EUROPEAN
COMMISSION

Community Research

SEVENTH FRAMEWORK
PROGRAMME

SEVENTH FRAMEWORK PROGRAMME
Capacities Specific Programme
Research Infrastructures

Grant agreement for: Integrating Activity - Combination of Collaborative Project and Coordination and Support Action

Annex I - "Description of Work"

Project acronym: **MICROKELVIN**
Project full title: European Microkelvin Collaboration
Grant agreement no.: 228464

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Table of Contents

PART A

A.1 Project summary

It is an unfortunate truth that current electronics is facing a brick wall in a decade or so when Moore's law has finally run its course down to atomic dimensions and no further miniaturization is possible. We need something new.

Coherent electron circuitry may provide that entirely new alternative. In nanocircuits the electrons can behave coherently over the circuit dimension and thus follow the rules of wave motion rather than Ohm's law. To achieve coherence, however, electron scattering lengths must be larger than the sample size. That demands high purity to limit impurity scattering but even limiting the thermal scattering by working at millikelvin temperatures we are still confined to circuits on the nanoscale. This provides the motivation for this application: there is an implicit imperative in nanoscience that there are enormous advantages to be gained by working at much lower temperatures.

Despite the clear demand, nanoscience in general is inhibited from advancing beyond the millikelvin regime by a lack of appropriate expertise and facilities. However, in Europe we *already* have the greatest concentration of microkelvin infrastructure and expertise in the world, developed by our quantum-fluids community. By integration and rationalization MICROKELVIN aims to put this existing infrastructure at the disposal of the wider community and together develop new techniques and materials to bring coherent structures into a completely new temperature regime. Our ultimate aim is the creation of a virtual European microkelvin "laboratory without walls" operating as a single entity. Integration will also allow us to pool our existing expertise and project it outward by creating new stand-alone machines able to access this temperature range anywhere. Such activity will also encourage European commercial interest in this opportunity.

This advance is inevitable in the long term, but the European lead in the microkelvin field gives us the opportunity now to be first with this new development.

The infrastructure is there. The need is manifest. We simply have to bring the two together.

A.2 List of beneficiaries

List of Beneficiaries

Beneficiary Number	Beneficiary name	Beneficiary short name	Country	Date enter project	Date exit project
1(coordinator)	Helsinki University of Technology	TKK	Finland	1	48
2	Centre National de la Recherche Scientifique, Grenoble	CNRS	France	1	48
3	Lancaster University	ULANC	United Kingdom	1	48
4	Ruprecht-Karls-Universitaet Heidelberg	HEID	Germany	1	48
5	Royal Holloway and Bedford New College	RHUL	United Kingdom	1	48
6	Scuola Normale Superiore di Pisa	SNS	Italy	1	48
7	Ustav Experimentalnej Fyziky Slovenskej Akademie Vied	SAS	Slovakia	1	48
8	Universitaet Basel	BASEL	Switzerland	1	48
9	Technische Universiteit Delft	DELFT	The Netherlands	1	48
10	BlueFors Cryogenics	BLUEFORS	Finland	1	48
11	Universiteit Leiden	UL	The Netherlands	1	48
12	Physikalisch-Technische Bundesanstalt, Berlin	PTB	Germany	1	48

A.3 Budget breakdown for the project

A3.2:
What it costs

Project Number ₁	228464	Project Acronym ₂	MICROKELVIN

One Form per Project

Participant number in this project ₈	Participant short name	Estimated eligible costs (whole duration of the project)						Total receipts	Requested EC contribution
		RTD (A)	Coordination (B)	Support (C)	Management (D)	Other (E)	Total A+B+C+D+E		
1	TKK	544,000.00	54,720.00	461,612.00	254,400.00	0.00	1,314,732.00	0.00	1,104,394.00
2	CNRS	448,000.00	474,160.00	418,165.00	3,200.00	0.00	1,343,525.00	0.00	1,018,194.50
3	ULANC	352,000.00	250,800.00	411,120.40	3,200.00	0.00	1,017,120.40	0.00	789,800.00
4	HEID	374,000.00	0.00	0.00	0.00	0.00	374,000.00	0.00	280,500.00
5	RHUL	384,000.00	0.00	0.00	0.00	0.00	384,000.00	0.00	288,000.00
6	SNS	114,800.00	0.00	0.00	0.00	0.00	114,800.00	0.00	86,100.00
7	SAS	64,000.00	0.00	0.00	0.00	0.00	64,000.00	0.00	45,000.00
8	BASEL	320,000.00	0.00	0.00	0.00	0.00	320,000.00	0.00	240,000.00
9	DELFT	136,000.00	0.00	0.00	0.00	0.00	136,000.00	0.00	102,000.00
10	BLUEFORS	88,000.00	0.00	0.00	0.00	0.00	88,000.00	0.00	66,000.00
11	UL	140,000.00	0.00	0.00	0.00	0.00	140,000.00	0.00	105,000.00
12	PTB	100,000.00	0.00	0.00	0.00	0.00	100,000.00	0.00	75,000.00
TOTAL		3,064,800.00	779,680.00	1,290,897.40	260,800.00	0.00	5,396,177.40	0.00	4,199,988.50

PART B

B.1 Concepts and objectives, progress beyond state-of-art, S/T methodology and work plan

B.1.1 Concept and objectives of the MICROKELVIN Collaboration

Low temperature infrastructure in Europe

MICROKELVIN Collaboration aims to create an integrated European virtual laboratory in microkelvin physics and technology. This will increase our ability to undertake complex experiments by increasing our critical mass in a very infrastructure-demanding field and will consolidate the European lead in this area. The principal activity by which we hope to drive this integration is the opening up existing expertise in the microkelvin temperature regime to nanoscience experiments. This will lead to a large jump in the capabilities of the integrating institutions while at the same time offering orders-of-magnitude extension in the temperature range over which nanoscience experiments are feasible, with very large benefits to that field.

Research at the frontier near absolute zero has long been a powerhouse of ideas in other areas of physics and beyond, from concepts in particle physics to practical ultrasensitive devices for application in technology and medicine. One in four Nobel prizes over the last century has gone to a low-temperature physicist. In the same period the lowest accessible temperatures have fallen by 10 orders of magnitude (4 K to 100 pK) far exceeding Moore's law over recent decades. Today some 250 (1000) low temperature research groups (researchers) in Europe work at sub-Kelvin temperatures. Ten major companies and 15 SME's have cryoengineering groups. Their total annual turnover is about 1 000 000 000 € and 50 000 000 €, respectively. There is a European need for around 100 low temperature scientist and cryoengineers per year.

While Europe is the current world leader in microkelvin physics, in terms of research workers, records held and research output, the effort is fragmented between universities and government laboratories and lacks the critical mass for high quality research and training programs. Industrial exploitation is also very low with no commercially available refrigerators able to reach the microkelvin regime. Only 20 laboratories worldwide can build their own microkelvin refrigerators with 12 located in Europe, almost all of which are involved in this action. Many current world low temperature records are held by partners of the MICROKELVIN Collaboration, one of which (TKK) has served the ultralow temperature research community in FP4, FP5 and FP6 as a transnational access-giving site (ULTI).

Recently interest in the sub 10 mK regime has increased, with the extension of two frontiers, nanoscale dimensions and microkelvin temperatures. Nanocircuits behave as quantum objects which can be incorporated *directly* into conventional electronic circuits, thus allowing engineering to tap directly this whole new range of quantum possibilities with clearly very great economic implications. To make full advantage of such systems we need to increase the coherence time of the nanocircuits. This obviously requires increased purity of the materials, improved architecture of the circuits, but also a large reduction in the influence of the surrounding thermal 'outside world'. Consequently, lower temperature operation would have a great impact on this field.

In summary, more efficient research work in the microkelvin regime, although demanding, will open new opportunities. This will require a higher level of networking and integration of the European low-temperature community. The MICROKELVIN Collaboration will open the microkelvin temperature regime to a wider range of scientists both by direct access and by the development of user-friendly refrigerators independent of liquid refrigerants. It will counteract European fragmentation, bring nanoscience into the microkelvin arena and stimulate industrial entry into the field.

