INFORMATION SOCIETY TECHNOLOGIES (IST) PROGRAMME

Contract for:

Shared-cost RTD

Annex 1 – "Description of Work"

Project acronym:	MONET
Project full title:	Mathematics On The Web
Proposal/Contract no.:	IST-2001-34145
Related to other Contract no.:	
Date of preparation of Annex 1:	December 18, 2001
Operative commencement date of contract:	

Contents

1: Project Summary

Objectives

Mathematics and its applications have become increasingly pervasive in many areas of modern life, making it important that companies, researchers and individuals use the most appropriate mathematical algorithms for their purpose. The aim of the MONET project is 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.

Description of the work

The project will be organised into a number of work packages, each representing a particular strand of the activities to be undertaken. The first task will be to gather a collection of user requirements for our framework and conduct a detailed assessment of the ability of the available technologies to meet them. This will lead to a detailed specification of how our framework will be built, and probably lead the Consortium to develop new relationships with appropriate bodies such as emerging W3C working groups. The second major group of activities will focus on developing ontologies and protocols to represent mathematical queries, describe mathematical services, describe the users of such services and explain the solution process. These will form a collection of "languages" which all the components in the MONET framework will use to communicate with one another. The third work package will develop an initial software implementation of the infrastructure needed to support mathematical services. Finally we shall use this infrastructure to construct two families of prototype services and demonstrate that together they can be used to solve a number of general mathematical problems.

Milestones and expected results

At the end of month 4 we will have conducted a detailed requirements analysis and identified the appropriate technology to be used in the remainder of the project.

By the end of month 12 we will have developed initial versions of the ontologies and the first software implementations of them.

By the end of month 24 we will have revised the ontologies, produced examples of services and demonstrated how they can interact with one another in a practical setting.

2: Project Objectives

The principal objective of this project is to develop advanced prototypes of key technologies which can be used to deploy and interact with mathematical services on the worldwide web, and to demonstrate their effectiveness in practice.

A user's *query* should consist of an unambiguous, semantically-rich description of the problem which they wish to solve plus constraints on the method of solution (e.g. preferred algorithms, whether a simple answer is sufficient or a proof or audit-trail of some kind is required, the list of services which the user is subscribed to etc.). Every mathematical service will describe itself in terms of the problems it is designed to handle, how it handles them (e.g. solve them numerically, look up the answer in a database etc.), who is allowed to access it etc. Services will advertise their presence when they start up by contacting one or more *brokers* whose job it is to match a user's query to the capabilities of the available services. Brokers may exchange information about available services with each other so that requests which cannot be handled locally can be passed on to a more remote service. Matching queries to services is non-trivial since it will often involve making qualitative decisions on the basis of domain-specific knowledge. Since the brokers are not expected to have much, if any, mathematical capability themselves, they will make use of advisors or *agents* which are a special class of service which can extract information needed to choose a solution service from a problem description (for example decide whether a differential equation is stiff or not), or to recommend a solution strategy.

The aim of MONET is to demonstrate that this structure is both feasible and practical. To that end, by the end of the project it is anticipated that the Consortium will have achieved the following concrete objectives:

- Identified key technologies for building, deploying and using mathematical services, and where necessary established relationships with the groups developing them (for example in W3C).
- Developed a mechanism for describing queries and a mathematical service description language.
- Constructed at least one broker which can match services to queries, along with other necessary infrastructure.
- Constructed at least two services for problem solving, one numerical and one symbolic. The symbolic service will also be capable of acting as an agent in helping the broker to select services.
- Demonstrated the combined use of these two services for solving a range of mathematical problems.
- Identified what further work is necessary to finalise the MONET framework and deploy it commercially.

3: Participant list

Role	No.	Participant name	Participant short name	Country	Date enter project	Date exit project
C	1	Numerical Algorithms Group Ltd	NAG	UK	Start	End
A	2	University of Bath	BATH	UK	Start	End
A	3	University of Western Ontario	UWO	C	Start	End
P	4	Stilo Technology Ltd	STILO	UK	Start	End
A	5	Victoria University of Manchester	VUM	UK	Start	End
P	6	Technical University of Eindhoven	TUE	NL	Start	End
P	7	Centre Nationale de la Recherche Scientifique	CNRS-I3S UMR	F	Start	End
P	8	University of Nice	UNSA-I3S UMR	F	Start	End

Note: The I3S Laboratory is a joint research facility of the University of Nice and CNRS and for administrative purposes is classified as two participants. All references in the remainder of this annex to “partner 7” refer to both the formal partners.

4: Contribution to programme/key action objectives

Action III.4.1 — Semantic Web Technologies This action line has four foci, and we will describe how this project is related to each of them.

- *Methods and tools for coding and structuring digital content, for defining and declaring its semantics. These would typically employ XML, RDF and other techniques for semantic interoperability and reasoning such as ontologies for domain specific applications.*

* Mathematics is a distinctive medium, and this project will provide mechanisms for describing the semantic attributes of mathematical content and mathematical services on the Web. OpenMath, an XML-encoding of mathematical objects, gives the partners in a mathematical conversation the common semantic framework needed to communicate mathematical information. It will therefore form the basis of the various ontologies that will be needed for problem, service, and query description.

- *Methods and tools for the derivation of semantic attributes of Web-based content . . . through, for example, automatic feature detection . . .*

* Most mathematics currently on the Web has very little semantics: it is often just images of mathematical text, and at best it is in a presentation language such as LaTeX or MathML (presentation). Such meta data as exists is generally just textual names designed to appeal to humans reading the results of search engines, rather than anything about which a broker could reason. It is hard to add semantics at this stage without extra information: it has to be done when the presentation is created. For example π could be 3.14159..., a permutation, a projection or even a meson. While fully automated categorization of mathematics is an ambitious goal, this project will develop mechanisms which can be used to categorise mathematical resources and, in particular, services.

- *Semantics-based tools for knowledge discovery and intelligent filtering and profiling such as information agents and specific query languages. . .*

* This project proposes to construct an intelligent broker which can be used to find appropriate mathematical services on the web, and a tool to help interpret the results returned by these services.

- *Information visualisation: intelligent and visual interfaces which take advantage of semantic information structures to provide users with radical new ways to navigate and search naturally through unknown and complex information spaces.*

* By representing the semantics of mathematical objects in OpenMath, we are able to translate them into domain-specific[1] and language-specific[2] XML/MathML, which can then be visualised (or spoken, or otherwise rendered) in the browser of the user's choice. In addition we propose to develop techniques which would present the process of solving a mathematical problem to users in a tractable and comprehensible manner, allowing them to query why a particular approach was taken and, if necessary, re-do part of a computation.

The OpenMath ontological framework addresses the issues of sustainability and scalability by providing an extensible family of Content Dictionaries, which can be public, or limited to a specific community, or private.

1. $i = \sqrt{-1}$ is generally called j in Electrical Engineering
2. the open interval $0 < x < 1$ is rendered $(0, 1)$ in Anglo-Saxon countries, but $]0, 1[$ in francophone countries

CPA 12 — Application Services Provision This action line has two foci, and we will describe how this project is related to each of them.

- *Development of open and reusable middleware for the efficient and flexible deployment of application services leased to an organisation and making use of external resources, possibly in combination with internal resources. The reuse of computing and data grid research prototypes and their integration with existing application development frameworks (CORBA, Java, etc.) could also be included.*

* The brokers and advisers proposed in this project are precisely "open and reusable middleware for the efficient and flexible deployment of application services". The issue of whether and how services are available, externally or internally, to an organisation is considered under the user profiles and forms one of the factors affecting a broker's choice of services.

- *Development of service management frameworks with adequate provision for resilience, persistence, security, confidentiality and end user privacy.*

* Confidentiality, integrity and privacy are important user requirements that will have to be present in user profiles and taken into account by brokers. In some circumstances, users may be unwilling to have certain key calculations performed off-site. We envisage a distributed object manager to handle issues of object persistence, knowing that mathematical objects can be large (multi-gigabyte Gröbner bases are not unknown, and have even formed part of patent applications) and valuable over a long time frame.

5: Innovation

Mathematical software is becoming increasingly pervasive and while there are still many users of general-purpose systems like the NAG Libraries, Matlab, Mathematica and Maple, increasingly we see mathematical components being embedded in domain-specific applications. Mathematical algorithms are used in many important areas ranging from engineering through weather forecasting to traffic control and even the ranking of "hits" in a web search engine. Mathematics affects a surprisingly large amount of what we do and good quality mathematics is therefore of fundamental importance.

There are two major aspects to the innovation in this project. On the one hand we propose a new way of deploying and interacting with mathematical software which has benefits to both the producers and users of such systems. On the other hand we propose using emerging technologies for deploying web services in a new and distinctive way.

5.1 Mathematical Software

Most current users of mathematical software access it through fixed, well-defined interfaces via general-purpose packages such as Matlab, Mathematica and Maple, or specialist packages for use in a particular problem domain. A few build their own solvers, often using components from numerical subroutine libraries, or link such components into general-purpose environments such as Excel. Most systems offer some kind of programming language and/or a system-specific mechanism for the dynamic linking of externally-compiled code. Users invest a great deal of time and effort into learning a system and developing a suite of personal programs and utilities.

Unfortunately, linking other software into a user's preferred environment, or translating a program from one system to another, is complicated and in general impossible to automate. Users have to rely on the original system developers to extend the system, add new algorithms, supply improvements and bug fixes etc. The period between releases of most commercial mathematical software systems is between one and two years so bugs can persist for a long time.

In addition to mathematical software, there are subscription-based services which provide access to databases of static mathematical objects or articles (most notably the American Mathematical Society's MathSciNet and the Springer/FIZ Zentralblatt service). The "language" that these services "speak" is distinctly non-mathematical, with searches being conducted on the basis of author names, keywords and so on. Increasingly we see mathematical journals being published electronically but the information which they contain is not structured in a useful way. As a result it is difficult if not impossible for these knowledge bases and software packages to interact.

Finally, users of mathematics often employ a variety of other tools. Equation editors and typesetting systems for publishing mathematics, visualisation systems, spreadsheets, theorem provers etc.

MONET would potentially unify all kinds of mathematical software, tools and services in a common framework where all components are able to communicate with one another in an appropriate way. The benefits to users are clear: they would be able to continue to use their current systems but would now have seamless access to a vast range of "back-end" technology.

There are also benefits to the developers of mathematical software, their market would no longer be limited to those systems which they supported or provided tailored versions for. Moreover a flexible, component-based market would allow developers to specialise in e.g. algorithm or GUI development.

This approach to mathematical software provision would introduce both competition and choice to the market. Users would no longer be limited to a small number of suppliers, but could choose to use software from a wide variety of sources. Developers could focus their efforts in niche products or concentrate on efficiency and accuracy instead of breadth of functionality as tends to be the case at present.

Mathematical Advice Using mathematical software is not always straightforward. Traditionally users would have approached an expert for advice and assistance, but such expertise is in short supply outside Universities and Research Centres. Many general purpose interactive packages try to offer "poly-algorithmic" interfaces which analyse a user's problem and select an appropriate solution strategy and its parameters. For example the command "solve" might use a different approach depending on whether the set of equations it were given was linear or non-linear. The problem with these interfaces is that they are inflexible in the sense that they are only designed to deal with a fixed number of pre-determined strategies, and that there is very little opportunity for a user to interact with the selection process. Such interaction might be desirable when a user knows from experience that a particular solution strategy will not work, or that there is an underlying structure to the problem which is obscured by numerical inaccuracies. In addition, groups of poly-algorithms do not compose well. Consider trying to minimise a definite integral which depends on a parameter. If the definite integrator is a poly-algorithm (which might do something as routine as changing the number of function evaluations in different regions), then the integral will probably be a non-smooth function of the parameter in the region of the change of poly-algorithm, even though each individual algorithm would be smooth. This highlights the importance of the solution strategy being determined on the basis of the whole problem.

An alternative approach is to develop a strategy where the choice of method depends on various weighted criteria, and the methods themselves are described in terms of their suitability for tackling problems with these criteria. The strategy is general but the choice of weights and criteria is very domain-specific and requires the involvement of a human expert. This is not a new idea and has been demonstrated in the past in systems for choosing numerical algorithms. The hardest part is in analysing the problem to determine the degree to which the properties on which the selection process will be based are present or absent. This can be quite a computationally-intensive process and involve solving several side-problems.

As a very simple example, consider the problem of computing:

$$\int_{0.0}^{1.0} \frac{\sin(x)}{x}\, dx$$

This clearly has a singularity at the point $x = 0.0$ so a simple quadrature algorithm will fail (and in practice any attempt to evaluate the integrand at $x = 0.0$ will cause a floating-point exception). There are integration methods designed to handle singularities at an end-point so one of these might be selected. However some analysis, which would be routine for most general-purpose symbolic systems, shows that this is a removable singularity, and that the integrand can be expressed as:

$$\begin{array}{llll} \dfrac{\sin(x)}{x} & \text{for } \epsilon & \leq & x \leq 1.0 \\ 1.0 & \text{for} & & x < \epsilon \end{array}$$

thus allowing a basic quadrature algorithm to be applied. However this integral is also known as the *sine integral* and can be computed by a Chebyshev expansion, or looked up in an appropriate set of tables. Any one of these approaches should yield the correct answer, and which is best is very much a subjective decision. A user's preference for a particular software package or need for high accuracy could well be the determining factor.

The key point about our approach is that the selection of methods available can be a dynamic process. The first thing that an advisor would do (whether a human or a software agent) would be to look at what tools are available for the job. The ability to locate and identify the functionality of services is thus a critical part of the MONET framework. The provision of advisory services to evaluate the suitability of the available services to a problem is essential to make the framework usable in practice.

