closely related EU research projects in the IST programme are MoWGLI and MONET. The CALCULEMUS-II research training network will continue the already existing cooperation of CALCULEMUS-I with these research projects. Some of the CALCULEMUS-II researchers are directly involved in these projects. MoWGLI and MONET describe their project objectives as follows:

The World Wide Web is already the largest resource of mathematical knowledge, and its importance will be exponentiated by emerging display technologies like MathML. However, almost all mathematical documents available on the Web are marked up only for presentation, severely crippling the potentialities for automation, interoperability, sophisticated searching mechanisms, intelligent applications, transformation and processing. The goal of the project is to overcome these limitations, passing from a machine-readable to a machine-understandable representation of the information, and developing the technological infrastructure for its exploitation. MoWGLI builds on previous standards for the management and publishing of mathematical documents (MathML, OpenMath, OMDoc), integrating them with different XML technologies (XSLT, RDF, etc).

The aim of the MONET project[13] is to offer mathematical algorithms through web services that can be accessed from a wide variety of software packages. The challenge is to develop a framework in which such services can describe their capabilities in as much detail as is necessary to allow a sophisticated software agent to select a suitable service based on an analysis of the characteristics of a user's problem.

MONET wants to demonstrate the applicability of the latest ideas for creating a semantic web to the world of mathematical software, using sophisticated algorithms to match the characteristics of a problem to the advertised capabilities of available services and then invoking the chosen services through a standard mechanism. The resulting framework will be powerful, flexible and dynamic, yet robust and easy to navigate, putting state-of-the-art algorithms at the disposal of users anywhere in the world.

[13] `http://monet.nag.co.uk/cocoon/monet/index.html`

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• A. Armando and T. Jebelean, editors. CALCULEMUS-1999. Electronic Notes in Theoretical Computer Science, Volume 23, Issue 3, 1999. • M. Kerber and M. Kohlhase, editors. CALCULEMUS-2000. AK Peters • S. Linton and R. Sebastiani, editors. CALCULEMUS-2001. • J. Calmet et al., editors. CALCULEMUS-2002, LNAI 2385. Springer • O. Caprotti and V. Sorge, editors. CALCULEMUS-2002-Work-in-Progress. • Th. Hardin and R. Rioboo, editors. CALCULEMUS-2003. MMIII ARACNE EDITRICE S.R.L.
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Proceedings of CALCULEMUS Autumn School
• C. Benzmüller and R. Endsuleit, editors. Autumn School 2002: Course Notes (Part I-III) • J. Zimmer and C. Benzmüller, editors. Autumn School 2002: Student Poster Abstracts

Table 13: Proceedings in CALCULEMUS-I

B9 Other Issues

Ethical or safety issues do not apply.

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Appendix: Letters of Support from Industrial Collaborators[14]

[14]Due to administrative problems the letter of support from NASA, USA, did unfortunately not reach us in time to be included in this proposal. However, it can be provided upon request.

ker To: Christophe Benzmueller Date: 19/11/2003 Time: 16:53:02 Page

ESCHER
TECHNOLOGIES

Christoph Benzmueller
AG Deduktionssysteme
FR Informatik
Universität des Saarlandes
D-66041 Saarbrücken
Germany

Fax +49-681-302-5076

Dear Christophe,

I am writing to confirm Escher Technologies' interest in participating as an industrial collaborator with the proposed Calculemus II network.

Escher Technologies provides tools for developing dependable software using formal methods. The use of automated reasoning technology is central to these tools, since formal methods can only be practically applied to large software development projects if the mathematical reasoning involved is performed almost entirely by computer.

We welcome this proposal to consolidate the work of the many centres of excellence in automated reasoning within Europe, and we look forward to working with the network to transfer the technologies into industrial-strength software development tools.

Yours sincerely

D Cr.

Dr. David Crocker (Technical Director).

7/2003 10:56 16508592844 SRI INTL PAGE 02

November 17, 2003

TO WHOM IT MAY CONCERN:

Hereby, I express my intent of collaborating within the Calculemus II Training Network.

I am a staff researcher at SRI International's formal methods group, which has been at the forefront of Formal Methods research for three decades. Our verification tools PVS, SAL, and ICS are in active use worldwide—both in industry and academia. Through our Visiting Fellow and International Fellow programs we welcome numerous academic visitors to our laboratory for periods ranging from a few months to several years.

My main interests are in developing novel algorithms for deciding logical theories and combinations thereof. These verification procedures are a key technology for symbolic reasoning and applications such as program analysis and compilation technology. We currently observe wide dissemination of these technologies not only in the design of hardware systems but also for developing many embedded systems in the airplane and car industry, since the complexity of modern designs can not be handled with traditional testing technology alone.