Objectives of MICROKELVIN

The MICROKELVIN Collaboration is a bottom-up approach of 12 partners to develop the applications of ultralow temperatures for physics. The partners are carefully selected to match the specific goals of the consortium. The detailed objectives, listed in the work plans of the individual activities, are balanced between integration to create a more advanced and more efficient research platform, new areas of frontier research and novel applications. They are also reflected in the following overall objectives of MICROKELVIN:

1. To integrate and upgrade the leading microkelvin facilities in Europe.
2. To assemble a critical mass to work effectively on large scale issues and provide access to a wider range of European users.
3. To create new capability by exploiting the combined microkelvin capacity of these facilities for new areas of physics, especially nanophysics.
4. To enhance the capacities of the access-giving facilities.
5. To network the members of the low temperature and related research communities, the scientists with cryoengineers and the end-users with access providers, to facilitate cross-disciplinary sharing of knowledge.
6. To disseminate the expertise of the core institutes to the wider community by the development of compact, user-friendly, refrigerators for microkelvin research in low-infrastructure environments.
7. To foster the development of the next generation of refrigerators and instruments for ultralow temperature measurements.
8. To develop strategies and tools for the long-term building of a virtual European Ultralow Temperature Laboratory.

The principal goal of MICROKELVIN is to integrate the European microkelvin infrastructure, thereby enhancing its capability to undertake more complex research, creating a high-performance European infrastructure, with the critical mass to provide the widest spectrum of services. Secondly we will thereby be able to provide wider and more efficient access to the facilities of the access-giving laboratories. Thirdly, by these means, we aim to develop the new field of nanoscience at microkelvin temperatures. Fourthly, to create in common new fixed facilities, new techniques, and mobile cryostats capitalizing on the pooled experience of the access-givers and associated networks, to enhance the access services and disseminate the best practice to other laboratories whether with current microkelvin capability or without. Finally, looking further ahead, to work towards a "virtual laboratory", operating as much as possible as a single entity, comprising in the first instance the core access giving units listed here but with the option of others joining later.

B.1.2 Progress beyond the state of the art

The low temperature research community is working in small research groups. Larger concentration of ultra low temperature scientists and refrigerators can be found only in few laboratories in the world. One of them is the Low Temperature Laboratory at TKK, which has acted alone as a transnational access site ULTI (= Ultra Low Temperature Installation) since 1995. Annually it has hosted about 20 scientists from the small European research groups in about 15 research projects. This has corresponded to 20% of the total access time what TKK has been able to deliver.

ULTI project served the low temperature community only by its access activities. MICROKELVIN, with its 12 partners, will mobilise the elite of the European low temperature community into Access, Networking and Joint Research Activities which will respond to present and future challenges of the community much more effectively than the ULTI project has done. Only MICROKELVIN will be able to respond to the fast expansion of nanoscience and open the microkelvin temperature regime to nanoscientists by developing special user-friendly refrigerators for them. MICROKELVIN will also be able to improve the foundations of low temperature techniques by taking full advantage of emerging nanotechnology in construction of new low temperature instruments and refrigerators. Today, microkelvin refrigerators are not commercially available. MI-

CROKELVIN will have the capacity to network to potential SMEs and help them to develop such a commercial unit.

B.1.2.1 Networking Activities

The MICROKELVIN Collaboration includes the following 4 Networking Activities:

NA1: Managing MICROKELVIN Collaboration
NA2: Coordination of transnational access
NA3: Knowledge and technology transfer
NA4: Strengthening European low temperature research

The NAs contain several elements, which will enhance the services of the access giving infrastructures in TA1-3 beyond the state-of-the-art. The quality of the access services depends on the effectiveness of communication systems between the users, the access giving sites and the Management Office. In NA1 we will implement WEB-based tools for asynchronous communications. The access applications will be processed by a common Selection Panel. The User Meeting is a good forum for new users to test new ideas. In Task 3 of NA2 the access giving sites will arrange common training courses for the users and unify e.g. the services of their machine and electronics shops. This is all for the benefit of the users.

MICROKELVIN will foster the culture of co-operation between its partners and neighbouring scientific and cryoengineering communities. MICROKELVIN has identified a large number of nearby science and engineering communities with mutual interests and common technology base. They include air- and space, astrophysics, cold atom and laser cooling, cosmology, high energy, metrology, quantum information processing and superconductivity research communities and industrial partners producing and/or manufacturing cryogenic liquids, ultra low temperature refrigerators, superconducting magnets, ultra sensitive sensors and cameras for security, and medical imaging devices. In NA3 MICROKELVIN will make a serious effort in knowledge and technology transfer between its partners and these communities as well as to public audience. The main tools for fostering collaboration and knowledge and technology transfer beyond the ultra low temperature community are the four scientific and one industrial workshop where the experts of the neighboring communities are invited to participate.

Finally, in NA4 the MICROKELVIN Collaboration is setting up an outreach program in low temperature physics beyond European borders. The program will strengthen the ERA by supporting scientific and technical exchanges with laboratories in Third Countries.

B.1.2.2 Transnational Access Activities

MICROKELVIN Collaboration includes the following three Access Activities:

TA1: Access to TKK
TA2: Access to CNRS
TA3: Access to ULANC

MICROKELVIN is offering high quality access to beyond the-state-of-the-art refrigerators in the microkelvin temperature regime. There are about 20 low temperature laboratories in the world which have altogether about 50 refrigerators capable of reaching sub-mK temperatures. In microkelvin experiments one has to separate the temperature of the coolant and the sample under study. Owing to heat leaks and poor thermal contact, the sample temperature can be considerably higher than that of the coolant. The three access giving sites of MICROKELVIN have seven of the microkelvin refrigerators. They hold several world records on the lowest coolant and sample temperatures, and offer the users the access and know-how to reach the lowest possible sample temperatures. One of the refrigerators, located at TKK, has cooled rhodium nuclei (coolant) down to 100 pK temperatures, which is the lowest temperature ever measured. The second refrigerator, located in University of Lancaster has reached the lowest recorded temperature of 6 μK for electrons in bulk metal (Pt and Cu). Both Lancaster and CNRS have managed to cool superfluid ^{3}He samples down to a record-breaking 80 μK temperature. Similarly, TKK has cooled the mixture of ^{3}He and ^{4}He to 100 μK temperatures, which has also demonstrated by a competing Japanese group. TKK also offers access to a rotating cryostat, which is one of three rotating sub-mK cryostats in the world.

The objectives of MICROKELVIN are to open the microkelvin temperature regime to the rapidly growing field of nanoscience. In order to reach this goal MICROKELVIN will support on-site preparation of nanosamples and offer access to clean-rooms at TKK and CNRS. Both of these sites have state-of-the-art clean-rooms whose main customers are professionals from the semiconductor industry.

B.1.2.3 Joint Research Activities

MICROKELVIN has the following 4 Joint Research Activities:

- JRA1 Opening microkelvin regime to nanoscience
- JRA2 Ultralow temperature nanorefrigerator
- JRA3 Attacking fundamental physics questions by microkelvin condensed-matter experiments
- JRA4 Novel methods and devices for ultra low temperature measurements

The MICROKELVIN Collaboration is building up access capacity by constructing in JRA1 three new microkelvin refrigerators, one on each access-giving site. These will be available for users at the beginning of 2011. Two of them (TKK and CNRS) will be pulsed-tube based nuclear demagnetization refrigerators, and commissioned for cooling nanosamples to ultralow temperatures. In addition of increasing the access capacity at TKK and CNRS they will also reduce the time spent on a single experiment by more than factor of two. These two refrigerators will be the first He-free microkelvin refrigerators. These prototypes, if successful, will lead the rest of the ultra-low community to adopt this He-saving technology and secure its future beyond the depletion of He reserves in 2030.

In JRA2 the consortium is going to use nanotechnology for constructing beyond the-state-of-the-art microrefrigerators for cooling nanosamples to ultralow temperatures. Microrefrigeration is a relatively young invention from 1994. It utilizes the thermal current accompanying the electrical current, when it flows through a tunnelling barrier (similar to the Peltier effect). The cooling power of the microrefrigerators is small but well-suited to refrigerating nano-size samples. One can also easily mass-produce them for parallel operation. They have already been demonstrated to cool electrons (the coolant) from 300 mK to 50 mK and other nano-size samples from 300 mK to 200 mK. These numbers are still far away from the low temperature records of conventional large refrigerators, which are 6 μK for bulk 3-dimensional electron samples and 4 mK for 2-dimensional electron gas in GaAs/AlGaAs heterostructures. The microrefrigerators are ideal for selfcooling their electron baths due to the poor thermal contact to the outside world via the phonon bath. In JRA2 the MICROKELVIN Collaboration will develop microrefrigerators for self-cooling their electron gas from 10 mK starting temperature to below 4 mK final temperature. At the same time the refrigeration of other nanosamples will be improved to 100 mK.