Mathematical Explanations As described above, many software packages offer so-called "poly-algorithms" which provide a unified interface to several algorithms. Various ad-hoc feedback mechanisms may be implemented to provide the user with feedback as to which method was chosen and why, but these usually amount to little more than tracing mechanisms and require a certain amount of knowledge about the underlying implementation to understand. We propose building special services which would collect information about why a particular approach was chosen and present it to the user. Since this is very similar to describing a mathematical proof we propose investigating automatic theorem-proving technology as a vehicle for this.

This is critical for understanding results, debugging and tracing computations, and tuning "expert advisors" to ensure that they make good decisions. Previous projects to build problem solving environments which link multiple software packages have not offered such a system and have been impractical to use as a result. The ability to tailor such an "explanation service" to use language and terminology appropriate to a user is an important aspect of MONET.

5.2 Service Provision

The semantic web has the potential to revolutionise many aspects of everyday life and the way we do business. While it is already possible to access much information on the web, it is often difficult to filter out items which are irrelevant. E-commerce is popular for items which are uniquely defined (e.g. a book or CD, or stocks and shares) or where the fitness for a particular purpose is absolutely clear (for example an airline ticket), but has yet to gain acceptance for purchasing which involves more qualitative decisions (e.g. purchasing clothes or even groceries, where if an item is out of stock then a suitable alternative must be provided).

Mathematical software falls very much into this latter category: the ability of a piece of software to solve a particular problem is rarely obvious and often requires experience and experimentation. Such software has often taken years to develop and represents a considerable intellectual investment, and having been in the field for many years is often seen as reliable and trustworthy. Thus incorporating such software into new online web services would seem preferable to writing new services from scratch.

We envisage using existing and emerging technologies for web service description. The process of web-service deployment and discovery will need to be dynamic and not rely solely on fixed, static registries, especially as the actual services available to different users of the same broker may vary. This provides a modular structure where services can be added and removed easily, and also ensures that if a service is unavailable (because it is busy, the machine running it has been shut down etc.) it will not be considered as a candidate for solving a problem.

While the technologies we use will (we hope) be standard, they will need to be tailored for mathematics, a process which will involve developing open, extensible vocabularies and ontologies for describing both mathematical problems and the software which solves them. We will also need to pay attention to commercial issues such as handling user validation, ensuring data integrity etc.

Finally, we propose building an object manager which will provide access to objects via a URI regardless of where they are physically located, the format they are currently stored in, whether they are held in memory or have been written out to a file system etc. This is important for a number of practical reasons, not least because mathematical objects and data sets can be very large and the process of transforming them to and from a linear format for transmission could be very time consuming. However it also allows us to de-couple the implementation of a piece of software from the way it is used. A conventional "transaction" between a user and a piece of software often involves a sequence of steps, each of which is dependent on its predecessors. In a distributed environment it is impossible and undesirable to insist that every service is capable of maintaining such running sessions for every user, even if in some cases this might be more efficient. Thus we use an abstract reference which can be resolved by the service into an object in its own memory, an object stored in a proprietary format, or an object in a standard format. Thus any service can support a "mathematical conversation", although the implementation details may vary. Two other important uses of the object manager are to support asynchronous computation and persistent storage of objects. For example a user might send a problem to a server and ask it to email him or her with the URI for the result when it had finished computing.

6: Community added value and contribution to EU policies

The primary objective of this project is to build a framework to allow distributed online agents to share common languages for describing mathematical capabilities and mathematical objects. It is clear that such a framework can only succeed if it is used by multiple systems. It is an important feature of the project that it includes partners from several different mathematical traditions and geographical locations. Some examples of the benefits of European collaboration include:

- It is important to support the different national traditions that occur within the multi-lingual European community. At the level of typographic conventions for mathematical notions, a semantically based markup language such as OpenMath or Content MathML allows the mathematical content to be conveyed whilst also allowing localised stylesheets. These stylesheets might provide different typographic presentations, or non visual presentations such as braille or speech.
- Similarly it is essential that European input is applied in the design of frameworks for e-learning. The educational traditions of Europe and North America, especially in mathematics, are quite distinct. The Consortium includes a number of partners with an interest in e-learning, who will ensure that MONET is a suitable framework in which to deliver courses which respect the differing educational methods used in different countries.
- The consortium includes partners from a number of different disciplines, Academic researchers, Mathematical software houses, specialists in Ontologies and Description languages, etc. It is necessary that all such disciplines are involved in the design of a framework such as MONET if it is to achieve its objectives of forming a common basis for the use of mathematical services in these disciplines. No single country can represent all the possible requirements of a framework such as MONET, and so it is vital that the development happens at a European level, together with wider coordination on a global level where appropriate.
- As discussed in the commercial exploitation section below, the specification of the MONET framework should allow smaller to medium size European enterprises to compete in the marketplace by offering specialised services to end-users, whilst allowing the users to be presented with a common interface to the different service providers. In addition to services offering specialised mathematical functionality, the MONET framework should make it cost effective to produce (for example) e-learning materials targeted at specific local communities/language groups.

  This should create significant business opportunities for European activity in an area that would otherwise be dominated by North American concerns.

In the area of web standards and protocols, European strategic interests must be addressed at a global level. Members of the MONET Consortium are already active in a number of international bodies and during the lifetime of the project we anticipate that these links will be extended and, in some cases, formalised.

- Several consortium members are members of the W3C's Math working group (responsible for MathML) and the new W3C Web Ontology working group (part of the recent W3C Semantic Web activity). Several key technologies that are to be used in the MONET framework are being developed at W3C, in particular RDF, WSDL and SOAP. In addition the Math Working Group of the W3C is proposing to investigate the use of MathML in web services. The MONET framework and in particular the Service Description and Explanation ontologies should be equally applicable whether the Mathematical objects are described in OpenMath or MathML, and we expect to coordinate (rather than compete) with the W3C in this area. This coordination proved very successful in the earlier OpenMath project, during which Content MathML and the core OpenMath Content Dictionaries were carefully aligned.

- In addition we expect to maintain links with bodies standardising languages for Ontology description. In particular the consortium includes one of the editors of the OIL and DAML+OIL language specifications. DAML is being developed by a consortium (based around DAML.org) lead by DARPA (the US Defense Advanced Research Projects Agency).
- The MONET Consortium will continue close links with the OpenMath Society (which is now responsible for the OpenMath standard document which was developed during an earlier IST project). As in the previous project, any further development and extension of the OpenMath standard would be undertaken by members of this consortium, under workpackage 2, however any additions to the OpenMath standard would need to be ratified by the OpenMath Society.

7: Contribution to Community social objectives

The contribution of the project to improving the quality of life and health and safety (including working conditions).

Many aspects of life are controlled explicitly or implicitly by mathematical processes. Whilst the wide availability of mathematical software tools has been beneficial, there is a significant danger that inappropriate tools and methods are currently being used to solve many problems, due to lack of information about availability of tools, or the possibility that end-users lack the mathematical sophistication required to choose appropriate algorithms in many cases. Thus the framework proposed by the MONET project to allow the description and discovery of mathematical services, and automated assistance in choice of service should provide significant benefits to the community.

Whilst there are general frameworks for resource description being developed, and the MONET project proposes to use these where appropriate, it is important that specific mathematical and European issues are addressed, and that would typically not be addressed without the involvement of the mathematical software community as proposed in this project.

There have been several major accidents involving mathematical errors: the Ariane 5 failure (the mathematical formulae that needed to be checked were embedded textually in the comments, but could not be automatically verified), the Mars lander (a problem of units), a U.S. Strategic Defense Initiative failure (again a problem of units) and so on. While expensive, fortunately none of these have led to loss of life, but this cannot be guaranteed to remain the case. By providing a mechanism in which the semantics of mathematics can be encoded accurately, and computed with directly, communication in large projects can be improved, and the risk of life-threatening failure reduced.

Particularly in Europe, there are variants of mathematical notation: $(0,1]$ (Anglo-Saxon) or $]0,1]$ (French), ϕ_x or ϕ'_x to denote $\frac{d\phi}{dx}$, and so on. Furthermore, algorithms often have different names (e.g. the well-known extended Euclidean algorithm is known in France as "l'algorithme de Bezout". Hence it is important, if the Web is to be used for communicating mathematics internationally, to make a distinction between the semantics of the mathematics and the way it is rendered or described, which the combination of OpenMath and MathML makes possible. In this project we propose to integrate these languages for describing mathematical semantics with a framework for online service description.

The contribution of the project to improving employment prospects and the use and development of skills in Europe.

The mathematical software market is currently dominated by a small number of large, general-purpose, software packages produced by North American companies such as The Mathworks Inc. and Wolfram Research Inc. Due to lack of interoperability between the systems, end users may find themselves "locked in" to one large system. This may make it difficult or inconvenient to use smaller, more specialised, packages for specific tasks. By developing a framework in which mathematical services may interoperate, the MONET project should make it possible for smaller, and specifically European, software companies to provide mathematical services on a commercial basis that interoperate with existing and new packages. Thus by providing a "level playing field" on which mathematical software companies may interact, MONET should improve the prospects for European SMEs in this area and also, by improving the accessibility to mathematical software, should improve the general level of mathematical skills within Europe.

8: Economic development and S&T prospects

The emergence of the Internet and the "World Wide Web" as a universal medium for the access to and processing of information, and increasingly for the conducting of commercial transactions, is providing tremendous opportunities to businesses. However the exploitation of the internet as a means of conducting business will only reach its full potential when the representation of information to be exchanged between business partners becomes formalised and standardised. The development and adoption of large scale, domain specialised ontologies is a means to this end.

Currently the provision of genuine web-based services where the complete transaction takes place online (as opposed to the use of the internet for selling goods such as books, CDs, travel tickets etc.) is very much in its infancy. A few subscription-based services offer access to rapidly changing information such as stock market figures or weather forecasts and, especially since the demise of Napster a number of companies have announced plans to provide commercial access to music and e-books. This is just the tip of a very large iceberg however. All these "services" share one important attribute: the commodity which they are ultimately supplying is well-defined and easily identifiable. To facilitate more complicated transactions requires the technology associated with the semantic web.

The two fundamental ingredients of the semantic web are standardised mechanisms for describing (and hence advertising) services, and languages or ontologies for representing and exchanging data in a particular application domain. Whilst current directories of services such as that provided by UDDI are static, we believe that these will be replaced by dynamically-updated service repositories. Although this project focuses on mathematical services, much of the experience gained will be relevant to the development and deployment of other scientific and indeed non-scientific services.

8.1 Commercial Exploitation

Within the Consortium there are two commercial partners: NAG Ltd, Europe's largest mathematical software vendor; and Stilo Technology Ltd., a company offering a range of products and service based on XML. The focus of each of these two organisations is, in the MONET context, highly complementary. Both of these partners have identified a number of short to medium-term exploitation strategies based on their existing business as described below.

8.1.1 NAG Ltd

In the thirty years of its existence NAG has produced many versions of its software designed for use in different settings. As the number of available languages and environments proliferates, NAG continues to devote significant effort to developing and maintaining versions of its core software which run in different language environments (Fortran-77, Fortran-95, C), or inside other software packages (as IRIS Explorer modules, a Matlab toolbox, Excel add-ins etc.). Ad-hoc embeddings including Active-X components and Java wrappers have been produced for individual customers. Generic mechanisms such as those proposed by this project which made this kind of embedding/wrapping process easier would be a major benefit to NAG, increasing both speed-to-market for existing products and also the size of that market itself.

The components which NAG develops are very specialised and the process of selecting the appropriate algorithm for a specific task often requires expert knowledge. The use of well-defined ontologies for problem and service description and agents for matching one to the other would greatly simplify this process and make embedding collections of NAG algorithms in new environments much more straightforward.

NAG has identified three specific exploitation paths as follows. The first is definitely achievable in roughly the lifetime of the project, the second shortly afterwards, while the third is more speculative.

1. By integrating existing general-purpose packages into the MONET framework, the market represented by their existing user bases (the size of which is usually estimated as several million people worldwide) will be opened up to third parties such as NAG. It is important to stress that existing packages such as Matlab, Maple and Mathematica already offer mechanisms for calling external code which are sufficient to allow a third party to perform this integration. Software packages based on NAG's numerical library components and using agents to choose solution strategies could be tailored to each package (e.g. by providing documentation in its "native" format) with minimal effort, thus reducing both development costs and time to market. Since developing such systems does not require collaboration from outside the project Consortium, some commercial exploitation along these lines should be plausible within the lifetime of the project, or soon after its conclusion.
2. A growing part of NAG's business is concerned with selling components to third-party software vendors. Usually this involves licensing an agreed, fixed, set of components or functionality to the vendor which they then incorporate into their product. Identifying those components in the first place and then producing the appropriate interface between them and the vendor's product is not only labour intensive but requires the involvement of highly-trained experts from both organisations. By using agent technology and well-defined ontologies for mathematical objects NAG believes that such interfaces can be produced more efficiently and rapidly than is currently the case. Moreover by providing the components as web services (available either via the vendor or directly from NAG) the deployment is no longer tied directly to the vendor's product's life-cycle, and more flexible commercial terms (based for example on the level of actual use) could be offered. In NAG's experience it currently takes 2–3 years to go from initial exploratory contacts with a vendor to seeing a final product in the field, so this form of exploitation is unlikely to bear tangible results during the project lifetime.
3. Looking to the medium and long term, MONET technology would help NAG position itself as a direct supplier of generic mathematical services to end-users. NAG has traditionally provided much of its software on the basis of an annual license fee or subscription and this model would transfer well to the provision of online services. The benefits to customers would include availability of NAG software in a variety of environments, simplified installation, immediate access to bug-fixes and improvements, and the ability to purchase access to a service almost instantly. From NAG's perspective it would no longer need to produce complete new products for different environments, would significantly reduce its sales and distribution costs, and would appeal to a much larger market than is presently the case.

