Annex 1

PART A: CONTRACT DETAILS AND OBJECTIVES

1 Full Title: Superstring Theory

Short Title: Superstrings

2 Proposal Number: 512194

3 Duration of Project: 48 Months

4 Contractors and Places of Implementing the Project

The Co-ordinator

1. Chalmers tekniska högskola, [Chalmers], Sweden

Other Contractors

2. Uppsala University, [UU], Sweden
3. The Chancellor, Masters and Scholars of the University of Cambridge, [UCAM-DAMTP], United Kingdom
4. King's College London, [KCL], United Kingdom
5. Queen Mary and Westfield College, [QMUL], United Kingdom
6. Centre National de la Reserche Scientifique, [CNRS], France
7. Universiteit van Amsterdam, [UvA], Netherlands
8. Max-Planck-Gesellschaft zur Förderung der Wissenschaften e.V., [MPG], Germany
9. Universitá degli Studi di Roma "Tor Vergata", [UNITOVRM], Italy
10. University of Crete, [UoC], Greece
11. The Hebrew University of Jerusalem, [HUJI], Israel
12. Masarykova univerzita v Brne, [MU Brno], Czech Republic
13. University of Cyprus, [UCY-Physics Department], Cyprus
14. Eötvös Loránd University, [Eötvös], Hungary

The Co-ordinator and the other Contractors are referred to jointly as "the Consortium".

The Co-ordinator Chalmers tekniska högskola which is carrying out part of the work has a group from Karlstad University associated to it.

The Contractor University which is carrying out part of the work has a group from Stockholm University associated to it.

The Contractor Queen Mary and Westfield College which is carrying out part of the work has a group from Imperial College associated to it. This group consists of former members that moved to Imperial College last year.

The Contractor CNRS which is carrying out part of the work is a joint research unit (UMR 8549) formed by the CNRS, the Laboratoire de Physique Thorique of the Ecole Normale Suprieure (LPTENS) and Laboratoire de Physique Thorique et Hautes Energies of the University of [CNRS] VI (Jussieu).

The Contractor Universiteit van Amsterdam which is carrying out part of the work has a group led by G. 't Hooft from Utrecht University associated to it and one person from NIKHEF.

The Contractor Max-Planck-Gesellschaft zur Förderung der Wissenschaften e.V. which is carrying out part of the work consists of the Albert-Einstein-Institut für Gravitationsphysik in Golm and one person in Hamburg Universität.

The Contractor Universitá degli Studi di Roma "Tor Vergata"which is carrying out part of the work has one group from Universitá degli Studi di Roma "La Sapienza", one group from Pisa and one from ICTP in Trieste associated to it.

The Contractor University of Crete which is carrying out part of the work has a group from Athens associated to it.

The Contractor The Hebrew University of Jerusalem which is carrying out part of the work has one group from University of Tel-Aviv and one from the Weizmann Institute associated to it.

5 Project Overwiew

5.1 Overall Objectives

The leading candidate for a theory for all fundamental interactions is the Superstring Theory/M-theory. Our current understanding of superstring theory is still somewhat primitive, despite the rapid recent progress. There is a good understanding of its perturbative formulations, which are the analogue of the Feynman diagram expansion of familiar quantum field theories. Furthermore recent discoveries, such as duality symmetries, Dirichlet branes and the gauge theory/gravity correspondence, have led to many insights into the structure of the underlying fundamental M-theory, and have provided a powerful arsenal of tools with which to address a host of non-perturbative questions. These developments have greatly enhanced our understanding of supersymmetric gauge theories and of the quantum physics of black holes. Nevertheless, some of the toughest challenges still lie ahead: on the one hand a true non-perturbative formulation of M-theory is lacking, and there are few clues about its symmetries or its high-temperature phase. Furthermore it is not known how to select one out of the many apparently consistent string vacua, and there is so far no understanding of the mechanism that is responsible for breaking spacetime supersymmetry without generating an unacceptably large cosmological constant. Finally, it is still unclear whether the puzzles associated with cosmological and black hole horizons will ultimately force a modification of the basic principles of quantum mechanics.