In JRA3 the 3 access giving sites will jointly develop techniques for answering selected fundamental physics question by means of microkelvin measurements. These experiments were initiated jointly by the 3 partners some time ago and are unique in the international low temperature community.

In every low temperature experiment one has to determine the temperature of the sample. The temperature measurement is usually a routine operation, except in case of nanosize samples. In general, the studies of nanosize samples are delicate because the measuring probes easily drive them out of equilibrium. The main thrust of JRA4 is to develop novel methods and devices, especially thermometers, for characterization of different properties of small samples. The new methods will serve not only the infrastructure of MICROKELVIN but will also be disseminated to the low temperature community outside MICROKELVIN.

B.1.3 S/T methodology and associated work plan

B.1.3.1 The overall strategy of the work plan

The overall workplan of the MICROKELVIN Collaboration is divided into Management (NA1), three Networking (NA2-4), three Transnational Access (TA1-3),and four Joint Research Activities (JRA1-4). The total number of activities is optimized to the number of realistic goals, partners and the size of the European low temperature community. The size and distribution of the Activities among Access, Networking and Research Activities is also balanced.

The selection of three access giving sites (TA1-3) will widen the spectrum of services and shorten the waiting time by keeping the relative volume of visitors below 20% of the total number of the users at each site. The three Networking Activities (NA1-3) are aimed at managing and optimising the access services (NA2), and supporting greater collaboration and dissemination of knowledge within the low temperature community and with nearby research areas, without forgetting SMEs and the general public (NA3). In NA4 MICROKELVIN will build capacity beyond 2012 by foresight studies, founding a Virtual European Low Temperature Laboratory and by networking beyond European borders. Finally, the four Joint Research Activities (JRA1-4) are geared towards improving European infrastructures and their services beyond the state-of-the-art in key technologies such as ultralow temperature refrigeration (JRA1, JRA2) and in thermometry (JRA4). In these JRAs the nanofabrication plays important role. In JRA3 we would like to jointly build capacity to attack challenging fundamental problems which are beyond the reach of any partner's capabilities.

The three Transnational Access Activities of MICROKELVIN are completely integrated with each other. The integration is coordinated in NA2. MICROKELVIN is using a common Selection Panel to select the users for all access giving sites. The Selection Panel is using jointly accepted selection principles (NA2). Common User Meetings and training courses are organized annually. Exchange of technical personnel between the sites will be arranged to standardize the services.

In the JRAs, the access giving facilities are coordinating a consortium-wide effort to improve their services. The various JRAs are designed to be largely independent. This will improve their management and reduce risks. The technical development work of JRAs is distributed among the consortium partners but the main part is conducted at the access giving sites. This will improve the transfer of the knowledge and technology to the users of MICROKELVIN facilities.

The various activities have several interdependences, which will require coherence in their timetables. The Activity Coordinators are responsible for the progress of their activities and for reporting about delays and anticipated risks to the MICROKELVIN Coordinator and the Management Committee. In case of problems, MC has the power to take necessary measures to correct them. The management procedures are described in more detail in NA1. In general, the integration of the partners and their individual efforts into a coherent consortium is done in the Networking Activities NA1-4.

B.1.3.2 The timing of the different WPs and their components

MICROKELVIN BARCHART

1st year

Networking and Joint Research Activities	Month	1	2	3	4	5	6	7	8	9	10	11	12
NA1:	Managing MICROKELVIN Collaboration												
Task 1	Set-up and daily running of the Management Office	D1											
Task 2	Tool for project management and communication	D2											
NA2:	Coordination of trasnational access												
Task 1	Selection Panel work												
Task 2	Organization of user meetings												
Task 3	Standardization of access services												
NA3:	Knowledge and technology transfer												
Task 1	Dissemination of network results												
Task 2	Dissemination of low temperature technology						D1		D1				
Task 3	Networking with other science communities												
Task 4	Industry-research network												
Task 5	Dissemination to public audience												
NA4:	Strengthening European low temperature research												
Task 1	Towards European Cryogenic Society												
Task 2	Third Countries Network												D1
Task 3	Virtual European ULT Laboratory												
Task 2	Forecast reprot												
JRA1:	Opening microkelvin regime for nanoscience												
Task 1	New facilitating technologyfor nanoscience at microkelvin temperatures												
Task 2	Compact microkelvin refrigerator												
Task 3	The next generation microkelvin facility												
JRA2:	Ultra low temperature nanorefrigerator												
Task 1	Thermalizing electrons												
Task 2	Microkelvin nanocoolers												
Task 3	Development of a 100 mK electronically-cooled platform												
JRA3:	Atacking fundamental physics questions by microkelvin condensed-matter experiments												
Task 1	Investigating quantum vortices as model comic strings												
Task 2	Investigating condensate-condensate phase boundaries as anlogue branes												
Task 3	Horizons, ergo-regions and rotating Black Holes												
Task 4	Q-balls in superfluid 3He												
Task 5	ULTIMA-Plus: Dark matter search with ultra-low tmperature detectors												D1
JRA4:	Novel methods and devices for ultra low temperature measurements												
Task 1	Contactless measurements												
Task 2a	SQUID amplifiers for microkelvin measurements												D3
Task 2b	High frequency SQUID amplifiers at the quantum limit												
Task 3a	Noise thermometer												D5
Task 3b	Ultra low temperature ^{195}Pt NMR-thermometer												
Task 3c	Coulomb blockade thermometer for nanosamples												D7 D8

2nd year

Networking and Joint Research Activities	Month	13	14	15	16	17	18	19	20	21	22	23	24
NA1:	Managing MICROKELVIN Collaboration												
Task 1	Set-up and daily running of the Management Office								D3				
Task 2	Tool for project management and communication												
NA2:	Coordination of trasnational access												
Task 1	Selection Panel work												
Task 2	Organization of user meetings	D1											D1
Task 3	Standardization of access services	D2											
NA3:	Knowledge and technology transfer												
Task 1	Dissemination of network results												
Task 2	Dissemination of low temperature technology												
Task 3	Networking with other science communities						D2						
Task 4	Industry-research network												
Task 5	Dissemination to public audience												
NA4:	Strengthening European low temperature research												
Task 1	Towards European Cryogenic Society												
Task 2	Third Countries Network												
Task 3	Virtual European ULT Laboratory												
Task 2	Forecast reprot												
JRA1:	Opening microkelvin regime for nanoscience												
Task 1	New facilitating technologyfor nanoscience at microkelvin temperatures												
Task 2	Compact microkelvin refrigerator												D3
Task 3	The next generation microkelvin facility												
JRA2:	Ultra low temperature nanorefrigerator												
Task 1	Thermalizing electrons						D1						
Task 2	Microkelvin nanocoolers												D3
Task 3	Development of a 100 mK electronically-cooled platform												
JRA3:	Atacking fundamental physics questions by microkelvin condensed-matter experiments												
Task 1	Investigating quantum vortices as model comic strings												D2
Task 2	Investigating condensate-condensate phase boundaries as anlogue branes												
Task 3	Horizons, ergo-regions and rotating Black Holes												
Task 4	Q-balls in superfluid 3He												
Task 5	ULTIMA-Plus: Dark matter search with ultra-low tmperature detectors												
JRA4:	Novel methods and devices for ultra low temperature measurements												
Task 1	Contactless measurements						D1						
Task 2a	SQUID amplifiers for microkelvin measurements												D3
Task 2b	High frequency SQUID amplifiers at the quantum limit						D4						
Task 3a	Noise thermometer												D5
Task 3b	Ultra low temperature ^{195}Pt NMR-thermometer						D6						
Task 3c	Coulomb blockade thermometer for nanosamples												D7 D8