The first two exploitation channels listed above could be undertaken in the foreseeable future on the basis of a successful outcome to the project. The first strategy is relatively low risk since it does not require the involvement of any outside organisations. The second does require the involvement and support of third parties which inevitably involves more risk, however on the basis of experience NAG believes that even some existing clients will find the ability to structure royalty payments on the basis of actual use of embedded components very appealing.

The third strategy requires an evolution in existing customers' attitudes and the widespread adoption of MONET or MONET-like technology. NAG would certainly encourage this, and would be prepared to offer a consultancy service to help other companies and organisations in their natural customer base to web-enable their software using the tools and technologies developed in the project.

8.1.2 Stilo Technology Ltd

Stilo Group companies develop and market content engineering technologies which enable enterprises more readily to automate the integration, creation, management and re-purposing of large quantities of textual and other data using XML. The Group's primary target customers are systems integrators and large enterprises seeking to implement sophisticated content management systems ("CMS") These are software solutions specifically designed to manage the content needs of the modern web site and enable teams of specialised contributors to work together to deliver effective and value-adding business applications. Today, much content is dynamically generated on demand, synthesised or aggregated from other, some times real-time data. In many application areas, for example in finance, the ability to communicate with mathematically aware applications in a standard way would be a significant advantage.

Market Trends A recent survey of UK banks by Abaxx Technology (in Computer Weekly, 28 September 2001) highlights a more general trend in IT. This is a move away from monolithic, bespoke systems into a more component-oriented environment using such techniques as application frameworks, all based on COTS (Customisable Off The Shelf) technology. Application frameworks (such as Java/J2EE for example) provide underlying structures adhering to industry standards to which users can add business functionality. There is a related technology trend towards more loosely-coupled, distributable systems. Both the Microsoft .NET programme and the Sun ONE initiative are based on this processing model.

Exploitation Strategy Stilo intends to use the expertise, tools and techniques developed in the project in the following ways:

- Enhancements to the functionality of existing products, particularly with regard to the potential inclusion of mathematical services support in our content engineering technology.
- Creation of new products and product lines. The tools and ideas developed for locating, describing and communicating with mathematical services will most probably have wider applicability in other areas of application service provision
- Support of our professional services and consultancy activities

8.1.3 Academic partners

Higher Education is a multi-billion Euro business in many countries, and that part of the education including mathematics (therefore much of science and engineering, also economics and other social sciences) is probably 25% of this total. While predictions of the death of traditional universities in favour of a totally e-learning world are wildly exaggerated, it is clear that Universities throughout the EU and beyond are trying to deploy e-learning where appropriate. This is greatly hampered by the absence of a reasonable way of displaying and representing mathematics on the net. Bath, Nice and TUE have all expressed interest in using MONET technology to develop tools and applications in this area.

8.2 Technical & Scientific Prospects

There are a number of different aspects to the technical and scientific results which it is hoped will follow from the project. In the first place we will further develop and evolve a number of emerging technologies, designed to deliver a new *semantic* web, in a concrete, practical setting. Although focussed very much on mathematics, our approach will certainly have applications in other areas of science and engineering. The principal interest of a number of partners, both academic (Manchester, UKOLN at Bath) and commercial (Stilo Technology Ltd), lies in developing the semantic web itself, and they are likely to look for new and novel applications beyond mathematics to take this aspect of the project forward. The involvement of several partners, namely Stilo, NAG, UWO and Bath, in W3C working groups means that where appropriate the work carried out under MONET will have a direct impact on wider work for developing standards and technologies for the web in general. For example, at the time of writing the W3C Math Group is setting up a sub-committee to consider whether it should develop extensions to MathML for mathematical service description as distinct from the work on general service descriptions being done elsewhere in W3C. Both Stilo and NAG are members of this sub-committee. It is worth noting that, during the OpenMath project, the European Consortium and the W3C Math Group collaborated successfully to produce a set of semantic descriptions for basic mathematical objects. Such collaboration is crucial in the world of web standards.

Several partners are experts in the development of mathematical software. Again this is a mix of both commercial partners (NAG) and academic partners (Bath, Nice and Western Ontario). If all these partners adapt their software to support MONET then their users will be able to solve larger problems, or existing problems more accurately and efficiently. This has the potential to effect numerous areas of science and engineering.

The flexibility and modularity which MONET is designed to bring will have a number of benefits too. In particular, the reduced development costs which follow from it make it viable to develop systems tailored for small or niche audiences. The advantages of this in a world where every discipline is becoming fragmented into more and narrower specialisations are clear.

9: Workplan

9.1 General description

The work programme consists of four technical workpackages, plus one workpackage devoted to management and another devoted to dissemination. The four technical workpackages are:

1. Existing & Emerging Technologies
2. Ontologies & Protocols
3. Infrastructure
4. Services & Applications

For each task we have indicated the partners involved and estimated the amount of funded effort each will devote to that task (in person months). We note that in some cases there will also be unfunded effort, for example through the involvement of permanent staff from the academic partners.

9.1.0 WP0: Project Management

Work Package Coordinator:	NAG
Principal Partners (effort):	NAG (12), Bath (2), UWO (2), Stilo (2), Manchester (2), Eindhoven (2), Nice (2)

The Project Management work package will provide resources for the management and coordination of the project, and for liaison between the Consortium and the European Commission. Based on its experience in several previous European projects, the coordinating partner will propose both a formal structure for decision making and a set of guidelines for the smooth operation of the project covering, for example, the handling of deliverables and the distribution of software. The coordinating partner will also appoint an individual with experience of managing projects of this nature to fill the rôle of project manager. Details of the management structures and techniques to be adopted are listed in section 9.7.

As provided for elsewhere in this contract, this work package will produce the periodic management reports and final report.

9.1.1 WP1: Existing and Emerging Technologies

Work Package Coordinator:	Stilo
Principal Partners Involved:	All

This workpackage is principally concerned with an investigation of existing technologies for service description, interaction and explanation such as UDDI, WSDL and DAML-S, and their suitability for use in MONET. It will also investigate low level protocols for component interaction such as XML Protocol, SOAP and HTTP, and methods for maintaining user profiles, such as W3C's Composite Capabilities and Preferences Profile (CC/PP).

The choice of technologies to use in the project will be based on an initial requirements analysis, investigating what functionality will be needed to build the demonstrators in workpackage 4 and also developing a number of scenarios which model the kinds of interactions which we would like to support.

In choosing which technologies to use we will consider their functionality, any related tools which support them, and also whether they are, or look like becoming, industry standards. For example DAML+OIL not only provides a language for writing ontologies, but is supported by tools for editing, validating and reasoning with them.

Task 1.1: Requirements Analysis

Task Co-ordinator	NAG
Partners (effort):	NAG (1.5), Bath (1), UWO (1), Stilo (0.5), Manchester (1), Eindhoven (1), Nice (1)
Start	1
Duration	2 months

The goal of this task is to make explicit MONET's requirements in areas such as problem definition and service description to inform the activities later in the project. This will be done by identifying a number of scenarios designed to accurately reflect real-world situations where MONET might be used, as well as investigating the practical requirements of building the services and demonstrators in work package 4.

Deliverables

D01 Requirements Analysis Report

Delivery date:	month 3
Dependencies:	None
Status:	Internal

Task 1.2: Investigation of existing and emerging technologies

Task Co-ordinator	Manchester
Partners (effort):	NAG (1.5), Bath (1), UWO (1), Stilo (0.5), Manchester (1), Eindhoven (1), Nice (1)
Start	2
Duration	2 months

This task will analyse and investigate the applicability of various existing and emerging technologies for use in the project. It will recommend which technologies the project should use, and which technologies, or technology areas, the project needs to watch.

Deliverables

D03 Report on Existing & Emerging Technologies

Delivery date:	month 4
Dependencies:	D01
Status:	Public

Task 1.3: Technology Watch

Task Co-ordinator	Stilo
Partners (effort)	NAG (1), Stilo (1), Manchester (2), Nice (1)
Start	5
Duration	18 months

This task will monitor developments both within and outside W3C. The Semantic Web activity of W3C is an obvious area of related technology, as is the Math working group. Outside W3C, there are, for example, the UDDI consortium and the OpenMath society. All the partners involved in this task are already involved in such groups.

Deliverables

D24 Update to Report on Existing & Emerging Technologies

Delivery date:	month 23
Dependencies:	D03
Status:	Public

9.1.2 WP2: Ontologies and Protocols

Work Package Coordinator:	Eindhoven
Principal Partners Involved:	NAG, Stilo, Manchester, Eindhoven, Nice

OpenMath is an ontological framework and its Content Dictionaries are an existing extensible ontology for describing static mathematical objects. It therefore forms an obvious starting point for this work package, which is devoted to developing the necessary ontologies for describing the various components and the dynamic transactions which will take place inside the MONET framework. Some work will be needed to extend the mathematical domains covered by OpenMath, and to ensure smooth interaction between OpenMath and other, more general technologies and their associated tools, such as the Resource Description Framework (RDF), and languages for defining ontologies such as DAML+OIL.

This work package will make use of an existing mechanism for user profiles, which will be identified in deliverable D03. Information from the user's profile will influence the brokers in their choice of services and the level and kind of explanations provided.

Task 2.1: Mathematical Problem Description Ontology

Task Co-ordinator	Eindhoven
Partners (effort)	NAG (1), Stilo (1), Manchester (2), Eindhoven (3.5), Nice (0.5)
Start	4
Duration	8 months

The purpose of this task is to develop a generic language in which to express the problems to be solved within the MONET framework. This would use OpenMath descriptions of the mathematical part of the problem, but would also permit qualifiers such as "symbolic", "numerical" to indicate required characteristics of the solution etc. This ontology is a key component of the next two, since queries and services need to speak a common language to ensure that the user's request is correctly satisfied. The language will be designed to have an extensible vocabulary and will be updated in the light of experiences in developing software implementations in work packages 3 and 4 which support it.

Deliverables

D04 Mathematical Problem Description Ontology: Initial Draft

Delivery date:	month 6
Dependencies:	D01, D03
Status:	Public

D11 Mathematical Problem Description Ontology: Final Version
Delivery date: month 12
Dependencies: D04
Status: Public

Task 2.2: Mathematical Query Ontology

Task Co-ordinator	Eindhoven
Partners (effort)	NAG (1), Stilo (1), Manchester (3), Eindhoven (2.5), Nice (0.5)
Start	4
Duration	9 months

This would be a wrapper around a problem description which would also include details of a user's non-mathematical requirements (for example a list of services subscribed to/to be avoided, the user's geographical location etc.). It may be possible to use an "off-the-shelf" mechanism for this, but at the time of writing this is not clear. The need for dialogue between services *as part of the service discovery process* may mean that existing protocols are not sufficiently powerful or flexible for our needs. The language will be designed to have an extensible vocabulary and will be updated in the light of experiences in developing software implementations in work packages 3 and 4 which support it.

Deliverables

D05 Mathematical Query Ontology: Initial Draft
Delivery date: month 7
Dependencies: D01, D03, D04
Status: Public

D13 Mathematical Query Ontology: Final Version
Delivery date: month 13
Dependencies: D05, D11
Status: Public

Task 2.3: Mathematical Service Description Language

Task Co-ordinator	Stilo
Partners (effort)	NAG (1), Stilo (3), Manchester (5), Eindhoven (4), Nice (1)
Start	4
Duration	10 months

This has to describe services in terms of what kind of problems they can handle (e.g. non-linear systems, differential equations), how they handle them (e.g. solver, database etc.), and in terms of non-mathematical characteristics such as availability, price and capacity. OpenMath Content Dictionaries, which describe the semantics of closely related sets of mathematical objects, will be used as the basis of the description of the problem classes. Once again, we would hope to embed this information inside an existing general mechanism. The initial design will be updated in the light of experiences in developing implementations of brokers and services in work packages 3 and 4.

Deliverables

D06	Mathematical Service Description Language: Initial Draft	
	Delivery date:	month 7
	Dependencies:	D01, D03
	Status:	Public
D14	Mathematical Service Description Language: Final Version	
	Delivery date:	month 14
	Dependencies:	D06
	Status:	Public

Task 2.4: Mathematical Explanation Ontology

Task Co-ordinator	Eindhoven
Partners (effort)	NAG (1), Stilo (1), Manchester (1), Eindhoven (4), Nice (1)
Start	4
Duration	6 months

This is an essential, indeed fundamental, component of our proposed structure which will allow a user to understand computations which take place in the MONET framework, either to satisfy him or herself that they are correct or, equally important, to "debug" a computation. Audit trails are an essential component of safety-critical systems and debugging is a fundamental part of software engineering. Unfortunately generic tools for tracing and debugging in heterogeneous environments are comparatively poor.

This ontology will provide an abstraction which will provide a user with a unified view of a computation which involves several different brokers and services each potentially written in a different language, using different data structures and with its own tracing and explanation mechanisms. This ontology will need to represent information about the solution process including:

- the choice of services available for a particular task and the reasoning behind a particular selection;
- decomposition of a problem into sub-parts;
- the portions of data sent to each service;
- choice of algorithm and explanation of decision;
- selection of optional/default parameters to an algorithm;
- results of calling algorithm including accuracy and error indications;
- availability of additional data which might be used to verify the correctness of the result.

In practice it must be able to handle incomplete descriptions and missing data since not every service will support this mechanism to an equal degree.

This information could be represented statically or dynamically, in the sense that a user might query a service for information about a previous computation it had performed or ask it to "re-run" all or part of a computation. We envisage the resulting information being displayed graphically to a user using a special tool to be developed in task 3.3.