Because of the ubiquity of verification technology in industrial developments ranging from the design stage down to hardware implementation, it is of utmost importance to foster the knowledge and understanding of these techniques in the Calculemus-II project.

Sincerely,

Dr. Harald Rueß,
Computer Scientist
Computer Science Laboratory

Email: ruess@csl.sri.com

SRI International

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5.38PM; .NTEL ;503 264 1730

Intel Corporation, JF1-13
2111 NE 25th Avenue
Hillsboro, OR 97124
USA

Friday 14th November 2003

To whom it may concern,

I am writing this letter in support of the follow-on project Calculemus-II. I am a Senior Software Engineer at Intel Corporation specializing in the formal verification of mathematical software. In my work, I have quite often relied on the kind of combination of theorem proving (HOL Light) and computer algebra (Maple, PARI/GP) that is the focus of interest in Calculemus. Thus, I can personally vouch for the significance of such combinations in practical applications, not to mention its pure intellectual interest.

If the project goes ahead, I certainly hope to become involved myself. I do not anticipate being able to host visiting researchers here, owing to Intel's more product-driven focus and concerns over intellectual property. However I would be very pleased to attend workshops and perhaps give a course at an Autumn School.

Yours sincerely,

John Harrison

John Harrison
Senior Software Engineer
Intel Corporation.

Lemma 1 Ltd.
c/o Interglossa
2nd Floor
31A Chain St.
Reading
Berks
RG1 2HX

+44 118 958 4409
14th November 2003

CALCULEMUS-II— Industrial Collaboration

Dear Dr. Benzmüller,

I am writing to confirm Lemma 1's interest in participating as an industrial collaborator with the proposed CALCULEMUS-II network. Lemma 1's business is centred around the development and use of tools for formal reasoning in the verification of systems. Our ProofPower system is in use by the major UK defence contractor QinetiQ as part of a suite of methods and tools used for the verification of control systems.

Our business is therefore closely connected with the scientific objectives of CALCULEMUS-II, particularly those concerned with industrial applications and interoperability. I am also very interested in exploring the potential offered by combinations of computer algebra systems and deductive systems. I feel it is perhaps premature to identify specific areas for case studies at this stage, but look forward very much to exploring the possibilities in collaboration with the proposed network.

Yours sincerely,

R. D. Arthan

R.D. Arthan

On behalf of Lemma 1 Ltd.
In the capacity of Director.

Registered Office: 27, Brook St, Twyford, Berks. UK, RG10 9NX
Registered in England no: 3305257
Tel: 0118 958 4409; alt: 0118 934 2340

19/11 2003 15:32 FAX 0461314591 ITC - IRST 002/002

LETTER OF INTENT

Ansaldo Segnalamento Ferroviario hereby confirms to have been informed of the objectives of the project CALCULEMUS II to be submitted by the University of Saarbruecken, under the Marie Curie Action within the 6° Framework Programme of the European Union.

If the project will be approved, Ansaldo Segnalamento Ferroviario will participate in the project by hosting selected young visiting researchers for training visits.

Signature

19 NOVEMBER 2003
Date

PIETRO MARINO
Clarification of signature (name)

RAMS DEPARTMENT
Function/title

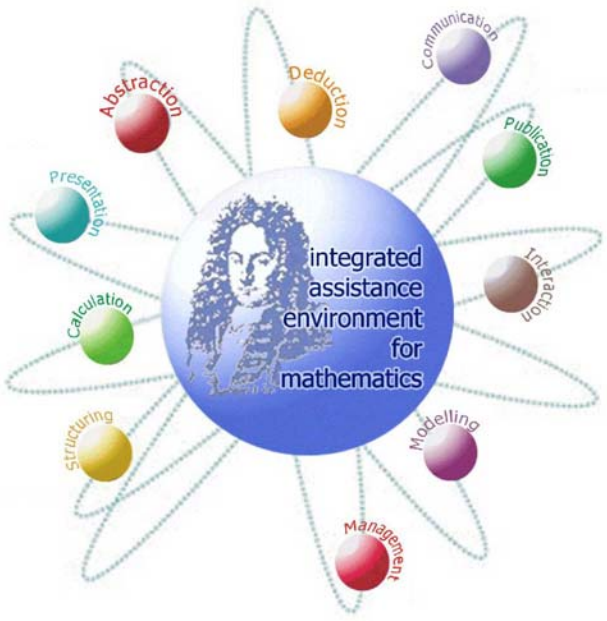
ENDPAGE

HUMAN RESOURCES AND MOBILITY (HRM) ACTIVITY

MARIE CURIE ACTIONS
Research Training Networks (RTNs)

PART B

CALCULEMUS-II



Systems for Computer-Supported Mathematical Knowledge Evolution

November 19, 2003