3rd year

Networking and Joint Research Activities	Month	25	26	27	28	29	30	31	32	33	34	35	36
NA1:	Managing MICROKELVIN Collaboration												
Task 1	Set-up and daily running of the Management Office												
Task 2	Tool for project management and communication												
NA2:	Coordination of trasnational access												
Task 1	Selection Panel work												
Task 2	Organization of user meetings												
Task 3	Standardization of access services												
NA3:	Knowledge and technology transfer												
Task 1	Dissemination of network results												
Task 2	Dissemination of low temperature technology												
Task 3	Networking with other science communities				D2								
Task 4	Industry-research network								D2				
Task 5	Dissemination to public audience												
NA4:	Strengthening European low temperature research												
Task 1	Towards European Cryogenic Society												D2
Task 2	Third Countries Network												
Task 3	Virtual European ULT Laboratory												
Task 2	Forecast reprot												D3
JRA1:	Opening microkelvin regime for nanoscience												
Task 1	New facilitating technologyfor nanoscience at microkelvin temperatures												D1
Task 2	Compact microkelvin refrigerator												D3
Task 3	The next generation microkelvin facility												D4
JRA2:	Ultra low temperature nanorefrigerator												
Task 1	Thermalizing electrons						D2						
Task 2	Microkelvin nanocoolers												
Task 3	Development of a 100 mK electronically-cooled platform												D5
JRA3:	Atacking fundamental physics questions by microkelvin condensed-matter experiments												
Task 1	Investigating quantum vortices as model comic strings												D2
Task 2	Investigating condensate-condensate phase boundaries as anlogue branes												D3
Task 3	Horizons, ergo-regions and rotating Black Holes												D4
Task 4	Q-balls in superfluid 3He												
Task 5	ULTIMA-Plus: Dark matter search with ultra-low tmperature detectors												
JRA4:	Novel methods and devices for ultra low temperature measurements												
Task 1	Contactless measurements												D1
Task 2a	SQUID amplifiers for microkelvin measurements												
Task 2b	High frequency SQUID amplifiers at the quantum limit												D4
Task 3a	Noise thermometer												
Task 3b	Ultra low temperature ^{195}Pt NMR-thermometer												D6
Task 3c	Coulomb blockade thermometer for nanosamples												D8

4th year

Networking and Joint Research Activities	Month	37	38	39	40	41	42	43	44	45	46	47	48
NA1:	Managing MICROKELVIN Collaboration												
Task 1	Set-up and daily running of the Management Office		D3										D3
Task 2	Tool for project management and communication												
NA2:	Coordination of trasnational access												
Task 1	Selection Panel work												
Task 2	Organization of user meetings	D1											D1
Task 3	Standardization of access services	D2											
NA3:	Knowledge and technology transfer												
Task 1	Dissemination of network results												
Task 2	Dissemination of low temperature technology												
Task 3	Networking with other science communities				D2				D2				
Task 4	Industry-research network												
Task 5	Dissemination to public audience												
NA4:	Strengthening European low temperature research												
Task 1	Towards European Cryogenic Society												
Task 2	Third Countries Network												
Task 3	Virtual European ULT Laboratory												
Task 2	Forecast reprot												
JRA1:	Opening microkelvin regime for nanoscience												
Task 1	New facilitating technologyfor nanoscience at microkelvin temperatures												
Task 2	Compact microkelvin refrigerator												
Task 3	The next generation microkelvin facility												
JRA2:	Ultra low temperature nanorefrigerator												
Task 1	Thermalizing electrons												
Task 2	Microkelvin nanocoolers												D4
Task 3	Development of a 100 mK electronically-cooled platform												D6
JRA3:	Atacking fundamental physics questions by microkelvin condensed-matter experiments												
Task 1	Investigating quantum vortices as model comic strings												
Task 2	Investigating condensate-condensate phase boundaries as anlogue branes												
Task 3	Horizons, ergo-regions and rotating Black Holes												
Task 4	Q-balls in superfluid 3He												D5
Task 5	ULTIMA-Plus: Dark matter search with ultra-low tmperature detectors												D6
JRA4:	Novel methods and devices for ultra low temperature measurements												
Task 1	Contactless measurements												D2
Task 2a	SQUID amplifiers for microkelvin measurements												
Task 2b	High frequency SQUID amplifiers at the quantum limit												
Task 3a	Noise thermometer												
Task 3b	Ultra low temperature ^{195}Pt NMR-thermometer												
Task 3c	Coulomb blockade thermometer for nanosamples												D8

B.1.3.3 Work package list/overview

Work package No	Work package title	Type of activity	Lead beneficiary No	Person-months	Start month	End month
NA1	Managing MICROKELVIN Collaboration	MGT	1	20	1	48
NA2	Networking European low temperature laboratories	COORD	1	3	1	48
NA3	Knowledge and technology transfer	COORD	2	2	1	48
NA4	Strengthening European low temperature research	COORD	3	2	1	48
TA1	Access to TKK	SUPP	1	0	1	48
TA2	Access to CNRS	SUPP	2	0	1	48
TA3	Access to ULANC	SUPP	3	0	1	48
JRA1	Opening microkelvin regime to nanoscience	RTD	3	84	1	48
JRA2	Ultralow temperature nanorefrigerator	RTD	1	95	1	48
JRA3	Attacking fundamental physics problems by low temperature condensed-matter experiments	RTD	2	78	1	48
JRA4	Novel methods and devices for ultra low temperature measurements	RTD	4	105	1	48
	TOTAL			389		

B.1.3.4 Deliverables list

List of Deliverables – to be submitted for review to EC

Del. no.	Deliverable name	WP no.	Lead beneficiary	Estimated person months	Nature	Dissemination level	Delivery date
D1	Opening and operation of Management Office	NA1	TKK	10	O	PU	1
D2	Opening and maintaining of website	NA1	TKK	4	O	PU and PP	1
D3	MICROKELVIN reports	NA1	TKK	6	R	PU	20, 40, 50
D1	User Meetings (Proceedings)	NA2	TKK, CNRS ULANC	2	R	PU	13, 37 (24, 48)
D2	Training sessions for users	NA2	TKK, CNRS ULANC	1	O	PU	13, 37
D1	Opening of the CryoTools data base (6) and E-mail lists of laboratories and industries (8)	NA3	CNRS	2	O	PU	6, 8
D2	LT-X workshops (18, 28, 40, 44) and Industrial meeting (32) with reports	NA3	All partners		R	PU	18, 28, 32, 40, 44
D1	Invitations to leading scientists and young researchers of Third Countries to MICROKELVIN meetings	NA4	CNRS		O	PU	12
D2	Report on European Cryogenic Society and Third Countries Network	NA4	CNRS	1	R	PU	36
D3	Ultralow temperature forecast report	NA4	ULANC	1	R	PU	36
D1	Prototype of nanocircuit stage for access service at ULANC (Task 1)	JRA1	ULANC	16	P	PU	36
D2	Prototype of compact nuclear cooling refrigerator for access service at CNRS (Task 2)	JRA1	CNRS	18	P	PU	24
D3	Prototype of compact nuclear cooling refrigerator for access service at TKK (Task 2)	JRA1	TKK	20	P	PU	36
D4	Next-generation microkelvin facility for access service at ULANC (Task 3)	JRA1	ULANC	30	P	PU	36
D1	Analysis of the combined ex-chip and on-chip filter performance (Task1)	JRA2	TKK	6	R	PU	18
D2	Demonstration of sub-10 mK electronic bath temperature of a nanoelectronic tunnel junction device achieved by the developed filtering strategy (Task 1)	JRA2	CNRS	24	R	PU	30