Deliverables

D07	Mathematical Explanation Ontology: Draft Version	
	Delivery date:	month 10
	Dependencies:	D01, D03
	Status:	Public

9.1.3 WP3: Infrastructure

Work Package Coordinator:	Nice
Principal Partners Involved:	NAG, Stilo, Eindhoven, Nice

Most existing mathematical software is not actually web-based in a deep sense, but rather stand-alone tools expecting to interact directly with a human being. We propose building a test-bed in which mathematical services can be deployed, consisting of *brokers* which can handle service publication and discovery, an *object manager* to process abstract references to mathematical objects in a uniform and reliable way, and an explanation and debugging tool to help a user to understand and modify the solution process.

This activity will be based on the ontologies and protocols workpackage, in particular the mechanisms for describing queries and services, and on the technologies identified as appropriate at the outset of the project. The principal work will be on developing a logical procedure for matching a request in one with the set of capabilities advertised in the other. The implementation of this will form the basis of the broker.

The deliverables lists here and in work package 4 use the standard software engineering terminology *initial beta version* to refer to software which is functionally complete but may have known problems, and is thought to be fit for testing and use by people other than its developers. In particular all the critical functionality is believed to work correctly and sufficient user-level documentation is provided for third-party testing. A *candidate release* is a version of the software which has been tested by people other than its developers, where all the advertised functionality is believed to work correctly and where the final documentation is present. Between these two stages it is expected that a number of further beta versions will be produced within the project. It is also assumed that a further round of testing of the release candidate would be required before a final version of the software was deemed fit for public release.

Task 3.1: Broker

Task Co-ordinator	Eindhoven
Partners (effort)	Stilo (9), Eindhoven (8), Nice (7)
Start	8
Duration	10 months

A mathematical broker has to match queries, as expressed in the mathematical query ontology, with its registered service descriptions described in the Mathematical Service Description language. It also has to take account of the non-mathematical characteristics of the services, a user's right to use them etc. Although logically separate from the computational part of a service, there is no fundamental reason why a broker should always be a physically separate piece of software. This task will create a specimen broker and, once its development is completed, package and document some of its components to produce a "broker API" to assist future developers of such software.

Deliverables

D08 Broker Initial Beta Version

Delivery date:	month 12
Dependencies:	D03, D05, D06
Status:	Internal

This deliverable will support the draft mathematical query ontology (D05) and mathematical service description language (D06). It will support limited matching of queries to available services, and on the basis of this experience will supply further requirements to the ontology development activities in work package 2.

D16 Broker Release Candidate

Delivery date:	month 16
Dependencies:	D08, D13, D14
Status:	Public

This deliverable will support the final versions of the mathematical query ontology (D13) and mathematical service description language (D14). It will support dynamic service discovery and be able to match queries to available services, and set up the necessary user/service interactions.

D18 Broker API Initial Beta Version

Delivery date:	month 18
Dependencies:	D16
Status:	Public

This deliverable will extract some parts of the broker software, for example software for matching queries to services, for parsing the serialised form of a query etc., and re-package it as a suite of documented, re-usable components to facilitate further broker development.

Task 3.2: Mathematical Object Manager

Task Co-ordinator	Nice
Partners (effort)	Nice (8), Eindhoven (5)
Start	8
Duration	8 months

Mathematical objects may exist in a persistent database, or inside a particular instance of a software package at a given time. The job of the Object Manager is to handle object references via a URI, taking into account the location and representation of the object. This will allow for asynchronous computation (i.e. "compute this object and place it in this location"), and also allow a dialogue between two services without complete objects being passed back and forward, only references to them. This is particularly relevant in mathematical applications, where datasets, raw or computed data for visualisation, and even sets of equations such as Gröbner bases can easily be measured in gigabytes, and where the structure of an object may be extremely non-linear so that serialisation is expensive in terms of both space and time. This object manager will have to manage object lifetimes, and issues such as the sharing of objects between co-workers, particularly for services which offer a whiteboard-style interface for use in collaborative working.

Deliverables

D09 Mathematical Object Manager Initial Beta Version

Delivery date:	month 12
Dependencies:	D01, D04
Status:	Internal

This deliverable will resolve references to objects via a URI. It will support persistent objects stored in both system-specific and system-neutral formats.

D17 Mathematical Object Manager Release Candidate

Delivery date:	month 16
Dependencies:	D09, D11
Status:	Public

This deliverable will be an improved version of D09, supporting access control to objects to enable sharing between co-workers.

Task 3.3: Explanation and Debugging Tool

Task Co-ordinator	Eindhoven
Partners (effort)	Eindhoven (7), NAG (3)
Start	12
Duration	8 months

The Explanation and Debugging tool is a special kind of service which will be built on the Mathematical Explanation Ontology produced in task 2.4. Its purpose is to provide a unified depiction of how a solution was arrived at and allow a user to replay or step through parts of it. Many of its features will be similar to a conventional debugger and it will not impose a large overhead on services which support it.

Deliverables

D19 Explanation and Debugging Tool Updated Beta Version

Delivery date:	month 20
Dependencies:	D01, D03, D07
Status:	Internal

This deliverable will interpret information described in terms of the explanation ontology (D07) and present it to the user in an easy-to-understand and navigable form. It will allow some limited re-playing of computations.

9.1.4 WP4: Demonstrator Services & Applications

Work Package Coordinator:	NAG
Principal Partners Involved:	NAG, Bath, UWO, Eindhoven

The purpose of this workpackage is twofold: to demonstrate the applicability of the ontologies, protocols and frameworks developed in other workpackages, and provide feedback and further user requirements to those activities. We propose developing two families of services based on existing numerical components (the NAG Library) and an existing symbolic solver (the Maple computer algebra system). The latter service will also be used to provide some extra "agent" capabilities to the broker to assist in its decision process. We will demonstrate how these services can be employed together to provide a comprehensive mathematical problem solving environment.

Task 4.1: Numerical Solver Service

Task Co-ordinator	NAG
Partners (effort)	NAG (10), Bath (4)
Start	8
Duration	14 months

This task will develop a solver service based on the NAG Library of numerical algorithms to deal with problems such as optimisation and integration. The NAG Library is designed as a collection of modular components and this task will correspond to building a service from scratch. Those parts of the software which are identified as generic will be re-packaged and documented separately to help developers of future services.

Deliverables

D10 Numerical Service Initial Beta Version

Delivery date:	month 12
Dependencies:	D01, D03, D05, D06, D07
Status:	Internal

This deliverable will offer a limited set of numerical functionality based on the NAG Library, for example optimisation or quadrature, to be identified in D01.

D20 Numerical Service Release Candidate

Delivery date:	month 20
Dependencies:	D10, D13, D14
Status:	Public

This deliverable will offer an extended set of functionality, including at least one problem area also handled by the symbolic services being developed in task 4.2.

D22 Service API Release Candidate

Delivery date:	month 22
Dependencies:	D20
Status:	Public

This deliverable will re-package and document some of the code written for D20 to enable it to be used in the development of other services. Functionality will include registration with broker, serialisation/de-serialisation of requests etc.

Task 4.2: Symbolic Solver Service

Task Co-ordinator	Bath
Partners (effort)	Bath (13), UWO (9)
Start	8
Duration	14 months

This task will develop a solver service based on the Maple computer algebra system. Maple is a relatively large, integrated package typical of many scientific packages in use currently, and this exercise will demonstrate that it is possible to develop a software wrapper which allows them to be deployed as a MONET service. The choice of functionality which the services offers will overlap that offered by the numerical service developed in task 4.1 to help demonstrate the functionality of the broker. Those parts of the software which are identified as generic will be re-packaged and documented separately to help developers of future services.

Deliverables

D15 Symbolic Service Initial Beta Version

Delivery date:	month 14
Dependencies:	D01, D03, D05, D06, D07
Status:	Internal

This deliverable will offer a limited set of symbolic functionality based on Maple, for example integration or root-finding, to be identified in D01.

D21 Symbolic Service Release Candidate

Delivery date:	month 20
Dependencies:	D13, D14, D15
Status:	Public

This deliverable will offer an extended set of functionality, including at least one problem area also handled by the numerical services being developed in task 4.1.

D23 Wrapper Tools Release Candidate

Delivery date:	month 22
Dependencies:	D21
Status:	Public

This deliverable will re-package and document some of the code written for D21 to enable it to be used in deploying other existing software as MONET services.

Task 4.3: Mathematical Problem Solving Environment

Task Co-ordinator	Eindhoven
Partners (effort)	NAG (2), Bath (2), UWO (3), Eindhoven (9)
Start	20
Duration	4 months

This task will demonstrate that the services developed in tasks 4.1 and 4.2 can be used together to solve a range of problems. As such it will also demonstrate the effectiveness of the infrastructure developed in work package 3.

Deliverables

D25 Mathematical Problem Solving Environment

Delivery date:	month 24
Dependencies:	D01, D16, D17, D19, D20, D21
Status:	Public

This deliverable will demonstrate the use of the infrastructure (broker, object manager and explanation service) and the symbolic and numerical services to solve a range of mathematical problems to be identified in D01.

9.1.5 WP5: Dissemination

Work Package Coordinator:	NAG
Principal Partners Involved:	All

This work package is devoted to publicising the work of the project via public workshops and the worldwide web, as well as publications in suitable conferences and academic journals. During the first year the Consortium will present its work at one of the public workshops organised by the OpenMath Thematic Network (IST-2000-28719). Towards the end of the final year it will organise its own dedicated event to showcase the achievements of the project and consider future activities based on it. In addition it will produce a *Dissemination and Use Plan* in the first six months and a *Technical Implementation Plan* towards the end of the project.

Task 5.1: Project Web Service

Task Co-ordinator	NAG
Partners (effort)	NAG (4)
Start	1
Duration	24 months

The project web server will provide access to public reports and software deliverables, as well as hosting the services developed in work package 4.

Deliverables

D26 Multimedia version of project web service

Delivery date:	month 24
Dependencies:	All Public Deliverables
Status:	Public

Task 5.2: Dissemination and Use Plan

Task Co-ordinator	NAG
Partners (effort):	NAG (0.25), Bath (0.25), UWO (0.25), Stilo (0.25), Manchester (0.25), Eindhoven (0.25), Nice (0.25)
Start	1
Duration	4 months

This task will draw up plans for the dissemination of knowledge gained during the project, and (to the extent that this can be foreseen at the beginning of the project) the exploitation plans of the results for the consortium as a whole, or for individual participants or groups of participants.

Deliverables

D02 Dissemination and Use Plan

Delivery date:	month 5
Dependencies:	None
Status:	Internal

Task 5.3: First Public Event

Task Co-ordinator	Eindhoven
Partners (effort):	NAG (0.25), Bath (0.25), UWO (0.25), Stilo (0.25), Manchester (0.25), Eindhoven (1.25), Nice (0.25)
Start	6
Duration	6 months

This will be a special session as one of the public workshops organised by the OpenMath Thematic Network (IST-2000-28719), and will take place during the first year of the project.

Deliverables

D12 Electronic Proceedings

Delivery date:	month 12
Dependencies:	None
Status:	Public

Task 5.4: Open Workshop

Task Co-ordinator	NAG
Partners (effort):	NAG (1.25), Bath (0.25), UWO (0.25), Stilo (0.25), Manchester (0.25), Eindhoven (0.25), Nice (0.25)
Start	18
Duration	6 months

This event will take place towards the end of the final year to showcase the achievements of the project and consider future activities based on it.

Deliverables

D28 Electronic Proceedings

Delivery date:	month 24
Dependencies:	None
Status:	Public

Task 5.5: Technology Implementation Plan

Task Co-ordinator	NAG
Partners (effort):	NAG (0.25), Bath (0.25), UWO (0.25), Stilo (0.25), Manchester (0.25), Eindhoven (0.25), Nice (0.25)
Start	18
Duration	6 months

This task will draw up a report detailing the Consortium's actual achievements in dissemination and its plans for exploitation of the results of the project.

Deliverables

D27 Technology Implementation Plan

Delivery date:	month 24
Dependencies:	D01–D28
Status:	Internal

9.2 Workpackage list

Workpackage list

Work-package No	Workpackage title	Lead partner	Person-months	Start month	End month	Deliv-erable No
WP 0	Management	NAG	24	1	24	N/A
WP 1	Existing & Emerging Technologies	Stilo	18	1	23	1,3,24
WP 2	Ontologies & Protocols	Eindhoven	38	4	14	4,5,6,7, 11,13,14
WP 3	Infrastructure	Nice	47	8	20	8,9,16 17,18,19
WP 4	Demonstrator Services & Applications	NAG	53	8	24	10,15, 20–23,25
WP 5	Dissemination	NAG	23	0	36	2,12,24 26,28
	TOTAL		193			

9.3 Workpackage descriptions

Workpackage description

Workpackage number:	0	Start date or start event:			Start of Project		
Participant number:		1	2	3	4	5	6	7
Person-months per participant:		12	2	2	2	2	2	2

Objectives The aim of this work package is to manage the project, liaise with the Commission and the reviewers appointed by them, to respond to external events, and to ensure that the aims and objectives of the overall project are met.

Description of work See section 9.7.

Deliverables Not applicable (although it will produce internal guidelines and regular management reports as well as the final report, as required under the contract).

Milestones and expected result

Workpackage description

Workpackage number:	1	**Start date or start event:**				Start of Project		
Participant number:		1	2	3	4	5	6	7
Person-months per participant:		4	2	2	2	4	2	3

Objectives This workpackage has three main objectives:

1. to collect user requirements and outline scenarios for the way in which MONET might be used;
2. to investigate existing and emerging technologies with a view to their use in the project;
3. to maintain contact with other groups and organisations doing relevant work (e.g. W3C working groups and other European Consortia).