Making progress towards answering these central questions is the long-term research objective of the Consortium. As usual in theoretical research, one cannot predict where major breakthroughs will come from. What will be done here is to describe some of the lines of attack that are considered at present as most promising. Many of these have been either initiated, or significantly developed by members of the Consortium. In pursuing these lines of research it is expected to obtain a number of intermediate results, some with possible applications in other fields of physics and mathematics, such as boundary critical phenomena, low-energy QCD or the interplay of algebra and geometry. The record and the combined expertise of the Consortium nodes should warrant that significant progress can be achieved in the next four years. The list and brief description of the various research projects that Consortium members will pursue is as follows :

• *Structure and Symmetries of M-Theory*
There is no fundamental formulation of M-theory. Determining its fundamental degrees of freedom through the study of its symmetries is a central topic of this proposal. There exist several approaches to the problem that the Consortium intends to follow: (i) explore the tensionless limit of strings, in which fields of arbitrary spins become massless; (ii) study compactifications to one or zero dimensions, where large algebraic structures appear to emerge; and (iii) investigate microscopic models of M-theory, such as those based on the Matrix Model. Nodes of the Consortium have made major contributions to these areas of research. Special attention will be payed to possible connections between these a priori different approaches.

• *Black holes and Holography*
The apparent conflict between the physics of black holes and quantum mechanics has been an outstanding puzzle since Hawking originally argued that a black hole radiates in a manner that is uncorrelated with the information carried by the matter that forms the black hole. This seemed to imply a loss of information and a breakdown of quantum mechanics. The recent developments in string theory, on the other hand, have led to a microscopic description of the thermodynamics of nearly-extreme charged black holes, which accounts for the precise rate of Hawking radiation and is consistent with quantum mechanics. An important question that the Consortium intends to study is whether these results can be extended to more general black holes, those in particular that become hotter as they radiate their mass away.

A closely related aspect of quantum gravity in general, and string theory in particular, is the 'holographic principle', which was first proposed by 't Hooft about fifteen years ago and which has found a sharp formulation in the context of the AdS/CFT correspondence. This is a general principle stating that the dynamics within any volume can be encoded on an arbitrary *surface* enclosing that volume. In other words, quantum gravity is secretly a theory in one lower dimension. The elucidation of this profound principle, which could have implications for practically all the problems listed here, will surely be one of the objectives of the research efforts of the Consortium.

• *Time-Dependence and Cosmology*
The remarkable progress of precision observational cosmology presses upon us the question of whether string theory can describe, or even better predict, the very early history of our Universe. There are many different aspects to this question for the Consortium to study: (i) can slow-roll inflation be naturally embedded in M-theory, and can string theory tachyons play the rôle of the inflaton field? (ii) does string theory resolve spacelike singularities like the Big Bang, and are pre-Big Bang scenarios such as the ekpyrotic Universe an option? and (iii) are there stringy signatures in the Cosmic Microwave Background? Another important question, in the light of the recent evidence that our Universe undergoes accelerated expansion, is how de Sitter space can be embedded in M-theory. Progress on these issues will almost surely require a better understanding of time dependence in string theory, for instance through the study of orbifold and other exact time-dependent backgrounds. Members of the Consortium have played an important role in work in these areas, and this will continue to be a significant part of the research efforts in the future.

• *Connections between String Theory and Yang–Mills*
String theory has long suggested a deep relationship between gauge theory and gravity. The connection has become very concrete within the context of the 'AdS/CFT correspondence', which states that string theory in an asymptotically anti-de-Sitter space-time is equivalent to a Yang–Mills quantum field theory on the boundary. This gives new insights into quantum gravity based on known properties of the Yang–Mills theory and, conversely, explains features of four-dimensional Yang–Mills in terms of properties of the string theory in the bulk.