D3	Analysis of sub-10 mK nano-cooling techniques including (i) traditional N-I-S cooler with low T_c, (ii) quantum dot cooler (Task 2)	JRA2	TKK	6	R	PU	24
D4	Demonstration of sub-10 mK nano-cooling with a N-I-S junction (Task 2)	JRA2	CNRS	24	R	PU	48
D5	Demonstration of 300 mK to about 50 mK cooling of a dielectric plat-form (Task 3)	JRA2	TKK	26	R	PU	36
D6	Demonstration of cooling-based improved sensitivity of a quantum detector (Task 3)	JRA2	RHUL	9	R	PU	48
D1	Report on microfabricated silicon vibrating wires tested in superfluid 3He at 100 μK	JRA3	CNRS	3	R	PU	12
D2	Publication on vortex creation in superfluid 3He	JRA3	ULANC	20	R	PU	24, 36
D3	Publication on 2D defects	JRA3	ULANC	18	R	PU	36
D4	Publication on Black Holes	JRA3	TKK	12	R	PU	36
D5	Publication on Q-balls in superfluid ^{3}He	JRA3	CNRS	9	R	PU	48
D6	Report on ULTIMA multicell parti-cle-detector operating underground	JRA3	CNRS	16	R	PU	48
D1	Report on the contactless decoher-ence and heat-cpacity measurement method (Task 1)	JRA4	HEID	21	R	PU	18, 36
D2	Report on the performance of high resolution μSQUID scanning mag-netometer (Task 1)	JRA4	CNRS	12	R	PU	48
D3	Report on the performance of mi-crocoils coupled to low inductance SQUIDs (Task 2)	JRA4	RHUL	18	R	PU	12, 24
D4	Report on the performance of wide bandwidth SQUIDs (Task 2)	JRA4	RHUL	15	R	PU	18, 36
D5	Report on current sensing noise thermometer for ultra low tempera-ture (Task 3)	JRA4	RHUL	15	R	PU	12, 24
D6	Rep. on 195Pt-NMR thermometer for ultra low temperatures (Task 3)	JRA4	PTB	8	R	PU	18, 36
D7	Report on metrologically compati-ble CBT sensor (Task 3)	JRA4	TKK	6	R	PU	12, 24
D8	Report on 10 mK (100 μK) GaAs quantum dot thermometer (Task 3)	JRA4	BASEL	10	R	PU	12, 24 (36, 48)

Summary of transnational access provision

Partici-pant number	*Organisa-tion short name*	*Short name of infrastruc-ture*	*Installation*			*Opera-tor country code*	*Unit of access*	*Esti-mated unit cost (€)*	*Min. quan-tity of ac-cess to be provided*	*Access costs charged to the GA*	*Estimated number of users*	*Esti-mated number of pro-jects*
			num-ber	*Short name*	*Esti-mated costs*							
1	TKK	LTL	1	Cryohall	2667346	FI	Facility-month	10259	27	276995	18	14
1	TKK	LTL	2	TKK Micronova	6256691	FI	Hour	150,17	100	15017	5	5
2	CNRS	CNRS	1	CNRS MI-CROKELVIN	2393590	FR	Facility-month	9206,12	27	248565	18	14
3	ULANC	MicroKLab	1	MicroKLab	1341780	UK	Facility-month	8945,20	27	241520,40	18	14

B1.3.5 Work package description

Work package number	NA1	**Start date or starting event:**			1.1. 2009		
Work package title	Managing MICROKELVIN Collaboration						
Activity Type	MGT						
Participant number	1						
Participant short name	**TKK**						
Person-months per participant:	20						

Objectives
Transparent effective management of MICROKELVIN Collaboration

Description of work

The overall management structure and procedures are described in section B2.1. NA1 describes the work of the Management Office.

The Management Office will be established in the LTL at TKK, under a contract for MICROKELVIN. It will be headed by the Project Coordinating Person (4 months) and includes a part-time administrator (12 months) and a part time web-officer (4 months). It will follow the daily activities of the whole MICROKELVIN project and provide assistance to the Management Committee and to the Activity Coordinators and Leaders.

The Management Office will support the Management Committee by executing daily management tasks like the financial and contractual issues, the management of budget and time, the monitoring and execution of quality checks, the reporting to the EC and the consortium, the communication and flow of information within the project and the maintenance of the project website.

When necessary, legal advice on the contractual and the IPR matters will be obtained at the Otaniemi International Innovation Centre (OIIC) of the TKK, which is the technology licensing office of TKK. OIIC is taking care of contracts from project negotiation to the exploitation of results, invention disclosures, protection and patenting of inventions and commercialization of them. Every measure will be conducted in co-operation of the research group and of the individual researcher. This service is free, i.e. included in the indirect costs of TKK.

Task 1 Set-up and daily running of the Management Office (TKK)

The Management Office will be opened by the Project Coordinating Person by appointment of the administrator and the web-site officer. The administrator is in charge of the daily routines of the MICROKELVIN administration. Duties will include the scheduling of the meetings of Advisory Board, General Assembly, Dissemination Committee, Management Committee and the Selection Panel, and the preparation of the meeting material. The main responsibility of the MO will be the timely delivery of the required reports, which means continuous monitoring of the progress, quality and risks of the individual work packages. For this the MO will develop performance indicators, reviews and risk management for individual TAs, NAs and JRAs.

Task 2 Tool for project management and communication (TKK)

An Internet-based groupware management tool will be created and maintained by the web-officer. The Web-based groupware environment will allow efficient asynchronous project management tools and communications between project partners. It includes tools for sharing documents, coordinating the project calendar, managing tasks, building web databases, following discussions, making announcements and running the project on the web. The system allows controlling access to sensitive files while allowing guests to view public ones, take polls, and manage expense reports.

The public project web-site will be created using the latest web-site technologies allowing social-networking, wikis, blogs etc that are defined according to the needs of the project. The aim is to facilitate creativity, collaboration, and sharing of knowledge and creating new information between and by people and networks involved with the subject during project.

Milestones:
M1: MICROKELVIN kick-off meeting (1)
M2: Management Committee email meetings: (1, 4, 8, 12, 16…)
M3: General Assembly and Advisory Board meetings (1, 12, 24, 36)
M4: Mid-term review (30)

Deliverables
D1: Opening and operation of Management Office (1)
D2: Opening and maintaining of web-site (1)
D3: MICROKELVIN reports (20, 40 and 50)

MA

Work package number	NA2	**Start date or starting event:**		1.1. 2009			
Work package title	Coordination of transnational access						
Activity Type	COORD						
Participant number	1	2	3				
Participant short name	**TKK**	CNRS	ULANC				
Person-months per participant:	1	1	1				

Objectives

To ensure optimal use of the research infrastructure in the access giving facilities.
To provide optimal support for small under-critical-size European low temperature research groups and SMEs, lacking own technical infrastructure.
To advertise the access activities.

Description of work

In NA2 the MICROKELVIN Collaboration will jointly coordinate the access to the three access giving sites at TKK, CNRS and ULANC. The minimum amount of total access is 81 facility-months for 45 user groups and 60 users, equally divided between the three sites.

Modality of access under this proposal

The ultra low temperature in-house measurements at the three sites typically require careful planning, lengthy construction work, and often several preliminary cool downs before all aspects of an experiment function in a satisfactory way. The work is rarely routine and in most cases a completely new measurement must be designed. This means that one has to learn how to conduct the experiment in the most efficient and informative way before the actual data taking can start. Individual projects tend to require 3-6 months of cryostat time and, therefore, the number of different experiments during a 4-year grant period is limited. Because of these restrictions and the difficulty of foreseeing exact scheduling, experiments will simply be conducted in succession such that a preceding measurement in a given cryostat is finished before a new project is started. All plans which have been approved by the Selection Panel will have priority. The Selection Panel is informed about the schedule of the in-house experiments. Since the grant period is limited, this aspect should not delay the in-house projects prohibitively or alternatively they may be recast as collaborations.

Support offered under this proposal

Scientific support

Scientific support for the users will be given by *the local operators* at the facilites as well as by the participants of the *User Meetings*. For efficient progress, the best situation is one where a new experimental proposal parallels and builds on the expertise gained from our present research and that of the user group involved. Representatives from the user group will visit the facility to discuss the planning, to become acquainted with the people, and to familiarize themselves with the working procedures. The proposals will be discussed both within the access giving facility and at the User Meetings. These procedures help to guarantee that the projects have been carefully prepared by the time they approach the stage of actual design and construction. The two-way interaction between a user group and the local access giving team will continue all through the project until its results are written up for publication.

Logistic and technical support

The access sites will support visitors in visa, travel and housing related matters by a local secretary. The host organizations have connections to fast computer networks, supported by a local operator, and electronic access to most scientific journals. The sites have an established infrastructure with well-trained support personnel for ultra low temperature research (see details in TA1-3).

Outreach to new users

The number of potential European user groups, i.e. experimental research groups (SMEs) working at sub-Kelvin temperatures is about 250 (15). Both the MICROKELVIN consortium and the respective infrastructures will announce the new access giving possibilities by direct email, by adding information to potential users on their web pages, at relevant European conferences and in low temperature journals. The announcement will specify that the new MICROKELVIN access is provided by three European infrastructures, detailing mode of access and specific type of research.