Description of work The first phase of this work package will be to develop high-level scenarios about how a user might use the MONET framework, as well as detailed low-level requirements covering both technological and functional requirements (task 1.1).
The second phase will be to analyse existing and emerging technologies to see which of them satisfy these requirements (task 1.2). Candidates already identified include UDDI, WSDL, DAML-S, SOAP, CC/PP, OpenMath, MathML and DAML+OIL.
The final phase will be to ensure that the project's view of these technologies remains current and maintain contact with relevant groups and organisations (task 1.3).

Deliverables
D01 Requirements Analysis Report
D03 Report on Existing & Emerging Technologies
D24 Update to Report on Existing & Emerging Technologies

Milestones and expected result After two months the project will have a detailed set of requirements on which to base future work. This will form the basis of most subsequent work in the project.

After four months the project will have identified the relevant technologies it should use.

During the lifetime of the project a "watching brief" will be maintained to ensure that the technological underpin of the work remains current, and that the project reacts properly to new developments.

Workpackage description

Workpackage number:	2	**Start date or start event:**			Month 4		
Participant number:		1	2	3	4	5	6	7
Person-months per participant:		4	0	0	6	11	14	3

Objectives To develop protocols and ontologies which will form the basis of the transactions which will take place in the MONET framework.

Description of work There are four logically distinct aspects to this work:
Task 2.1 Mathematical Problem Description Ontology
Task 2.2 Mathematical Query Ontology
Task 2.3 Mathematical Service Description Language (MSDL)
Task 2.4 Mathematical Solution Explanation Ontology

Deliverables
D04, D11 Mathematical Problem Description Ontology: Initial Draft/Final Version
D05, D13 Mathematical Query Ontology: Initial Draft/Final Version
D06, D14 Mathematical Service Description Language: Initial Draft/Final Version
D07 Mathematical Explanation Ontology: Draft Version

Milestones and expected result The first major milestone will be the delivery of D05 and D06 which will allow work in WP 3 & 4 to start.
The second major milestone will be D07 which will allow development of the explanation component to begin.

Workpackage description

Workpackage number:	3	**Start date or start event:**			Month 8		
Participant number:		1	2	3	4	5	6	7
Person-months per participant:		3	0	0	9	0	20	15

Objectives To develop a specimen framework for mathematical services.

Description of work The work is divided into three main parts:
Task 3.1 development of an example broker
Task 3.2 development of a mathematical object manager
Task 3.3 development of an explanation tool

Deliverables
D08, D16 Broker Initial Beta Version/Release Candidate
D09, D17 Mathematical Object Manager Initial Beta Version/Release Candidate
D18 Broker API Initial Beta Version
D19 Explanation and Debugging Tool Updated Beta Version

Milestones and expected result The first major milestone will come at the end of the first year when a broker, supporting the technologies identified in WP1 and those developed in WP2, becomes available. This will allow for collections of services to be combined into a single application.
The final result will be an improved broker plus an object manager and explanation tool, both tested through use in WP4.

Workpackage description

Workpackage number:	4	**Start date or start event:**			Month 8		
Participant number:		1	2	3	4	5	6	7
Person-months per participant:		12	19	12	0	0	9	0

Objectives To test the ontologies and frameworks developed in other workpackages in a practical setting and, conversely, to provide feedback and further requirements to those activities based on practical experience.

Description of work This workpackage will develop two families of services, one numerical (task 4.1) and the other symbolic (task 4.2), and show how they can be embedded in the MONET framework to deliver a mathematical problem solving environment (task 4.3).

Deliverables

D10, D20 Numerical Service Initial Beta Version/Release Candidate
D22 Service API Release Candidate
D15, D21 Symbolic Service Initial Beta Version/Release Candidate
D23 Wrapper Tools Release Candidate
D25 Mathematical Problem Solving Environment

Milestones and expected result The expected results are a set of collaborating services which can be used to solve particular applications.

Workpackage description

Workpackage number:	5	**Start date or start event:**			Start of Project		
Participant number:		1	2	3	4	5	6	7
Person-months per participant:		6	1	1	1	1	2	1

Objectives To publicise the work of the project via public workshops and the worldwide web, as well as publications in suitable conferences and academic journals.

Description of work The coordinator will host a web service (task 5.1) which, in addition to a conventional web site containing information about the project, will provide a central point of access to MONET software and facilities for third parties to experiment with MONET services.
The Consortium will hold a special session at an OpenMath Thematic Network meeting in the first year (task 5.3) and its own workshop in the second (task 5.4).
The Consortium will produce a *dissemination and use plan* (task 5.2) and a *technology implementation plan* (task 5.5).

Deliverables
D02 Dissemination and Use Plan
D12 Electronic Proceedings
D26 Multimedia version of project web service
D27 Technical Implementation Plan
D28 Electronic Proceedings

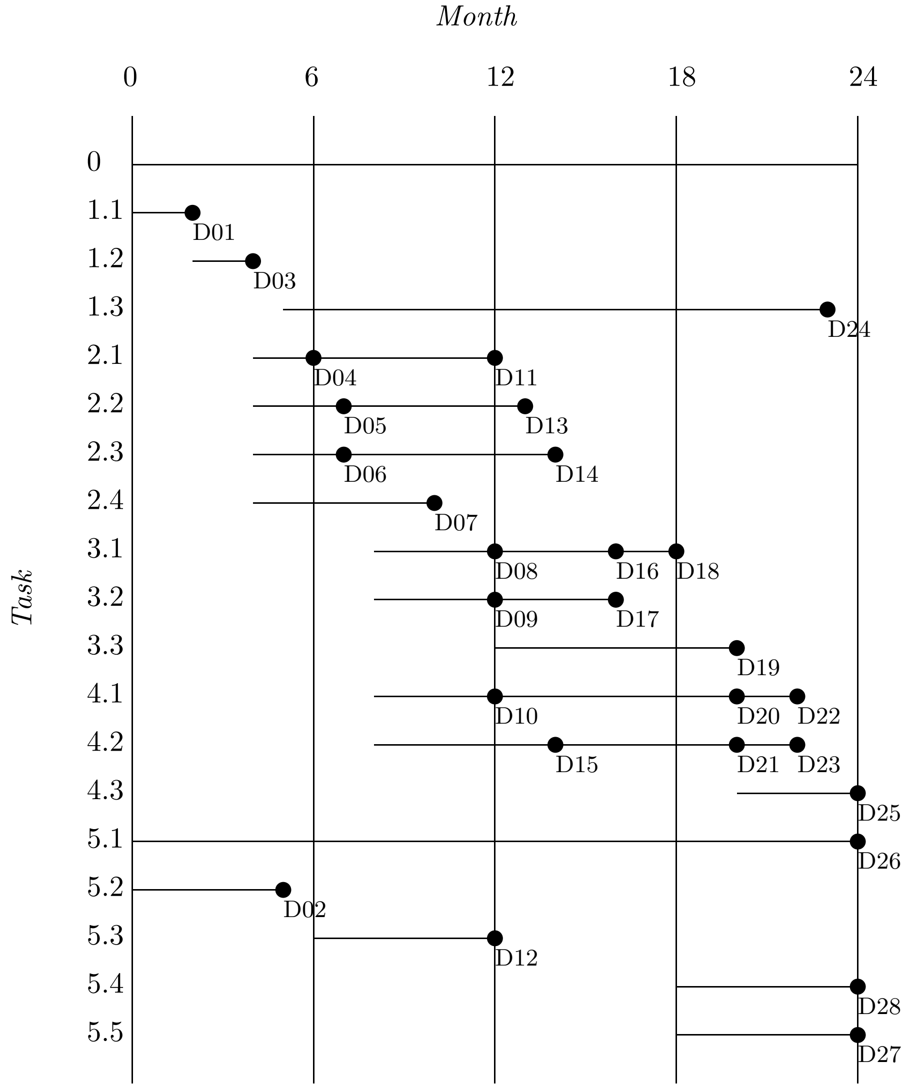
Milestones and expected result The coordinator will host a web service which, in addition to a conventional web site containing information about the project, will provide a central point of access to MONET software and facilities for third parties to experiment with MONET services.
Towards the end of the project a workshop will be held to showcase the work of the project and gain feedback from other interested parties and potential users.

9.4 Deliverables List

Del. no.	Deliverable Name	WP no.	Lead part.	Est. person-months	Del. type[1]	Security	Delivery (proj. month)
D01	Requirements Analysis Report	1	NAG	7	Report	Internal	2
D02	Dissemination and Use Plan	5	NAG	2	Report	Internal	5
D03	Report on Existing & Emerging Technologies	1	VUM	7	Report	Public	4
D04	Mathematical Problem Description Ontology: Initial	2	TUE	4	Draft Ontology	Public	6
D05	Mathematical Query Ontology: Initial	2	TUE	4	Draft Ontology	Public	7
D06	Mathematical Service Description Language: Initial	2	Stilo	6	Draft Ontology	Public	7
D07	Mathematical Explanation Ontology: Draft	2	TUE	8	Draft Ontology	Public	10
D08	Broker Initial Beta	3	TUE	9	Beta Version	Internal	12
D09	Mathematical Object Manager Initial Beta	3	Nice	8	Beta Version	Internal	12
D10	Numerical Service Initial Beta	4	NAG	8	Beta Version	Internal	12
D11	Mathematical Problem Description Ontology: Final	2	TUE	4	Ontology	Public	12
D12	Electronic Proceedings	5	TUE	2	Proceedings	Public	12
D13	Mathematical Query Ontology: Final	2	TUE	4	Ontology	Public	13
D14	Mathematical Service Description Language: Final	2	Stilo	8	Ontology	Public	14
D15	Symbolic Service Initial Beta	4	Bath	12	Beta Version	Internal	14
D16	Broker Release Candidate	3	TUE	5	Prototype	Public	16
D17	Mathematical Object Manager Release Candidate	3	Nice	5	Prototype	Public	16
D18	Broker API Initial Beta	3	TUE	10	Beta Version	Public	18
D19	Explanation and Debugging Tool Updated Beta	3	TUE	10	Beta Version	Internal	20
D20	Numerical Service Release Candidate	4	NAG	4	Prototype	Public	20
D21	Symbolic Service Release Candidate	4	Bath	8	Prototype	Public	20
D22	Service API Release Candidate	4	NAG	2	Prototype	Public	22
D23	Wrapper Tools Release Candidate	4	Bath	2	Prototype	Public	22
D24	Update to Existing & Emerging Technologies	1	Stilo	5	Report	Public	23
D25	Mathematical Problem Solving Environment	4	TUE	16	Prototype	Public	24
D26	Multimedia version of project web service	5	NAG	4	CD ROM	Public	24
D27	Technical Implementation Plan	5	NAG	2	Report	Internal	24
D28	Electronic Proceedings	5	NAG	3	Proceedings	Public	24

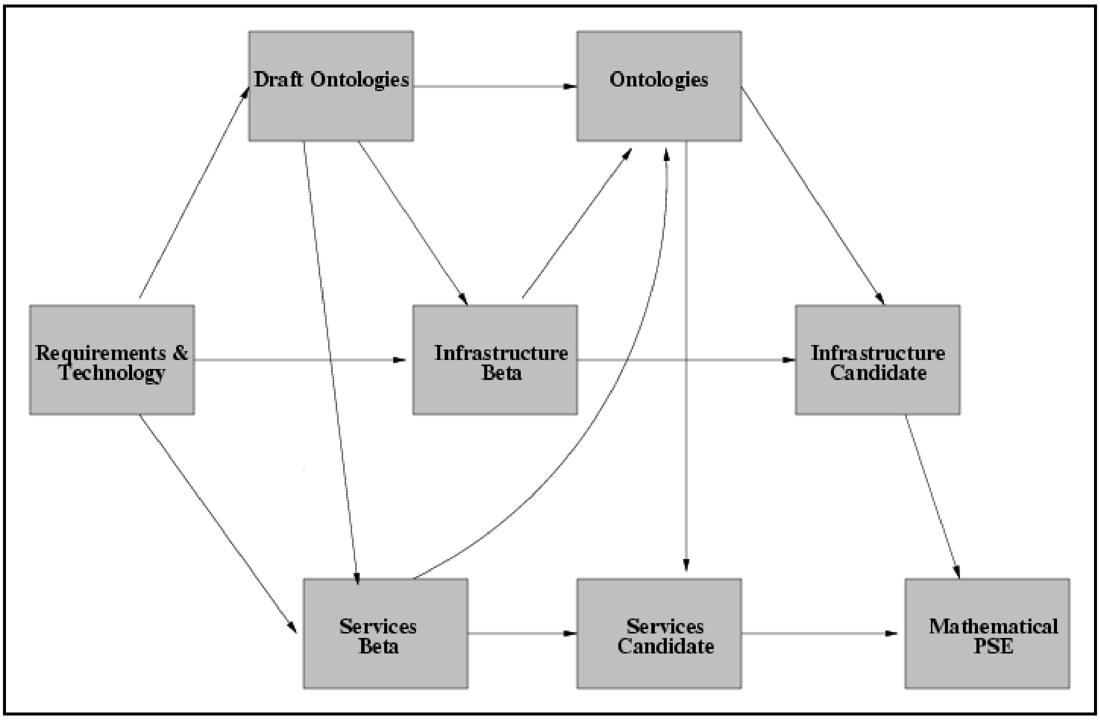
1. N.B. All deliverables will include a written report

9.5 Project planning and timetable



The above picture shows the timeline for each task along with an indication of when each deliverable is due. Work package 0 (project management) has no deliverables *per se* but will be responsible for producing the periodic management reports, as required elsewhere in the contract.