The earliest and best-studied example of the correspondence identified type IIB string theory in $AdS_5 \times S_5$ with the scale-invariant maximally supersymmetric Yang–Mills theory in four dimensions. In trying to test this correspondence one encountered two technical limitations: (i) strings could not be quantized in $AdS_5 \times S_5$, because of the non-trivial Ramond-Ramond flux, limiting one to the supergravity approximation, and (ii) perturbative calculations on the two sides could only be compared for special quantities which are protected by supersymmetry and can be extrapolated from weak to strong coupling. The situation has changed in the last two years, thanks in part to landmark contributions of members of the Consortium. One of these was the discovery of a maximally supersymmetric plane wave solution that arises as a limit of the anti-de Sitter geometry, and is related to a subsector of the dual Yang-Mills theory. Strings can be quantized in this background, allowing tests that go beyond the supergravity approximation. By pushing these tests to non-protected quantities, young members of the Consortium have recently discovered surprising hints of an underlying integrable structure. It is expected that more progress will be made in the near future by pursuing this very fruitful line of research.

A related subject in which members of the Consortium have initiated dramatic progress is that of $N = 1$ supersymmetric gauge theory. It was shown that in many cases one could calculate the vacuum structure and full non-perturbative superpotentials using matrix-model techniques motivated by string dualities. The study of string and gauge theories with $N = 1$ or $N = 0$ supersymmetry will continue to be an important part of the research programme. Results in this direction could have implications both for the study of realistic string vacua, and for the study of strong interactions in the low-energy regime, where the QCD coupling becomes strong and perturbation theory breaks down.

• *Compactification and Geometry*
One of the central problems of string unification concerns the manner in which gravity and the Standard Model may arise as the low-energy limit of the theory. The traditional scenario, based on the weakly-coupled heterotic superstring, required the extra dimensions to be compactified on a Calabi–Yau manifold whose size did not exceed about 100 times the Planck length. The advent of dualities and p-branes opened the way to a host of other possibilities. One of them is to turn on non-trivial fluxes in the compact space, thereby breaking part of the supersymmetry while fixing some of the compactification parameters, or 'moduli'. Another possibility, particularly natural in the context of the type I theory, is to confine the interactions of the Standard Model to the world-volume of a brane, while gravity permeates the full embedding space. An exciting feature of this scenario is that it allows to lower the string and compactification scales near the limits set by current accelerator and micro-gravity experiments. Finally, an interesting new class of models is obtained by compactifying M theory on a singular seven-dimensional manifold of G_2 holonomy.

Members of the Consortium have played an important role in the development of such alternative compactification schemes, and will continue to study them in the future. The Consortium will focus especially on the construction of realistic string vacua, on the problem of explaining the measured low-energy gauge couplings in a natural manner, and on the issues of moduli fixing and the cosmological constant. The larger programme investigating the relations of string theory and geometry will also continue to be an important part of our research effort.

• *D-branes and Boundary Conformal Field Theory*
The correspondence between string perturbation theory and two-dimensional conformal field theory has been important in the development of the subject. More recently attention has shifted to CFTs on surfaces with boundaries which arise in the study of D-branes, and are also relevant for boundary critical phenomena. Several groups in the Consortium have a high international profile in this area of research, which will continue to be part of our programme. The topics that the Consortium plans to study include open-string tachyon condensation, and D-branes in exact curved space-times like Calabi-Yau manifolds or pp waves.

5.2 Overall Approach and Methodology

The techniques used in this area of theoretical physics involve a combination of physical ideas and modern mathematical techniques spanning a very wide range of expertise. For example, the classification of supersymmetric solutions of M-theory involves the geometry of manifolds of special holonomy (which include Calabi–Yau spaces) and of G-structures, both topics of great current interest among pure mathematicians. Perturbative string theory is intimately related to certain two-dimensional critical statistical mechanics systems, which are of intrinsic interest in what may seem, at first sight, to be a different branch of theoretical physics. There are many other examples as to how interdisciplinary techniques enter into string theory. These include the relationship between the geometry of embeddings of membranes and other p-branes into ten or eleven-dimensional space-times with quantum mechanical systems in low dimensions. The thermodynamic interpretation of black hole physics and its quantum mechanical formulation also enters into the research programme in a fundamental manner. A key rôle in this development is understanding the stringy description of black hole quantum mechanics in terms of 'D-branes'. Since string theory is a theory of gravity it is also linked to cosmological considerations related to the early Universe, which involves another kind of expertise.