Review procedure under this proposal

The users of the MICROKELVIN access giving sites will be selected by a common Selection Panel. The majority of the members of the SP will come from outside the MICROKELVIN consortium. One of the members will represent industry. They will meet in person during the MICROKELVIN kick-off and User meetings. In the interim, the selection will be conducted at least twice a year by email voting. A list of user candidates, based on the proposals received, will be prepared by the MICROKELVIN administrator for a vote. The list of accepted, ongoing and completed projects will be posted on the public MICROKELVIN web-site.

We encourage those efforts of fundamental importance demanding greater investment in hardware and manpower than is possible for a typical academic research group. The following selection criteria will be used:

- The accepted experiments have to represent excellent science with unique goals.
- They have to be technically feasible for the available instruments in our facilities.
- Scientific and technical progress is expected.
- Preference is given to first time users from countries lacking low temperature facility.
- Special attention will be paid to new EU-countries and young starting professors.

Task 1: Set-up of common selection guidelines, Selection Panel, and its working schedule (TKK, CNRS, ULANC)

The Selection Panel will be appointed by the General Assembly. It will be familiar with the access giving potential and complementarities of the three sites, as well as with the common selection principles.

Task 2: Organizing User Meetings (TKK, CNRS, ULANC)

The objective of the User Meetings is to review the work done in TA1-3 activities, to provide user feedback, to stimulate further more challenging experimental work and to advertise the transnational access.

Task 3: Standardization of the access services (TKK, CNRS, ULANC)

The objective of Task 3 is to improve and integrate the access services by sharing technical services, support personnel and by organizing common user training sessions. This is closely related to NA4, Strengthening the European low temperature research.

Milestones:

M1: Appointment of common Selection Panel by the General Assembly (1)

M2: Meetings of the Selection Panel (in person: 1, 13, 37; email: 6, 12, 18..)

Deliverables

D1: User Meetings (Proceedings) (13, 37) (24, 48)

D2: Training sessions for new users in connection of User Meetings (13, 37)

Work package number	NA3	**Start date or starting event:**		1.1.2009		
Work package title	Knowledge and technology transfer					
Activity Type	COORD					
Participant number	1	2	3	4	5	6	7
Participant short name	TKK	**CNRS**	ULANC	HEID	RHUL	SNS	SAS
Person-months per participant:		2					
Participant number	8	9	10	11	12		
Participant short name	BASEL	DELFT	BLUEFORS	UL	PTB		
Person-months per participant:							

Objectives

Dissemination of the network results within the network, to nearby scientific communities, to industry and to public audiences

The transfer of best practices within the network and with the outside world

Description of work

The partners of the MICROKELVIN Collaboration will generate scientific and technical knowledge in one of the frontiers of science, the extreme low temperature range. This border has been steadily moving towards absolute zero temperature, thanks to the development of new physical ideas and improved techniques. The first objective of NA3 is their efficient dissemination among the partners, as a first step. Once tested and validated, these ideas and techniques should be disseminated as recommendations, publications, patents, or know-how transfer licenses.

Research at ultra low temperatures has revealed exotic phenomena such as superconductivity and superfluidity which have always aroused the interest of ordinary people. In NA3, MICROKELVIN will also disseminate its results via popular literature, public lectures, and via participation in public demonstrations and exhibitions.

A considerable amount of knowledge already exists in the field of low temperatures. Access to this information, however, faces presently several difficulties. Publications carry important technical information, but it is incomplete or hidden, because the relevant articles often have a different scientific or technical scope. The partner laboratories, with their long standing expertise and knowledge of the community, are in an excellent position to organize the scattered information in a more useful form. The information should be incorporated in a collective database, accessible not only at the level of the partners, but by the larger community.

Potential users of the scientific and technical knowledge of MICROKELVIN include nearby scientific communities, as well as nearby industrial partners. More specifically, dissemination will be organized by a Dissemination Committee, formed by the NA Leader (CNRS) and representatives of the Partners (one identified person per partner), in liaison with the Management Committee and the Project Web-officer.

Task 1: Dissemination of the network results (All partners)

The results produced by the partners will first be made available through the dedicated Intranet Web site, in order to foster internal discussion and to allow for a first evaluation. Once ready for publication, the authors will be encouraged to submit their work in journals of international level, acknowledging support by the European Community through the MICROKELVIN Collaboration. The same procedure applies to lectures, reports, or any other form of dissemination.

The results, once validated, will also be made public through the "Extranet" pages of our web-site.

Task 2: Dissemination of low temperature technology (CNRS, supported by all partners)

The technical information presently scattered in publications, thesis manuscripts, laboratory reports, web "calculators" will be collected, evaluated, organized by subjects and key-words, and incorporated in an open data base, which will be fed in a first step by the partners, and later by a broader group of experts. This will yield "CryoTools : Tools for the users of Cryogenics; Data base – Materials, good practice, instrumentation, literature guide".

The power of this method to collect and organize information has been demonstrated, in other matters, by a well-known Web-based Encyclopedia.

Notes of "best-practice" in several sensitive fields (refrigeration, thermometry, low-noise electronics…) and a public WEB-based library of low temperature experimental theses containing valuable recipes will be created and maintained up-to-date within CryoTools.

Task 3: Networking with other scientific communities (All partners)

Networking with nearby scientific communities, such as air- and space, astrophysics, cold atom and laser cooling, cosmology, high energy, metrology, quantum information processing and superconductivity communities is of clear mutual interest. Although contacts exist, these are very unsatisfactory nowadays. We plan to disseminate relevant information produced by our community in the most usable form to the representative bodies of these neighboring communities (organizers of conferences and schools, scientific committees, commission members).

This task includes 4 networking activities (LT-X) that has the aim of strengthening highly competitive research communities in their low temperature frontier:

1) LT-nano network (TKK coordinator)
2) LT-particle detectors network (CNRS coordinator)
3) LT-Cosmology network (ULANC coordinator)
4) Ultra Low Temperature Physics (RHUL coordinator)

Task 4: Industry-research network (CNRS, supported by all partners)

Networking with nearby industrial partners producing and/or manufacturing cryogenic liquids, ultra low temperature refrigerators, superconducting magnets, ultra sensitive sensors and cameras for security, and medical imaging devices is lacking in Europe. Present contacts are limited to a national level.

We plan to organize one meeting dedicated to a better mutual knowledge of the European potential in the development of very low temperature instrumentation, to create a Network of users and suppliers of Cryogenic data in order to transfer knowledge among research laboratories and to European industry: "Industry-Research Network: information, dissemination, contact, opening new markets through innovation".

Task 5: Dissemination to public audience (All partners)

The scientific and technical results generated by the MICROKELVIN Collaboration are expected to attract considerable interest from the general public. The Absolute Zero of temperature, the surprising properties of systems such as superconductors, neutron stars, cosmological topological excitations, Dark Matter, etc…are fascinating subjects easily published in the general press, including magazines aimed at children and teenagers. A special effort will be made to encourage publication in several European magazines, newspapers, in several European languages to ensure adequate diffusion. One member of the Dissemination Committee will be appointed as the person responsible for this action.

In this task Web and e-mail communication will play an important role; three aspects will be preferentially covered:

a) advertising new technical information and potential applications b) advertising training courses in cryogenics, low temperature physics and related subjects. c) advertising conferences, workshops and meetings in low temperatures and in related fields. Establishing updated e-mail lists is essential for this purpose, and will be done with high priority. **Milestones:** M1: Meetings of the Dissemination Committee (month 1, 13, 37)
Deliverables D1: Opening of the CryoTools data base (6) and E-mail lists of laboratories and industries (8) D2: LT-X workshops (18, 28, 40, 44) and Industrial meeting (32) with reports

Work package number	NA4	**Start date or starting event:**			1.1. 2009		
Work package title	Strengthening European low temperature research						
Activity Type	COORD						
Participant number	1	2	3	4	5	6	7
Participant short name	TKK	CNRS	**ULANC**	HEID	RHUL	SNS	SAS
Person-months per participant:		1	1				
Participant number	8	9	10	11			
Participant short name	BASEL	DELFT	BLUE-FORS	LEID			
Person-months per participant:							

Objectives

To strengthen ERA in low temperature physics
To establish a European Cryogenic Society
To foster collaboration with countries outside Europe
To fight against fragmentation by founding a Virtual European Low Temperature Laboratory
To forecast the effect of low temperature innovations and need for low temperature infrastructures

Description of work

A Network activity dedicated to strengthen the European low temperature research, in coordination with national (Institut Français du Froid, etc…) and international (International Institute of Refrigeration, IUPAP-C5) related initiatives, to fight against fragmentation, to improve European visibility at the international level, and to forecast the future trends in low temperature research:

Task 1. "Towards a European Cryogenics Society" (CNRS and all partners)

Establishing a formal coordination mechanism between industry and academic research in the field of Cryogenics is desirable. The present status is simply a sum of historical contacts at national level, in the UK, France, Germany and Finland, between a given company and a neighbouring laboratory. Usually a group of SMEs (mechanical construction, electronics, etc…) is active as subcontractors. The system does not benefit from any synergy in research or industrial production at the European level.