9.6 Graphical presentation of project components



The above diagram shows how the various groups of deliverables are related. The initial requirements analysis and technology survey feed directly into the work on ontologies, and also the implementation of services and infrastructure. These first versions provide feedback to the ontology developers which will be taken into account when producing the final versions. The candidate releases of both services and infrastructure will support these final versions and will form the basic components of the Mathematical Problem Solving Environment demonstrator.

9.7 Project management

The Coordinating partner, The Numerical Algorithms Group Ltd., has extensive experience in managing international collaborative activities both inside and outside the ESPRIT framework. The following formal structures have been used successfully in several previous projects.

9.7.1 Project Manager

The Project Manager will be appointed by the Coordinating Partner and will be responsible for the day-to-day running of the project. These duties will include organising project meetings, collating and completing progress reports, liaising with the Commission and coordinating the technical work of the project. The Project Manager will also coordinate project-wide dissemination activities and external contacts. It is the intention of the Coordinating Partner to appoint Dr Mike Dewar, who previously managed the FRISCO and OpenMath projects, and who is currently coordinating the OpenMath Thematic Network, to this post.

In addition, each partner will appoint a team leader, responsible for their local project management and as to liaison between the Project Manager and their local administration.

9.7.2 Project Management Committee

The Project Management Committee is responsible for ensuring that the goals of the project are achieved. It will therefore review progress towards those goals, and initiate any required changes in the overall project plan in order to achieve them. Its meetings will be organised by the Project Manager and will take place roughly every six months.

At his discretion, or at the request of any members of the Committee, the Project Manager may propose alternatives to physical meetings, for example by allowing some of the members to participate by telephone. However any such arrangement can only be made with the prior agreement of all members of the Committee.

At its first meeting the Project Management Committee will appoint a Chairman, on the recommendation of the Coordinating Partner. This Chairman will be responsible for chairing meetings and ensuring that the Committee is effective in working towards the aims and objectives of the project. In addition, the Chairman will act as an arbiter should any policy conflicts arise, according to the dispute resolution procedure described below. It is anticipated that the Chairman of the Project Management Committee will be Professor James Davenport of the University of Bath.

Every effort will be made to achieve decisions by consensus, however each project partner will have one voting member on the Committee with the authority to commit that partner in terms of project actions. In addition the Project Manager and the Chairman of the Committee will be non-voting members. Associate partners may choose to attend meetings of the PMC at their discretion, otherwise it will be the responsibility of the full partner to whom they are associated to represent their interests.

9.7.3 Management of Work Packages and Tasks

It is obviously important that the allocation of responsibilities for technical coordination at the task and work package level is made clear by each partner. To facilitate this each partner will identify individuals with the following responsibilities:

Work Package Coordinators The individual responsible to the Project Manager for organisation of a work package, appointed by the lead site identified in the work plan.

Task Coordinators The individual responsible to the Work Package Manager for a particular task, appointed by the Work Package Coordinator in consultation with all sites involved.

All Work Package Coordinators and Task Coordinators must be identified to the Project Manager as early as possible, and certainly before the activity they are responsible for begins. The Project Manager will maintain a list of these individuals and make it available to all the partners on a regular basis.

9.7.4 Dispute Resolution Procedure

The following procedures shall govern the resolution of disputes between the parties. A dispute is defined as a severe disagreement between at least two parties about a technical or managerial aspect of either a particular work programme (or task) or about the Project as a whole. The term dispute includes identified areas of possible future dispute, which may be avoidable.

1. A (possible) dispute may be raised by any party: it requires a written statement identifying the problem to be passed to the Project Manager, who will then inform the Chairman of the Project Management Committee.

2. After due consultation with the Project Manager the Chairman will decide on the required action from the following options:
   (a) he tries to resolve the dispute; and/or
   (b) he puts the dispute on the agenda for the next meeting of the Management Committee; or
   (c) he calls a special meeting of the Management Committee to consider and resolve the dispute.

   If a dispute occurs during a meeting of the Management Committee, the Chairman may, at his discretion, choose to attempt to resolve the dispute immediately without waiting for the next meeting.
3. Information about the dispute which is presented at a meeting of the Management Committee must be circulated to all members of the Committee, using both telefax and electronic mail. Information is in time if it arrives at the site of each Committee member at least one (1) week before the dispute resolving meeting. If information arrives late at a member's site, then this member has the right to defer the decision to a later meeting.
4. The dispute will be debated by the Management Committee according to the following rules:
   (a) the two or more alternatives of the decision must be clearly stated;
   (b) for each of the alternatives offered at least one supporter must be present at the meeting;
   (c) each alternative will be presented to the meeting by one of its supporters;
   (d) sufficient time for discussion must follow the presentation of each alternative at the meeting.

   The Project Manager is responsible for ensuring that appropriate notification of the outcome of the voting and of the decision is given to each party.
5. These procedures may be changed only by a two-thirds resolution of the Management Committee.

9.7.5 Changes to the Project Budget

Any partner may alter the estimated breakdown of its own allowable costs with the prior written (by letter, fax or email) approval of the Project Manager. The Management Committee may agree to change the apportionment between the parties of the estimated allowable costs of the Project as a whole, subject to the following conditions:

1. Details of the proposed changes, and the views of all the partners directly involved, must be circulated to all members of the Management Committee using both telefax and electronic mail. Information is in time if it arrives at the site of each Committee member at least one (1) week before the dispute resolving meeting. If information arrives late at a member's site, then this member has the right to defer the decision to a later meeting.
2. The representatives of all parties involved must be given the opportunity to present their point of view at the meeting.
3. A decision of the Management Committee to change the apportionment must be unanimous in the first instance. If the Management Committee is divided, then the issue shall be regarded as a dispute and the normal dispute resolution procedure invoked.

10: Clustering

The MONET Consortium will collaborate with the OpenMath Thematic Network (IST-2000-28719) and participate formally in at least one of its workshops during the first year of the MONET project. Collaboration will be managed by NAG which is the coordinating partner of both projects.

Further clustering and collaboration with projects in the Semantic Web programme will be undertaken if appropriate.

11: Other contractual conditions

11.1 Subcontract between Eindhoven and Dr. Olga Caprotti

The Technical University of Eindhoven proposes to perform a significant amount of its work via a subcontract with a former employee, Dr. Olga Caprotti. Dr. Caprotti is an expert in OpenMath and in Theorem Proving and Automated Reasoning. In particular she will contribute to the work on ontologies for mathematical problems and queries (deliverables D04/11 and D05/13), the prototype broker (D08/16) and to the mathematical explanation ontology (D07) and the explanation tool to be based on it (D19).

Dr. Caprotti joined the OpenMath IST project after her graduation from RISC in Linz with a PhD in symbolic computation. She was an editor of the OpenMath standard and continues to be an active member of the OpenMath Society. She has gained invaluable experience in building client-server applications connecting mathematical software systems such as GAP, Maple, COQ, CoCoA and R, where the communication is carried out using OpenMath. It is this experience which the Consortium believes will be invaluable in developing both the underlying MONET protocols and in the software which supports them.

At the time of writing Dr. Caprotti is moving from Austria to Sweden for family reasons, and has no professional affiliation there. She cannot be employed directly by any of the partners to work on the project since personnel costs are only regarded as allowable when the staff in question are employed on-site (i.e. use the overhead of the contractor). For this reason it is proposed to employ her via a sub-contract.

The Consortium believes that Dr. Caprotti's unique experience and skills will be invaluable in helping the project to achieve its objectives. However, should Dr. Caprotti be unable to complete her obligations under this subcontract, for example due to *force majeure*, the Consortium will seek another suitable person to complete the work as an employee of one of the partners. If necessary an appropriate part of Eindhoven's personnel budget will be transferred to another partner to facilitate this.

11.2 Travel & Subsistence Costs

The Consortium has budgeted €10,000 per partner per year for technical and project management meetings, on the basis of eight trips/meetings at €1,250 per person. This will include attendance at the kick-off and annual peer review meeting and, if appropriate, the annual concertation meeting and programme conference as required elsewhere in this Annex. In practice the Consortium will meet as a whole roughly every six months, with special interest groups meeting more frequently as required.

In addition, the Co-ordinator has budgeted a further €6,000 per year to cover the additional costs of the regular progress meetings with the project officer (two a year in Luxembourg and up to two elsewhere) and visits to partner sites to monitor progress.

The University of Western Ontario expects to participate in only some of the project meetings, and has drawn up its budget on that basis.

11.2.1 Travel outside the EU

As the University of Western Ontario is situated in Canada some travel outside the EU will be required for technical collaboration, particularly as part of task 4.2 (Symbolic Solver Service), and possibly also for the Project Coordinator.

12: Reporting and Dissemination

12.1 Foreword

This chapter is an integral part of Annex I — Description of work, as agreed between the Consortium and the European Commission (EC). It sets out a number of practical provisions and operational timescales regarding management and progress reports, including yearly public reports; deliverables and activities relating to project- and programme-level awareness and dissemination; periodic peer reviews; and concertation and project-clustering activities. Some or all of these activities, reports and events may be addressed elsewhere in Annex I. The amount of the EU financial contribution set out in the Contract is inclusive of funds destined to cover any costs incurred by the Contractors in the performance of the tasks detailed in this Appendix. In the event of any conflict between this chapter and Annex III — Special Conditions for the IST Programme, the latter shall take precedence.

12.2 Project Documentation

The Contractors undertake

(a) To provide a brief project Fact Sheet suitable for web publishing, within one month from the start of the project, and to maintain and update it until the Contract expiry date. The Fact Sheet will outline the project rationale and objectives, specify the project's technical baseline and intended target groups and application domains, and detail intermediate and final outputs. Said Fact Sheet will be used by the Commission for its own dissemination and awareness activities throughout the project lifecycle, and will be published on EC and EC sponsored websites.

(b) To set up a project Website within three months from the start of the project, and to maintain and update it until the Contract expiry date. Said site will provide project overviews and highlights; up-to-date information on intermediate and final project results, including public reports and synthesis reports drawn from selected confidential material; project events, including e.g. user group meetings, conferences and workshops; contact details, etc. The Website will be cross-linked from/to other relevant EC and EC sponsored sites.

(c) To provide at the latest by the first peer review (see 3. below), a comprehensive MS-PowerPoint or HTML Presentation detailing all the key features of the project. A final, augmented version of this Presentation will be transmitted to the Commission together with the project's final report, and will where appropriate contain additional multimedia assets (e.g. video clips). Said Presentation will be used by the Commission for its own dissemination and awareness activities, during and after the completion of the project, and will where appropriate be published on EC and EC sponsored websites, and other electronic publications.

(d) To supply at the latest by the date of submission of the final report a web enabled (or CD/DVD based) Showcase, and to grant the Commission the right to use said Showcase for its own dissemination and awareness activities, including web based and electronic publications, after the completion of the project. The Showcase will feature a meaningful subset (software, data, etc.) of the functionality characterising the project demonstrator(s) arrived at, along with relevant copyright notices and contact information, and suitable installation aids and run-time interfaces.

Item (d) above applies to projects and other actions which are intended to produce runnable software and/or electronic datasets and do not use technical platforms (e.g. non-standard hardware, pre- requisite commercial software) which would make the Showcase unsuitable for use in a normal web or office/exhibition environment.

12.3 Peer Reviews

All the actions (including RTD projects, accompanying measures, thematic networks, working groups, etc.) established within the IAF area of Key Action III will in principle undergo one peer Review in each calendar year. As a general rule, no Reviews will be held in the first 10 months of implementation of the action. Section 2 of Annex III sets out the provisions governing the technical verification procedure in RTD, demonstration and combined projects.

12.4 Reporting to the Project Officer

The Co-ordinator undertakes to produce the following Reports in the English language on behalf of the Consortium, and to forward them to the EC Project Officer according to the following conditions and timescales. Note: All timings are relative to T1 (project start date); Tn denotes the project end date; both dates as defined in the first indent of Article 2 of the Contract.

Due Date	**Title**	**Coverage**	**Distribution**
T3, T9, T15, …	Quarterly management report	Brief report summarising main achievements, activities and events in the reporting period, including where appropriate problems, delays etc. encountered. To be drawn up according to a template supplied by the EC.	Project Officer and Peer Reviewers
T6, T12, T18, …	Semestrial progress reports (as defined in Article 4 of the General Conditions)	Detailed overview of the work completed/launched in the reporting period, resources employed, departures from the work schedule, and plans for the next phase. Combined with deliverables due in the reporting period and corresponding cost statements.	Project Officer and Peer Reviewers
15 November in each calendar year	Annual public reports	For a broad public outside the consortium. To document the main results obtained and promote the objectives of the project. Designed for web publishing according to a template provided by the EC.	Public
Tn+2	Final report	To describe in detail all the work carried out and the results obtained under the Contract. Together with the end-of-project deliverables, including the technology implementation plan, it will be a means to assess the output of the project. A non-public part will include a.o. technical documentation, results arising from tests and assessments, prospects for further development and deployment, and exploitation plans. A chapter of the final report will assess the portability of the results arrived at and their scalability and suitability for other tasks and domains.	Public synthesis report. Main report reserved to Project Officer and Peer Reviewers

The Final Report will be accompanied by a CD-ROM, or an equivalent digital storage medium, containing all the contractual reports and other ‘paper-based’ deliverables (e.g. market analyses, system specifications, test results, technology implementation plan, etc.), for long-term secure storage in the Commission archives.