In addition to purely analytical methods there is an important rôle to be played by computer methods both in the theoretical aspects of the programme as well as the more phenomenological aspects. This involves large-scale algebraic programming (for instance, in the analysis of Kac–Moody and Virasoro algebras and their extensions) as well as numerical simulations (particularly in the modelling of phenomenological aspects). Generally, the computing facilities that are provided by the Consortium's institutions are excellent and can support large-scale projects of this type.

The wide range of expertise required by this area of research means that the communication between scientists with overlapping interests but distinct backgrounds is indispensable. Scientists in different countries have their own style, with different emphasis on the various facets of the longer-term research objectives. Various sub-problems require knowledge and techniques that are found in very few institutions. Our Consortium spans most of the major areas, including world experts on general relativity and black holes, conformal field theory, open string theory and D-branes, supersymmetric gauge theories, matrix models and others. They are spread geographically from Israel, Budapest, the Czech Republic and Cyprus in the East to the UK in the North-West and Sweden in the North. The Consortium expects that the younger students and scientists will be crucial for the efficient communication of expertise between nodes.

The direct scientific contacts are of prime importance. Our Consortium will promote particularly (a) frequent exchanges of the younger scientists between the nodes, (b) pedagogical lectures with question sessions at the annual meetings, (c) discussion groups and working groups at annual meetings, and (d) visits by senior scientists who could give informal introductory lectures on their field of expertise in other nodes. In addition,full use of standard means for communicating ideas and expertise in the form of electronic databases, conference talks, scientific journals and e-mail exchanges will be used.

PART B: IMPLEMENTATION

1 Description of the joint Research/Training Project

1.1 Research

When describing the various contractors they will be referred to with the names of the cities where the respective university is situated. That makes it much easier to read than to read the acronyms.

The broad research objectives of the Consortium, cover the central themes of the subject as described in section 5.1 in part A. They require different and complementary expertise, and will be tackled accordingly by the appropriate sub-units of the overall collaboration, as listed below. It is also indicated in this list specific tasks that are expected to be accomplished during the first two years of the Consortium, and which could be assessed at the time of the Mid-Term Review. The intention is to build on existing collaborations between the nodes in order to tackle some of these shorter-term objectives. The rapid evolution in this area of research makes it hard to be very precise about the detailed tasks that will be performed in the longer run – so it is preferable to define the longer-term milestones as 'progress' towards the broader goals of the proposal. This progress could be assessed in the final report through the quality and impact of the joint publications on the five central themes of the programme. It is proposed to keep these themes under constant review, and to set up strategy forums at the annual Consortium meetings which would adapt and reorient short-term tasks, or define new ones, so as to keep in pace with the world-wide developments in this exciting field of research.

The following is a list of how the broader research goals and the corresponding shorter-term tasks to be assessed at the Mid-Term review will be distributed among the nodes of the Consortium.

1. *Duality Symmetries and Non-perturbative String Theory*: The broader goal is to develop an understanding of the structure of M-theory, especially its degrees of freedom and its symmetries, in order to formulate a unified theory of the physical forces. Short-term objectives include the analysis of Kac-Moody algebras and related structures and their rôle in M-theory ([**KCL**], [**MPG**], [**CNRS**]), the systematic study of higher spin systems and their symmetries ([**QMUL**], [**UNITOVRM**], [**Chalmers**], [**UU**]), the study of (2,0) conformal theories and related systems ([**QMUL**], [**Chalmers**], [**CNRS**]), the further elucidation of U-duality symmetries ([**QMUL**], [**MPG**], [**UoC**], [**HUJI**], [**UvA**]) and supergravity limits ([**KCL**], [**UvA**], [**CNRS**], [**MPG**]).

2. *Black holes, Cosmology, Holography and Time-Dependence*: The broad objective is to understand black holes and cosmology in M-theory, to understand the cosmological constant and to elucidate the holographic principle of quantum gravity. In the short-term we expect to construct and analyze cosmological models in M-theory ([**UCAM-DAMTP**], [**QMUL**], [**CNRS**], [**HUJI**]) to study de Sitter space and its proposed holographic dual ([**QMUL**], [**UCAM-DAMTP**], [**UvA**]), to study time-dependent

backgrounds, and in particular time-dependent orbifolds, in M-theory, investigating stability and cosmological applications (**[UCAM-DAMTP]**, **[KCL]**, **[QMW]**, **[CNRS]**, **[HUJI]**).