The United States of America and Japan have developed networking activities (Cryogenic Society of America, Cryogenic Association of Japan), which now play a substantial role in disseminating scientific, technical and commercial information. Their members include research centres, Universities, SMEs and large companies in the Cryogenic field. American companies have developed complementary skills, and they have become very efficient in the Cryogenics market and the associated high-tech instrumentation. The MICROKELVIN collaboration provides an excellent opportunity to establish the conditions for the creation of a "European Cryogenics Society" focused on low temperature techniques and physics. One meeting of industrial and academic partners will be organised for this purpose.

Task 2. Third Countries Network (CNRS and all partners)

One way to strengthen the ERA in the field of Cryogenics is to improve the scientific and technical exchanges with laboratories in Third Countries. Historical contacts and collaborative projects exist at national level. The UK, France, and Germany have been rather active implementing bilateral agreements, and this has given rise to scientific, technical and commercial outcomes. These uncorrelated efforts, however, have not succeeded in counterbalancing the influence of the United States of America in many important areas of the world. We plan to invite leading experts and young researchers working in high level laboratories of developing countries to attend and participate in the meetings of the MICROKELVIN collaboration. A Network of Third Country low temperature laboratories will be created and associated with the MICROKELVIN collaboration. The objective is to foster collaboration with China, Eastern countries (Georgia, Russia and Ukraine) and Latin American countries (Argentina, Brazil, Mexico) with a high level of Cryogenic expertise, and to establish formal links with the USA and Japan Cryogenic Societies.

Task 3. Virtual European ULT Laboratory (TKK, CNRS, ULANC and all partners)

A major part of the world capability in ultralow temperatures lies in European research institutions. Almost all the world records and cutting-edge facilities are European. To capitalise on, and consolidate, this advantage Lancaster, Helsinki and Grenoble, which already enjoy substantial ties, have already taken the first steps to creating a European microkelvin "laboratory without walls", the Distributed European Microkelvin Laboratory. Negotiations with local universities and national funding agents for formally creating the European virtual laboratory will be undertaken.

To ensure that this integration is sustained beyond the present project, it is desirable to strengthen the present "Distributed European Microkelvin Laboratory" and to associate with this core facility the ring of European laboratories participating in the MICROKELVIN Collaboration.

Task 4. Forecast report (ULANC and all partners)

Ultralow temperature physics is very much a European speciality, but contrarily to other fields (neutrons, X-rays…), there is presently no comprehensive report on the existing facilities and results, or a report on future infrastructures. The MICROKELVIN Collaboration is the most suitable forum to prepare an interdisciplinary foresight study of innovations in instrumentation and refrigeration, in methods, concepts, and equipment on the global development of low temperature physics and related research, and determine the European future need for equipment and (access giving) infrastructure.

Milestones:

M1: Meeting for the creation of the European Cryogenic Society (10)
M2: Formal creation of Third Countries Associated Low Temperature Network (10)
M3: Distirbuted European Microkelvin Laboratory statutes (TKK; CNRS, ULANC) (48)

Deliverables

D1: Invitation of leading scientists and young researchers of Third Countries to MICROKELVIN meetings (24 people over the 48 months) (12)
D2: Report on the European Cryogenic Society and Third Countries Network (36)
D3: Ultralow temperatures forecast report (36)

Work package number	TA1	**Start date or starting event:**			1.1. 2009		
Work package title	Access to TKK						
Activity Type	SUPP						
Participant number	1						
Participant short name	**TKK**						
Person-months per participant:							

Description of the infrastructure

Name of the infrastructure: Low Temperature Laboratory (LTL)

Location (town, country): Espoo, Finland

Web site address: http://ltl.tkk.fi/

Legal name of organisation operating the infrastructure: Helsinki University of Technology

Location of organisation (town, country): Espoo, Finland

Annual operating costs (excl. investment costs) of the infrastructure (€): 620 000

Description of the infrastructure

The long research traditions provide the backbone for the access giving infrastructure in the LTL. The laboratory was founded in 1965. The pioneering cryostat combining $^3He/^4He$ dilution refrigeration and adiabatic nuclear demagnetization became operational in 1969. Our first rotating nuclear refrigerator, a pioneer as well, was started in 1978, and in 1980 it reached 0.3 mK. In 1983, antiferromagnetic spin order at 58 nK was observed in copper, using a cascade nuclear refrigerator. An improved version of this machine became operational in 1998. It provides a platform for many types of experiments down to 10 µK electronic temperatures. Our work has several times resulted in new world records of refrigeration. Since the year 2000 the lowest nuclear spin temperatures are 100 pK and –750 pK on the positive and negative sides of the absolute zero, respectively.

In 1996 the low temperature nanoelectronics research was initiated at the LTL. Since the year 2000, the LTL has operated a semi clean room of 50 m^2, equipped with a modern electron beam lithography facility. In 2002, we gained access to the state-of-the-art semiconductor processing equipment in a 2600 m^2 clean room (class 10/100/1000), Micronova, located 200 m from the LTL. Micronova is unique in the Nordic countries and among the 5 largest in Europe. In 2007 the LTL moved into new premises. The new LTL has a total of 2 400 m^2 for laboratories, mechanical workshops and offices. The central experimental areas are the cryohall of 500 m^2, twice the normal height, the semi clean room of 100 m^2 (class 10 000) and the mechanical workshop (220 m^2).

The in-house low temperature physics research includes experimental and theoretical studies *(i)* of refrigeration and cryogenics in the liquid helium range and below, *(ii)* of quantum fluids and solids, *(iii)* of nuclear magnetism, *(iv)* of electrical transport in normal and superconducting structures of nanometer size and (*v*) of ultrasensitive nanofabricated cryosensors. The research personnel in the low temperature physics research are organized into five experimental groups, two of them working in ultra low temperature physics and three in nanoelectronics, and 1 theory group. Each of the groups typically consists of 2 – 3 graduate students, 1-2 post-doctoral scientists, and a senior researcher leading the work. The users of the infrastructure would join one of these groups to prepare and conduct their experiments.

Services currently offered by the infrastructure

The campus of TKK (2700 employees, http://www.tkk.fi) is located in Espoo, Finland, 7 km west of the centre of Helsinki and 25 km from the Helsinki-Vantaa International Airport. The greater Helsinki area is served by frequent flights to the rest of Europe as well as by a well functioning public transportation. Visitors to the LTL are housed in apartments or hotels within a short distance from the campus area. The campus of TKK provides effective access to a distributed computer network and free internet access to most scientific journals.

The LTL will offer not only to the traditional ultra low temperature experiments (Installation 1: Cryohall) but also to nanofabrication of cryogenic sensors (Installation 2: TKK Micronova). In ultra low temperature experiments the following equipment, located in the Cryohall (Installation 1) are available for the visitors:

1) a rotating cryostat with a 300 μK base temperature
2) a stationary cryostat with a 10 μK base temperature
3) 2 cryostat with 20 mK base temperature
4) 2 cryostats with 20 mK base temperature, 24 hour cool down time to 100 mK temperature, and 0-10 GHz range for high frequency experiments
5) magnetometer model MPMS 5T (Quantum Design), for fast susceptibility, magneto- and Hall resistance measurements at 1.6-400 K temperatures and 0- 5 Tesla fields.

The low temperature experiments of the local scientists and the visitors are supported by

2 technicians working in the 220 m^2 machine shop of the LTL
1 technician delivering the cryoliquids
1 chief engineer in charge of cryohall and semi clean room.+

In TKK Micronova (Installation 2) the visitors will have access to all the modern semiconductor processing equipment. The installation is served by 2 technicians, a chief engineer and a senior technology expert.