12.5 Meetings

The Contractors will ensure adequate representation at the following Meetings:

Frequency	Type of meeting	Purpose	Participants	Venue
1	Project Kick-off meeting	To launch the project and refine plans and arrangements for the first 3-6 months of work. Where appropriate, to meet and exchange non-confidential information with representatives of Support Projects (cf. section 6) and other related RTD projects.	Consortium members, Project Officer, IAF management	Luxembourg
Up to 4 per calendar year	Progress meeting	To review progress and discuss any significant problems and deviations.	Co-ordinator and Project Officer	2/year in Luxembourg; up to 2/year elsewhere, in connection with Consortium meetings
1 per calendar year	Peer Review meeting	To evaluate intermediate and final results. To assess quality, impact and effectiveness of project work.	Co-ordinator and relevant workpackage leaders, Project Officer, Peer Reviewers	Luxembourg; where possible coupled with Concertation meeting
1 per calendar year	Concertation meeting	To present work in progress and demonstrate intermediate results. To identify and discuss areas of common interest. To plan joint investigations and dissemination activities. See section 6.	Coordinators of IAF consortia and/or workpackage leaders, plus external experts, suppliers and users where appropriate	Luxembourg; elsewhere where dictated by practical and technical constraints
1 per calendar year	Programme Conference and Exhibition	To actively participate in discussions and demonstrations organised by the IST programme.	Co-ordinator and/or workpackage leaders	Tbd

12.6 Clustering and Concertation

To enhance the overall value and coherence of RTD work, and its relevance to European and worldwide developments, the Commission intends to put in motion a number of Support Projects addressing e.g. best practice and standards work; pan-European network(s) of excellence encompassing technology foresight and research roadmaps, cross-disciplinary training and technology transfer in the IAF field; and information exchanges between IAF projects and with other relevant projects and laboratories. The Contractors may be invited to contribute to and participate in periodic concertation meetings or special interest groups organised by these and other forthcoming Support Projects. Further provisions relating to concertation and information exchange and dissemination are detailed in section 1 of Annex III — Special Conditions.

A: Consortium Description

A.1 Consortium Overview

The Consortium is led by The Numerical Algorithms Group Ltd. (NAG), Europe's largest vendor of mathematical software. NAG has a great deal of experience in managing European collaborations and in particular coordinated the OpenMath RTD project and is currently managing the OpenMath Thematic Network. NAG also brings extensive experience in ad-hoc and formal standardisation activities (the Basic Linear Algebra Subset [BLAS], Fortran-90, Java Grande, MathML etc.) to the Consortium.

A number of partners have been involved in the OpenMath project and bring expertise in representing mathematical semantics. Stilo Technology Ltd. is heavily involved in the wider issue of standards and protocols for the web and, along with NAG and the University of Western Ontario, has a representative on the W3C Math Working Group. Stilo has experience of the commercial application of many XML technologies and ontologies to real-world applications. The University of Manchester is a world leader in the development of the theory and application of description logics and one of the prime movers behind the DAML+OIL ontology meta-language. We believe that this combination of experience and expertise is ideally suited to the task of creating ontologies and protocols for describing mathematical problems, services and solutions.

The Technical University of Eindhoven (TUE) bring expertise in integrating OpenMath with the formal structures used by logic systems and theorem provers, and of integrating computer algebra with theorem proving. They will use that expertise to develop procedures and software to help a user to navigate and understand the mathematical solution process.

The University of Nice has an extensive track record in developing tools and environments for linking mathematical software packages. TUE also have experience in integrating different software packages through their novel electronic book *Algebra Interactive!* which now forms the basis of undergraduate mathematics courses in several universities. NAG develops and markets the visual programming language and environment IRIS Explorer which is a framework for linking components for mathematical problem solving and visualisation. This experience will be invaluable in developing the MONET infrastructure.

A number of partners in this consortium are experienced in the development of mathematical software of various kinds, and will apply that expertise to the development of services. NAG will lead the development of the numerical service, based on its renowned libraries of numerical subroutines. The University of Bath has helped develop a number of symbolic packages including Reduce and AXIOM, and will lead the development of the symbolic service. The University of Western Ontario is a major contributor to the Maple system, one of the three most widely used interactive mathematical packages in the world, and will assist Bath in developing the symbolic service.

In addition, NAG and Bath have experience in the design and implementation of "expert systems" for the selection of solution strategies for mathematical problems. In particular they have developed systems which use computer algebra packages such as AXIOM and Reduce to analyse and pre-process numerical problems. This experience will form the basis for the design of software agents for selecting mathematical algorithms within the MONET framework.

A.2 Consortium Members

A.2.1 The Numerical Algorithms Group Ltd

The Numerical Algorithms Group (NAG) develops and provides world-leading software to solve complex mathematical problems. It has offices in the UK, France, Germany, Japan and the US and has created a world-wide collaborative network of the world's best mathematical experts. In 1971 NAG developed the first mathematical software library that now has over 10,000 users world-wide and contains over a thousand mathematical and statistical functions. The range of products and services that NAG offers has continually expanded into statistical, symbolic, visualisation and numerical simulation software, compilers and application development tools and wide-ranging consultancy

To meet its customers' needs the NAG Libraries span many computing languages and platforms and are continually being upgraded to take advantage of the latest technologies - multi-processor PCs, for example. NAG's consultancy service offers its own expertise in developing software, coupled with world-leading knowledge of numeric computation. Customers who can't develop their own application, need a specific solution or just advice on how to get the best from the NAG Libraries can benefit. NAG's software grew out of university mathematics departments, but industries and businesses all around the world have been using it for everything from space flights to agriculture. Simply defined as "sophisticated number crunching" the software continues to evolve at a dramatic pace to meet the surge in complexity of mathematical problems in all walks of life from aircraft design to portfolio management.

NAG believes strongly in the importance of collaboration as the only way of keeping abreast of technological developments, and it has a strong record in participation in and management of projects at a national and international level. It is also committed to the development of and adherence to standards to improve the efficiency and flexibility of its software. In particular NAG coordinated the recent OpenMath IST project and is currently managing the OpenMath Thematic Network. It also participated in the development of W3C's MathML 2 recommendation.

Key Personnel

Dr. Mike Dewar is a Senior Technical Consultant in the Software Environments Division of the Company. His PhD was in the area of integrating symbolic and numerical approaches to problem solving and, after working as a lecturer in Computer Science at the University of Bath, he joined NAG in 1994. He is responsible for packages in both the Reduce and AXIOM computer algebra systems and has contributed to the Aldor Compiler. He previously served as project Coordinator for the ESPRIT projects FRISCO (21.024) and OpenMath (24.969), and is currently managing the OpenMath Thematic Network (IST-2000-28719). He is a member of the Executive Committee of the OpenMath Society, an organisation set up to maintain OpenMath at an international level, and an Honorary Reader in Computer Science at the University of St. Andrews.

Dr. David Carlisle is also a Senior Technical Consultant in the Software Environments Division. He holds a PhD in mathematics from the University of Manchester and before joining NAG in 1998 was a research fellow at the Universities of Manchester and Cambridge. He was one of the major authors of the LaTeX 2_ε typesetting system, and in his spare time still contributes to the LaTeX3 project. He is a member of the W3C Math Working group, and was a co-editor of the MathML 2 Recommendation. He worked on the OpenMath Project (24.969) and is an editor of the OpenMath standard, and is currently filling the rôle of CD Maintainer in the OpenMath Thematic Network.

A.2.2 University of Bath

The University of Bath is a comparatively small, science-oriented, university, ranked in the top ten of British universities by all the league tables: indeed the Financial Times' last league table said "Bath has definitely earned its place in Britain's own Ivy League". It is the only University in the top ten to make a year of industrial placement, sometimes abroad, a feature of almost all its undergraduate degrees — indeed in 1998–9 a student was on placement at ZIB and subsequently wrote the OpenMath↔MathML translator[1] based on Reduce. The University is committed to the appropriate use of e-Learning technology, and, after a pilot in 2000–1 led by Professor Davenport, is now rolling out the use of Blackboard[2] and BoxMind[3] throughout the University, with expertise provided by the University's Centre for the Development of New Technologies in Learning which is also developing one of the "fast track" courses for the U.K.'s e-University project.

The Department of Computer Science, though newly formed in 2001, is merely a restructuring of the Computing Group of the Department of Mathematical Sciences, which goes back to the foundation of the University. As such, it achieved a rating[4] of 5 in the 1996 national Research Assessment Exercise, and is confident of doing at least as well in the 2001 exercise. It has participated in several European projects, notably PoSSo (for which Professor Davenport's group provided the technical manager), OpenMath (of which Professor Davenport was the Chairman) and the OpenMath Thematic Network (of which Professor Davenport is the Chairman).

The University is also home to the nationally funded centre of expertise in digital information management UKOLN `www.ukoln.ac.uk`, and Professor Davenport is one of the University's representatives on UKOLN's Management Committee. UKOLN has several rôles, among which are acting as the UK Higher Education Funding Council's member of the World-Wide Web Consortium, and providing UK Higher Education's "Web Focus". It publishes the electronic newsletter *Ariadne*, and has taken part in several European projects, notably SCHEMAS, DESIRE and Renardus. Staff within UKOLN have experience of working with technologies associated with the Semantic Web such as XML, RDF and the Dublin Core.

Key Personnel

Professor Davenport Professor Davenport has worked on the interface between Mathematics and Computer Science for over thirty years. His major interest is computer algebra, where he wrote his thesis[5] and the first major textbook[6] on the subject. He was a major designer of the Axiom computer algebra system, and has also contributed extensively to Reduce. He was the first holder of the Ontario Research Chair of Computer Algebra at ORCCA. He also works in cryptography, having been part of the team that broke the discrete logarithm problem

1. L. Alvarez Sobreviela: A Reduce-based OpenMath ↔ MathML Translator. *ACM SIGSAM Bulletin* special issue on OpenMath **34**(2000) 2, pp. 31–32.
2. `www.blackboard.com`
3. `www.boxmind.co.uk`
4. The scale has seven points: 1, 2, 3b, 3a, 4, 5, 5*.
5. *On the Integration of Algebraic Functions*, Springer Lecture Notes in Computer Science 102, Springer-Verlag, 1981.
6. Davenport, J.H., Siret,Y. & Tournier,E., *Calcul Formel*, Masson, 1986 and 1993; English translation *Computer Algebra*, Academic Press, 1988 and 1993; Russian translation Mir, 1991.

over GF(2^{127}) in 1982, and in networking, where he has done much consultancy for the UK Government and industry. He is also the University's Director of Information Technology, where he has responsibility for the University's Computing Service and Library, as well as several initiatives such as e-Learning and Web accessibility.

A.2.3 University of Western Ontario (UWO)

The University of Western Ontario is one of the premier research-intensive universities in Canada. With approximately 25,000 students and 1200 faculty, the University comprises the full range of academic and professional programs, from science and engineering through medicine, law and music. The university is the lead institution in Canada's current super-computing effort, SHARC Net.

The Department of Computer Science is one of the most rapidly growing in Canada, with approximately 30 research and teaching faculty members. Degrees are offered at the bachelors', masters' and doctoral levels in Computer Science. Several joint degrees are offered at the bachelors level, including an innovative program in Computer Science and Law. Major areas of research in the department include image analysis and computer vision, distributed systems management and network quality of service, formal languages, compilers and computer algebra. The Department of Applied Mathematics is one of only two in Canada, with a strong graduate program and research areas including computational fluid flow, high energy physics and financial mathematics.

The Ontario Research Centre for Computer Algebra (ORCCA) is a joint effort between the departments of Computer Science and Applied Mathematics at UWO, and the department of Computer Science at the University of Waterloo. The centre runs a program of invited Research Chairs, about which special programs are organized. The past year's program focused on Symbolic Linear Algebra, and the current year's centres on Mathematical Communication (MathML, OpenMath, etc.) The major areas of research of the centre are symbolic methods for differential equations, symbolic-numeric algorithms for polynomials, mathematical communications and software systems for computer algebra.

Researchers at the centre have direct experience in the conduct of European projects, and have worked closely with some of the MONET participants, specifically NAG and the University of Nice in this context. It is understood that the EU shall not fund the Canadian participation in the current project.

The members of ORCCA have significant technology transfer experience, seeing the results of their research efforts taken up in industrial contexts from pulp and paper processing to software development. Most directly related to the present proposal is the participation in the MathML and OpenMath standard definition efforts, the successful alignment of these standards with each other and with other industry standards, and the adoption of these standards in commercial products, such as Maple 7.

Key Personnel

Stephen M. Watt (Ph.D. Waterloo) is Chair of the Department of Computer Science at UWO, and the Director of the ORCCA. Previously he was a Professor at Université de Nice and Responsable Scientifique of the SAFIR project at INRIA. Prior to that he was a Research Staff Member at the IBM T. J. Watson Research Center for 12 years. He has extensive experience working with both the NAG and Waterloo Maple companies, has previously served as

Chairman of the ESPRIT project FRISCO (LTR 21.024), and presently serves on both the OpenMath executive committee and the W3C Math Working Group. Dr. Watt is one of the principal authors of Maple, Axiom and Aldor, and is active in the areas of symbolic-numeric algorithms, internet-based mathematics, and compilers. Dr. Watt shall serve as the UWO principal investigator for this project.

Robert M. Corless (Ph.D. British Columbia) is a Professor in the Department of Applied Mathematics, and the Deputy Director of ORCCA. He is Chair of the ACM Special Interest Group on Symbolic and Algebraic Manipulation (SIGSAM). He is the author of "Essential Maple" (Springer-Verlag, 1995) and over 70 technical papers. As one of the contributors to the Organic Mathematics Workshop (Simon Fraser University, December 1995) he is one of the early contributors to internet-based mathematics. Dr. Corless works in the area of symbolic-numeric algorithms, numerical analysis and dynamical systems.

William Naylor (Ph.D. Bath) is an ORCCA postdoctoral fellow at UWO, having previously worked on the OpenMath ESPRIT project. His current research is in the automated creation of mathematical stylesheets for XML markup of mathematical content.