3. *Connections between String Theory and Yang–Mills theory*: A major ultimate goal is to develop a string theory interpretation of QCD and the physics of confinement and hadrons. Another goal is to solve general Yang Mills theories, using brane dynamics, matrix theory, supersymmetry and the AdS/CFT correspondence. In the short-term we will continue to investigate brane realisations of various supersymmetric gauge theories (**[KCL]**, **[QMW]**, **[HUJI]**), as well as the AdS/CFT correspondence (**[UCAM-DAMTP]**, **[UNITOVRM]**, **[UoC]**, **[HUJI]**, **[KCL]**, **[QMW]**, **[UvA]**, **[MPG]**, **[UCY-Physics Department]**), the integrability of N=4 super Yang Mills (**[Chalmers]**, **[UU]**, **[MPG]**), strings in plane wave backgrounds (**[UU]**, **[UCAM-DAMTP]**, **[UoC]**, **[UvA]**, **[KCL]**, **[QMW]**) and to use matrix model approaches to solve $N = 1$ gauge theories (**[UvA]**, **[CNRS]**, **[Chalmers]**)

4. *Compactification and Geometry*: One goal is to establish the connection between string theory and experimental observations in both particle physics and cosmology, the other is to understand the interplay between string theory and geometry. Particular emphasis will be placed on the view that our four-dimensional Universe is embedded in higher dimensions. Projects to be completed by the Mid-Term Review include an analysis of the phenomenology of various scenarios (**[UCAM-DAMTP]**, **[CNRS]**, **[UNITOVRM]**, **[UoC]**), a systematic study of supersymmetric geometry with the aim of achieving a classification **[KCL]**, **[QMW]**, **[UCAM-DAMTP]**, **[UU]**, **[MU Brno]**) and a study of compactifications with twists and fluxes (**[KCL]**, **[QMW]**, **[UCAM-DAMTP]**, **[Chalmers]**)

5. *Bulk and Boundary Conformal Field Theory and Statistical Mechanics*: The broad goal is to further develop conformal field theory, and other related subjects such as integrable models and topological field theories, with an eye towards applying them to string perturbation theory, supersymmetric field theory, supergravities and matrix models. One of the tasks will be to elucidate boundary conformal field theory, which is important for studying D-branes in curved backgrounds and type I compactifications (**[Chalmers]**, **[UCAM-DAMTP]**,**[KCL]**, **[QMW]**, **[UNITOVRM]**, **[CNRS]**, **[Eötvös]**, **[MPG]**, **[MU Brno]**). Another task will be the study of infinite-dimensional symmetries of supergravities in low dimensions (**[CNRS]**, **[MPG]**, **[KCL]**, **[QMW]**), and applications of BCFT to problems in condensed matter and statistical mechanics (**[Chalmers]**, **[UCY-Physics Department]**).

The distribution of tasks described in the above list is based (a) on the expertise of participating scientists in the various nodes, and (b) on the reality of existing collaborations. We expect, however, that the proposed Consortium will facilitate not only the geographic but also the thematic mobility of young researchers, who will play a pivotal rôle in the project. Our community is one in which collaboration comes naturally – we have an exceptionally well-organised system of electronic archives for publications, dating back to 1991, and make extensive use of the internet for communicating ideas. It is our intention to make full use of such resources to complement the direct contact (through exchange visits, annual meetings etc) that would be made possible by the Consortium.

1.2 Training and Transfer of Knowledge

The network as a whole undertakes to provide a minimum of 444 person-months of Early Stage and Experienced Researchers whose appointment will be financed by the contract. Quantitative progress on this, with reference to the table contained in Part C and in conformance with relevant contractual provisions, will be regularly monitored at the consortium level.