A.2.4 Stilo Technology Ltd

Stilo Technology Ltd is a wholly-owned division of Stilo International plc, the first specialist XML company to be listed on the Alternative Investment Market (AIM) of the London Stock Exchange. In addition to Stilo Technology Ltd, Stilo International plc wholly owns Omnimark Technologies Corporation in Ottawa, Canada, and holds a majority shareholding in eidon GmbH in Nuremburg, Germany. Group companies develop and market content engineering technologies which enable enterprises more readily to automate the integration, creation, management and re-purposing of large quantities of data using XML. Customers include major systems integrators (CGEY, CSC, Siemens, EDS); Fortune 500 companies (IBM, SUN, Boeing); Government agencies (the US Department of Defence, European Parliament); and many of the world's largest publishing organisations, including the US Government Printing Office and Reed Elsevier. With offices now in Canada, USA, UK, Germany, Belgium, France and distributors in Australia and Japan, Stilo companies operate in some of the world's leading markets and so are additionally able to provide global customers with local training, sales, consultancy and supporting services. Stilo Technology Ltd has a research and development responsibility within the group, investigating new standards, technologies and models of service provision, and developing innovative approaches, tools and techniques to meet the requirements of the evolving markets. Stilo Technology Ltd was a member of the ESPRIT OpenMath project (EP24969), and is a member of the OpenMath Thematic Network (IST-2000-28719). Stilo Technology Ltd is also a member of the W3C.

Key Personnel

Stephen Buswell — Chief Technology Officer After reading mathematics at Oxford, Stephen Buswell has worked in IT in the UK, Europe and North America at organisations including Logica, European Payment Systems Services and, as an independent consultant, the Polish Ministry of Finance. Applications included telecommunications, finance and control software for life sciences experiments on board Spacelab. Stephen co-founded Stilo in 1992, since when he has specialised in markup languages, information architecture and web technologies. Stephen is a member of the W3C Math Working Group and a Principal Writer of the MathML Recommendation for mathematics on the web. He worked on the ESPRIT OpenMath project (EP24969), and is a member of the ESPRIT OpenMath Thematic Network (IST-2000-28719). Stephen is also a member of the W3C Advisory Committee.

Nick Taylor — Senior Developer Nick specialises in enterprise architectures using the Java 2 Enterprise Edition, distributed computing using CORBA and application integration. He was previously Research Fellow at the University of the West of England, participating in a number of successful collaborative research projects. MOTOS (Management of Traffic in Open Systems), a DTI funded investigation into the use of open systems for real-time traffic monitoring, used neural network technology to predict traffic flows and potential congestion. TRENDS (Traffic Engineering Data Services) an ESPRIT funded project, was a CORBA/Java implementation of the principles of the MOTOS project using live traffic . FollowMe, an ESPRIT project, investigated the use of mobile agents as a means by which information could be delivered to a variety of devices such as PDAs and mobile phones. Nick has extensive Java experience and holds an MSc in Communicating Computer Systems.

Nick James — Senior Developer Nick has worked as a software engineer and project leader for twelve years. He specialises in data management and database software, and has in depth knowledge of database systems. He has worked as an engineer producing a sophisticated object oriented database, and has produced advanced software for the GIS industry. Nick has experience in a wide range of industrial areas including finance and space, usually working with large data management problems. He is currently working an ontology-based system for knowledge management and complex data transformation.

A.2.5 University of Manchester

The University of Manchester Department of Computer Science has a long and distinguished research record dating back as far as 1948 when they developed the world's first stored-program digital computer. Currently, the department has a strong reputation for research across a wide area of Computer Science and in particular in the area of information management.

The Information Management Group (IMG) carries out research in different aspects of data intensive application development. Current research seeks to extend the functionality of database systems, to exploit Description Logics (DLs) in advanced applications, and to make advanced information management systems easier to use. IMG is one of the leading international centres for research in the theory and practical application of DLs, having been responsible both for the implementation of THE state of the art DL reasoner (FaCT) and its use in a range of innovative applications including the OilEd ontology editor.

Members of IMG have wide experience in national and international projects in areas such as Managing Semi-Structured Information (DWQ, CAMELOT, STARCH, COHSE), Object Data bases (ODESSA, DOQL, POLAR) and User Interfaces to Data Intensive Systems (TEALLACH, KALEIDOQUERY, INFOLENS). IMG maintains close links at Manchester University with the Bioinformatics Group and also has a range of projects in this area (TAMBIS, GIMS, RASH, IRBANE). IMG also benefits from close links with the Formal Methods Group, the Medical Informatics Group and the Advanced Interfaces Group.

Key Personnel

Ian Horrocks is a Lecturer in Computer Science. He graduated in Computer Science from Manchester in 1982, winning the prize for most outstanding graduate. After working in industry he returned to Manchester to complete a PhD in 1997. His FaCT system revolutionised the design of DL systems, redefining the notion of tractability and establishing a new standard for implementations. He designed the OIL language, is an editor of the DAML+OIL language and is a member of the Joint EU/US Committee on Agent Markup Languages. He is the lead researcher on several EPSRC projects and was a leading researcher on the DWQ project (Esprit 22469). He has published widely in major journals and conferences, winning the best paper prize at KR'98. He is a member of the programme/editorial committees of several international conferences, workshops and journals. His current research interests include knowledge representation, automated reasoning, ontological engineering and the Semantic Web.

Carole Goble is a Professor in Computer Science, and co-leads the Information Management Group. She has been on the faculty since 1985, and has worked in the Multimedia and Medical Informatics groups. She was/is an investigator on a number of projects using Description Logics (DLs) as modelling and retrieval languages for: medical information systems (PEN&PAD, GALEN), semantic hypermedia systems (COHSE), picture archives (STARCH), mediating disparate bioinformatic information sources (TAMBIS, TAMBIS-II), and improved protein function prediction using ontologies (Irbane). She is co-investigator in a basic research project on DL-based ontology servers (CAMELOT). She has over 40 publications in the area and has served on many conference committees on databases and multimedia. Her current interests lie in conceptual modelling, the use of ontologies and thesauri in a range of metadata and data-intensive applications, including multimedia, hypermedia, medical informatics and bioinformatics.

A.2.6 Technical University of Eindhoven

The "Technische Universiteit Eindhoven" (TU/e) was founded in 1957, and is now the second largest university of technology amongst the thirteen universities in The Netherlands. The TU/e consists of eight departments in the fields of Applied Physics, Biomedical Technology, Building and Architecture, Chemical Engineering and Chemistry, Electrical Engineering, Mathematics and Computer Science, Mechanical Engineering, and Technology Management. The TU/e has 2750 employees of which 120 are full professors and 425 assistant and associate professors. The TU/e provides 13 five-year undergraduate study programmes ("ingenieur") for 5000 students, 10 two-year courses in technological design ("master of technological design") for 250 postgraduates, as well as various PhD-programmes ("doctor") for 500 postgraduates. Lecturers and students make use of modern information and communication means (e.g. almost all students have laptops). TU/e leads prominent Dutch research schools and institutes, and holds a strong position in international networks.

The Department of Mathematics and Computer Science is active in the fields of algebra, applied analysis, scientific computing, systems and control, discrete mathematics, combinatorial optimisation, coding and cryptography, stochastic operation research, statistics, scheduling, information systems, distributed real time systems, computer graphics, programming methodology, parallel systems, formal methods, and embedded systems. The department has over 120 employees of which 14 are full professors and 70 assistant and associate professors. The number of undergraduate students is approximately 800. The department also hosts RIACA, the Research Institute for Applications of Computer Algebra, which plays a pivotal role in the development of mathematical computation.

The Eindhoven research team consists of Prof.dr. A.M. Cohen, Dr H. Cuypers, Dr H. Sterk, Dr H.A. Wilbrink, Prof.dr. A.E. Brouwer, together with three junior researchers. The group 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 an OpenMath Library for the construction of phrasebooks, several phrasebooks for interfacing mathematical software, and Interactive Algebra Lecture Notes (published by Springer Verlag). The group has extensive teaching experience (at under- and postgraduate level) in their respective specialties. It is currently a member of both the Calculemus project (RTN1-1999-00301) and the OpenMath Thematic Network (IST-2000-28719).

Key Personnel

Professor Arjeh M. Cohen studied mathematics and theoretical computer science at Utrecht University. His research fields are Discrete Algebra and Geometry, and Mathematical Computation. He worked at Rijnmond Authority, Rotterdam, the University of Twente, Enschede, and CWI, Amsterdam, and at Utrecht University. Since 1992, he has been a full professor of Discrete Mathematics at Eindhoven University of Technology. He is scientific director of RIACA, chairman of the board of the Research School EIDMA, and president of the OpenMath Society. He has authored about eighty papers in refereed journals, nine books (edited books included), and three software packages.

Dr Hans Cuypers studied mathematics in Nijmegen and Utrecht. His research fields are Geometry and Groups, and Interactive Mathematics Books. He worked at East Lansing (Michigan) and Kiel. Since 1991 he has been a professor of Discrete Mathematics at Eindhoven University of Technology. He is manager of RIACA. He has authored about forty papers in refereed journals, and two books (edited books included).

A.2.7 University of Nice

The Uniersité de Nice-Sophia Antipolis (UNSA) is a public university with some 27,000 students. The two units principally responsible for teaching information technology courses are the Dept. of Informatics and the Information Technology Engineering School ESSI (École Supérieure en Sciences Informatiques). Both units together have over 1000 students in various programs, at various levels. The CNRS-affiliated laboratory I3S (Informatique, Signaux, et Systmes á Sophia-Antipolis) has some 150 researchers, largely drawn from the above university units, active in all aspects of information technology. The M@INLINE (Multimedia Activities Involving Non-Linear Information for Networked Education) group is the intersection of people involved in technologies for informatics and communication from several institutes: the Informatics Dept. of UNSA, ESSI, I3S, and the Institut Universitaire de Formation de Maitres (IUFM). M@INLINE groups under the same label researchers from complementary domains, all oriented towards multimedia education and distance-learning. Non-Linear information and its application to distance-learning correspond to a real need, both from public education and private industry. We are particularly interested in developing tools to communicate content using a mix of multimedia sources, to personalize content, to aid in non-linear navigation through content, and to test and evaluate results. M@INLINE's activities can be divided into 3 categories: distance-learning, interactive editing, and visualisation.

Distance Learning We are concerned with the creation and development of course material with digital support (CDrom, intranet, web, etc). This is closely tied to the development and evaluation of the appropriate tools for distance learning in an extension of work undertaken in the European Trial-Solution project (IST-1999-11397). Briefly, the aim of this project is to develop the necessary technology (metadata and tools) to create new courses based on existing material. Proposed methods and tools will allow a teacher to use existing courses which have been pre-processed by splitting them into small chunks. The teacher could then integrate these slices from various sources into personalised courses.

Interactive Editing The second aspect of M@INLINE, associated with the European OpenMath project (Esprit 24-969), is oriented to the publication of mathematical material over the web. OpenMath is a platform-independent standard for the representation of mathematical objects allowing their exchange between various software tools (computer algebra systems, databases, etc.) in a meaningful way. This project saw the development of JOME (Java OpenMath Editor) an interactive formula renderer (selection, drag and drop, iconification / uniconification, etc.) designed as a Java Bean software component. JOME can be integrated into different kinds of applications or applets to make mathematics come alive on the web!

Visualisation Communication via images plays an important role in understanding the meaning of information. A third aspect of the project is oriented towards interactive communication via images, including the development of techniques for distributed visualisation. The principal application will be presenting course material via multimedia tools.

For administrative reasons this partner appears twice in the summaries in part A as both the University of Nice and CNRS.

Key Personnel

Michel Buffa is a Maître de Conférences at UNSA in the Informatics Department, head of the Maître d'Informatique Appliquée á la Gestion (MIAGE) program, and a member of I3S. He has taught courses specialising in image synthesis as well as the Internet and Java. His research is oriented towards real-time 3-D distributed graphics, as well as distance-learning platforms. He has participated in the European Realize project.

Jean-Marc Fedou is a Professor at UNSA and head of the Informatics Dept., and is a member of I3S. His research interests include combinatorics and computer algebra, and he was one of the developers of the Calico system. He has participated in the European OpenMath project.

Marc Gaëtano is a Maître de Confèrences at ESSI-UNSA, and a member of the Computer Algebra and Functional Equations (CAFE) project of the Institut National de Recherches en Informatique et en Automatique (INRIA). He has taught courses including algorithms, programming, and computer algebra systems. His research interests are principally in distributed computer algebra systems, and he has participated in the European FRISCO, PoSSo and OpenMath projects.

Stéphane Lavirotte is a Maître de Conférences at the IUFM in the New Technologies Dept., and a member of I3S. He has taught courses including algorithms, programming, operating systems and man-machine interfaces. His research centers on graphical user interfaces for computer algebra systems, document analysis and recognition (optical formula recognition), and also online teaching techniques for scientific courses. He has participated in the European Trial-Solution and OpenMath Thematic Network projects.

Peter Sander is a Professor at ESSI-UNSA and a member of I3S. He was head of the Vision and Robotics postgraduate (DEA) program, and has taught courses ranging from introductory programming with Java, to image processing, to postgraduate differential geometry. His research interests are in visual communication via distributed multimedia systems. He has participated in the European Realize, OpenMath, Trial-Solution, and OpenMath Thematic Network projects.

Jean-Paul Stromboni is a Maître de Conférences at ESSI-UNSA and a member of I3S. He has taught courses on Control Theory, Electronics, Applied Physics. His present research interests focus on the use of so-called new technologies in the fields of open learning and computer aided teaching.

Jean-Yves Tigli is a Maître de Conférences at ESSI-UNSA and a member of I3S. He has taught courses on networks, distributed software systems, robotics, and man-machine interfaces. His research centers on distributed systems and tools, and interfaces for cooperative distributed systems. He has participated in the Mauve and Narval European projects.