Superstring theory is a most competitive area of research. It attracts researchers whose talents span areas ranging from pure mathematics to the phenomenology of particle physics and astrophysics. Training young researchers in this wide range of specialities is only possible in the context of a Consortium such as our's that includes many of the leading contributors to all areas of the subject. One measure of the excellence of the proposed Consortium can be judged by the number of prestigious prizes awarded to its members (including a recent Nobel Prize). The Consortium plans to provide a lively environment for young researchers by actively linking the individual groups together and linking the excellent training activities already provided by the individual nodes. It intends to arrange courses and schools where the early-stage and experienced researchers will interact with each other as well as with senior scientists. The pooling of resources in this manner will give young European researchers many of the advantages that are already enjoyed by their counterparts in the USA. Most leading American universities have strong string theory research groups and many others have recently formed new groups. Typically these universities have very active graduate schools and postdoctoral programmes that have attracted some of the best young European researchers. An important aspect of a European Consortium in Superstring Theory is that it will generate a research infrastructure that can offset this brain drain to the USA. On the other hand, the close links between senior European researchers with their counterparts in the USA will ensure a continuing flow of ideas and personnel between Europe and the USA.

The principal nodes in the Consortium have similar composition, with a good balance between pre-doctoral and more senior permanent members. These nodes are all in a good position to teach and train young researchers. These researchers will form a most important rôle in the networking interactions between the nodes and the appointment of such researchers is a main priority for these nodes.

On the other hand, an exchange of graduate students and openings for graduates students from other European groups including ones from Less-Favoured Regions, the New Countries and the Associated States will benefit all nodes. In certain nodes graduate students are involved in teaching, which makes it harder for them to travel for extensive periods. This accounts for the modest scale of the proposed graduate student programme.

Those principle nodes are well established and have several senior researchers. They have extensive experience in training pre-doctoral and post-doctoral researchers which will be extended to those appointed by the Consortium. Each of these nodes have programmes of advanced lectures, formal and informal seminars and journal clubs. Each young researcher will have a supervisor who will be one of the permanent staff in the node. The supervisor will be responsible for monitoring research progress and discussing the future career of the young researcher. He will be the one responsible for the setting up of a Career Development Plan for the researcher. Each node will have regular discussions concerning the progress of the group's research at which any problems with the appointees will be highlighted by the supervisor concerned.

The rôle of the post-doctoral researchers is central to this proposal. Not only are they in a very active phase of their research careers but we expect them to provide a crucial Networking link between the nodes. Unlike the permanent staff, these young researchers will be working on the project 100 per cent of the time and will therefore be more mobile. They will also play a rôle in guiding the early-stage researchers. It will also be very important that the post-doctoral fellows spend times in other nodes. Especially we will make it a rule that they all spend some months in the new nodes from the new countries. By having a steady flux of young researchers visiting these new groups they will be quickly incorporated into the Consortium and its activities.

We will strongly encourage the mobility of early-stage researchers within the Consortium. The training of early-stage researchers in particular specialities may well require someone who is a research student from one institution to spend periods in some other institution within the Consortium in order to acquire some specific research technique.

The Consortium intends to train the researchers as follows.

1. *Workshops.* Each year, we will organise a summer workshop where senior people from the Consortium teach the young pre-doctoral and post-doctoral researchers the latest trends in string theory as well as giving more basic courses in the field. We will encourage the experienced postdoctoral researchers to give lectures in these schools to train them to lecture at international meetings.

2. *Annual Conferences.* We intend to have annual conferences involving all members of the Consortium in which young researchers and the senior people will lecture about recent advances in the field. These will be important occasions for evaluating the progress of the overall project. A session will be set aside for members of the Consortium Management Committee to report on the progress made by the various nodes.

3. *Visits.* The early-stage and experienced researchers will be encouraged to travel between the nodes. This will provide a method of fostering the collaborative parts of the project and will provide the opportunity to learn the special skills of the different groups.

4. *Supervision.* The young researchers will be supervised by the senior people in the groups. Each supervisor will make a serious effort to check that the complementary skills of the various groups are transmitted to the young researchers.

5. *Training in complementary skills.* All the groups of the Consortium belong to major academic institutions and we will encourage the young researchers to use the infrastructure of each node to learn more about other subjects as well as about ethical aspects and similar issues.

6. *Balance of gender.* The Consortium does not have a good balance of gender among the senior researchers. This is a reflection of the subject where very few female scientists have been given tenure at the major institutions. The Consortium will seek actively to hire qualified female researchers in order to improve the balance.

It should be mentioned here that members of the Consortium has arranged the yearly Superstring Conference, which gathers some 400 - 500 researchers in the field and especially all the leading ones, four times the last eight years. Also the very well established summer schools at Les Houches, Cargèse and [UoC] have been organized by the members of the Consortium several times in the last ten years. The new group in [UvA] arranges every summer a summer workshop that has become very popular. Also these meetings will be part of the programme of the Consortium. We will encourage all our young researchers to apply to those meetings. All of these extra activities involve also scientists from outside the Consortium. In this way the young researchers will meet also leading scientists from other groups. The training of researchers in theoretical physics depends crucially on the interaction between the young researcher and their supervisor. For pre-doctoral researchers this usually begins with guided reading of research articles, followed by guidance on introductory research projects. The supervisor plays a key rôle in introducing the post-doctoral researchers into the collaborative research of the Consortium. The supervisor will also provide guidance on writing papers and publishing results.

Another important element in research training is the provision of activities within each node in the form of seminars, joint lectures, etc. The nodes of the Consortium differ in size and scope. For this reason the training facilities differ between the nodes. Therefore, the interchange of researchers between the nodes is a valuable part of their training.

The third training aspect arises from the joint activities of the Consortium enumerated above.

2 Management

The overall management of the Consortium will be administered by a *Management Committee*. This will consist of the Scientists-in-Charge of the 14 nodes, and will be chaired by the Consortium coordinator, [Chalmers] assisted by the Deputy Co-ordinator. The Management Committee will be responsible for all strategic decisions concerning the Consortium. These include general scientific issues, financial administration issues, and other decisions concerning the most effective use of the resources of the Consortium. The committee will in particular decide where and when to hold the Consortium conferences, workshops and schools, which are the main communal activities. Within the committee the planning of the meetings will be led by the Meeting Co-ordinator, [CNRS], and the Workshop Co-ordinator [UoC]. It will be the duty of the members of this committee to supervise the local functioning of the Consortium (including the integration of Consortium postdocs, local training activities, and shorter visits) and to report directly to the Chairman on progress or problems regarding the individual nodes. In nodes that consist of more than one group, the Scientist-in-Charge will be helped in the above task by one scientist from each of the groups seconding the main partner.

The organisation of each Consortium event, decided or approved by the Management Committee, will be delegated to a special *Organising Committee*. This will be responsible both for material aspects of the organisation (such as finding a venue and ensuring secretarial help), and for setting up the detailed scientific and training programme of the event. The composition of these Organising Committees will depend on the special needs of each event, and will be designated by the Management Committee. A typical Organising Committee will include 2–3 members from the node hosting the event, 2–3 senior scientists from other nodes with expertise on the scientific themes of the meeting, and at least one Consortium postdoctoral researcher.

The appointment of young researchers within the Consortium will proceed in three stages. First, applications will be received and stored through the Consortium's website. Access to this application material will be password-restricted to the members of the Management Committee, who will be responsible for disseminating it to the other senior scientists of their node. In the second stage of the procedure each partner team will convene independently, and decide on an ordered short list of candidates that the team would like to appoint as Consortium postdocs. These short lists will then be submitted to the Management Committee, whose role will be (i) to approve the proposed appointments, and their adequation with the Consortium's research objectives, and (ii) to coordinate the offers whenever possible (for instance by combining node resources in order to attract an exceptionally strong candidate). The responsibility for the final negotiations and the appointments will rest with the individual nodes of the Consortium.

The members of the Management Committee will stay in regular email contact throughout the duration of the Consortium. They will handle this way daily matters, and also set the agenda for their biannual meetings that will be held in the margin of Consortium workshops and conferences. The Organizing Committees will meet in the margin of the Consortium event preceding the one they are supposed to organise, and will otherwise communicate by email. Consortium postdocs will be also encouraged to meet on the margin of communal events, assess the training aspects and make suggestions to improve the functioning of the Consortium.

The Consortium funds will be distributed from the node in [Chalmers] to the other participating nodes, with guidance from the Management Committee. The Scientists-in-Charge will manage the individual node funds, which will cover the costs of the young researchers and of the Consortiuming. The accounting and financial aspects of the management will be handled by the legal organisations in each node, as described in the forms A2. The individual nodes will be responsible for distributing the financial support to their sub-units. The Community financial contributions towards management-related expenses will be managed centrally by the node in [Chalmers]. The Co-ordinator will be responsible for the collection of cost statements and for writing the annual reports. The balance of funding between the Consortium nodes will be reviewed periodically by the Management Committee, which will make adjustments to the detailed distribution of resources, as necessary. The Co-ordinator will be assisted locally by a Project Officer that will handle the administration of the network. This is why there is cost related to management set aside for the Co-ordinator.

It has been a strategic decision of this Consortium to put a limit on its overall size, and to keep its management structure as light as possible (avoiding for instance the multiplication of committees and of task pre-assignements). Indeed, unlike other fields of (especially experimental) science, theoretical physics is characterized by periods of rapid evolution, by unpredictable changes of direction, and by collaborations that rarely exceed three authors at a time. Thus, although it is important to create an environment of fluid information flow and quality training, where scientists with complementary expertise can join when necessary forces, it is also essential to leave free room to their creativity and initiative. A light management structure and planning flexibility are, for these reasons, best adapted to the needs of the field.

The results of the joint projects and of the Consortium's research will be disseminated publicly by the following standard means:

(a) through submission to the electronic archives and publication in refereed scientific journals,

(b) through presentations at international conferences, including Consortium meetings, and publication in conference proceedings,

(c) through the Consortium web site. This will give online access and an archive of the Consortium conferences, progress reports, the most significant recent publications, pedagogical lectures and a discussion forum.

3 Indicators of Progress and Success

3.1 Quantitative Indicators of Progress and Success to be used to monitor the Project

3.1.1 Research Activities

The Consortium will follow eseentially the guidelines set up by the Commission. The following measures are appropriate for the Consortium.

- Organisation and participation in workshops and conferences.
- Specialist exchange among Consortium teams.
- Scientific awards and prizes given for work in the Consortium.
- Number of citations for the most important papers written by the Consortium.

3.1.2 Training/Transfer of Knowledge Activities

The following measures are appropriate here

- The rate of recruitment of ESR and ER for each participant and for the Consortium as a whole.
- The time and duration of each individual appointment.
- The number of names and level of involvement of senior researchers associated with guidence of the ESR and ER.

- The number of trips by the ER's within the Consortium.
- The participation of the ER's to conferences and workshops.
- The organization of events for the ESR and the ER.

3.2 Qualitative Indicators of Progress and Success to be used to monitor the Project

3.2.1 Research Activities

It is often hard to make qualitatative statements about progress in theoretical physics. Results can be dormant for many years before they fit into a more general pattern. Hence the means to measure the progress is to compare with the goals set up in sect.1. Some of the items listed in sect 3.1.1 are also valid here. However, to mention some means to measure the progress the following items can be used.

- Results that show progress in the points anticipated in sect 3.1.1.
- Number of invitations to important conferences.
- Scientific awards and prizes given for work in the Consortium.
- Number of citations for the most important papers written by the Consortium.

3.2.2 Training/Transfer of Knowledge Activities

To measure the progress and success of the training of young scientists one has to follow what happens to them. it is not enough to measure how content the researcher has been with his/her stay at a particular place. The few specific points to list here are

- The success of the young researechers to go on to interesting research positions after a stay at one of the nodes.
- The success of the young researchers to learn new fields during a stay at one node.
- The level of satisfaction regarding the training of the young researchers.

3.2.3 Management

To measure the success of the management one has to look into the overall achievments of the Consortium such as

- The level of satisfaction of the young reseachers and the nodes.
- How well the various activities planned for by the Consortium are implemented.

Finally one should remember that some of the vital progress in Superstring Theory that members of the Consortium made some thirty years ago, often in isolation, took quite some time to be appreciated. For the younger generations these results are now part of the basic knowledge in the field but at the time they were made, they were completely ignored by the establishment of the the time. A theoretical result in a subject at the edge of the field can take quite some time to be appreciated.