Description of work

Modality of access under this proposal: **Described in NA2**

Support offered under this proposal: **In NA2**

Outreach of new users: **In NA2.**

Review procedure under this proposal: **In NA2**

Implementation plan

Short name of installation	Unit of access	Unit cost	Min. quantity of access to be provided	Estimated number of users	Estimated number of days spent at the infrastructure	Estimated number of projects
Cryohall	Facility-month	10 259	27	18	810	14
TKK Micronova	hour	150	100	5	200	5

Unit of access:

Cryohall: The unit of access is Facility-month = visit at the facility for 1 month (30 days) by one or more researchers of the user group. The access cost covers the preparatory work with the assistance of the listed support persons, use of the listed equipment and the secretarial support in housing and travel arrangements.

TKK Micronova: The unit of access is hour = one hour of processing time by one researcher in the clean room. The access cost covers the use of chemicals and all processing equipment, as well as the assistance of listed personnel.

Work package number	TA2	**Start date or starting event:**		1.1. 2009			
Work package title	Access to CNRS						
Activity Type	SUPP						
Participant number	2						
Participant short name	**CNRS**						
Person-months per participant:							

Description of the infrastructure

Name of the infrastructure: CNRS – Institut Néel - MICROKELVIN Facility

Location (town, country): Grenoble - France

Web site address: http://neel.cnrs.fr/

Legal name of org. operating the infrastructure: Centre National de la Recherche Scientifique

Location of organisation (town, country): Paris, France

Annual operating costs (excl. investment costs) of the infrastructure (€): 600 000

Description of the infrastructure

The Institut Néel is a proprietary laboratory of the CNRS, associated with the University of Grenoble. Research at the Institute is organized into three departments: Low Temperatures, Nanosciences, and Functional Materials. The Institut Néel (415 people) has 19 research groups and a dozen technical support groups. About 140 permanent staff is directly involved in low temperature research. It is the largest European centre dedicated to the investigation of low temperature science and technology (the former CRTBT, "Centre de Recherches sur les Très Basses Températures" is now incorporated in the Institut Néel).

The equipment available at the Institut Néel includes about 30 dilution refrigerators, 3 of them with a nuclear demagnetisation stage, others equipped with very low temperature STM, AFM and SQUIDs, and a large number of ^{3}He and ^{4}He cryostats.

The technical staff in cryogenics, electronics, and nanofabrication (50 engineers and technicians) is highly trained and specialised in low temperature applications.

Technical support facilities include a national nanofabrication platform (NANOFAB), several mechanical, welding, electronics, vacuum workshops, etc. The laboratory runs in addition the Grenoble cryogenic fluids liquefaction plant, the second largest in Europe (after CERN).

The Grenoble low temperature team has acquired an international reputation for the development of very low temperature and high power dilution refrigerators. These machines have opened the millikelvin range to current experiments in Condensed Matter, Astroparticle detection, nanosciences, etc. They also constitute the first stage of modern nuclear demagnetisation refrigerators, such as the Grenoble and Lancaster units (low temperature record for cooling bulk matter below 100 microkelvin). New cryogen-free dilution refrigerators have been developed (CNRS-Air Liquide), showing a high expertise in the cryogenic field. Low temperature thermometry, including primary thermometry, standards and fixed points, has been developed in-house and in the framework of collaboration with metrological institutions.

The Institut Néel (http://neel.cnrs.fr) is located in the Grenoble Scientific Polygon, together with important research centres such as CEA, HMFL, ILL, ESRF and EMBL. This ensemble constitutes one of the main research physical areas in Europe. It is characterised by an intense scientific life, several seminars are given every day on many subjects.

Services currently offered by the infrastructure

The Institut Néel facilities are reserved for own personnel, or only available in the framework of collaborations. The current project would allow European scientists to benefit from the same conditions as local users. The main instruments to be made available are:

1) The ultra-low temperature dilution refrigerator and nuclear demagnetisation DN1 (100 microkelvin), equipped with two different nuclear stages (Lancaster-type and lamellar type)
2) The ultra-low temperature dilution refrigerator and nuclear demagnetisation DN2 (100 microkelvin - presently being installed - available end 2009)
3) The ultra-low temperature dilution refrigerator and nuclear demagnetisation DN3 (100 microkelvin, available end 2009); this refrigerator will be used in the Canfranc underground site (LSC) for experiments requiring good cosmic-ray shielding.
4) The high cooling power and very low temperature dilution refrigerator DR1 (T<5 mK)
5) The very low temperature pulse-tube cooler based dilution refrigerator PT-DR3 (T<8 mK)
6) The dilution refrigerator based 50 mK-STM facility,
7) The dilution refrigerator based 100 mK-micro-SQUID facility,
8) Access to the thermometric platform, to the low-field continuous and pulsed NMR spectrometers, and ancillary equipment.

The technical personnel is generally considered a very valuable resource of the Grenoble site: the low temperature experiments will receive technical support and access to the cryogenic, nanofabrication and electronics technical support services (2 cryogenic engineers, 6 cryogenic technicians, 3 cryofluids technicians, 2 electronic engineers, 8 electronic technicians, 1 nanofabrication engineer, 5 nanofabrication technicians, etc., and dedicated workshops with state-of-the art equipment).

Travel to Grenoble is made via the International airport of the Region Rhône Alpes (Saint-Exupéry – 1h shuttle bus) or a local airport (St Geoirs, ½h shuttle bus); TGV trains run from Paris and Roissy-CDG (3 hs), and standard trains from Geneva, Lyon, Valence, Strasbourg, etc… Hotels in Grenoble are of reasonable quality and moderately priced. The Institut Néel can be reached from the city centre by public transportation in a few minutes.

Description of work

Modality of access under this proposal: **Described in NA2**

Support offered under this proposal: **Described in NA2**

Outreach of new users: **Described in NA2**

Review procedure under this proposal: **Described in NA2**

Implementation plan

Short name of installation	Unit of access	Unit cost	Min. quantity of access to be provided	Estimated number of users	Estimated number of days spent at the infrastructure	Estimated number of projects
CNRS	Facility-month	9 206	27	18	810	14

Unit of Access

The unit of access is facility month = visit at the facility for 1 month (30 days) by one or more researchers of the user group. The access cost covers the preparatory work with the assistance of the listed support persons, use of the listed equipment and the secretarial support in housing and travel arrangements.

Work package number	TA3	**Start date or starting event:**			1.1. 2009			
Work package title	Access to ULANC							
Activity Type	SUPP							
Participant number	3							
Participant short name	**ULANC**							
Person-months per participant:								

Description of the infrastructure
Name of the infrastructure: Lancaster Ultralow Temperature Laboratory
Location (town, country): Lancaster, United Kingdom
Web site address: http://www.lancs.ac.uk/depts/physics/research/condmatt/ult/index.htm
Legal name of organisation operating the infrastructure: Lancaster University
Location of organisation (town, country): Lancaster, United Kingdom
Annual operating costs (excl. investment costs) of the infrastructure (€): 313 500

Description of the infrastructure

The Lancaster Ultralow Temperature Group is part of the Department of Physics of Lancaster University. The university is a new foundation from the sixties but has already risen to inclusion in world's top 150 universities as ranked in 2007 by THES-QS. The department is divided into the three principal divisions of Theoretical Physics, High Energy Physics and Condensed Matter Physics.

The ultralow temperature group's three advanced nuclear-cooling cryostats constitute the highest performance cluster of machines for low temperature work worldwide. Unusually all our machines are built completely in-house which means that it can be designed to be much more versatile and to a much higher specification than is possible with commercial machines. The basic units are advanced dilution refrigerators which have base temperatures between 1.75 and 2.6 mK (the 1.75 mK figure being a world best). These all carry modular versatile nuclear cooling stages in various forms capable of cooling a metallic sample to 6 μK and superfluid ^{3}He to around 80 μK.

The nuclear stages are a unique design which reduces the external heat leak to a minimum and has been taken up in various other laboratories with the result that the term "Lancaster-style" nuclear cooling stage is a recognised term to describe the design. The cryostats are all arranged in a specially adapted suite of rooms, and are isolated from ground and building vibration by sitting on up to 50 tonne concrete blocks floating on air springs. A new custom built hall has just been commissioned for a fourth and most advanced machine designated specifically for nanoscience and quantum computing applications which we intend to design and build as a common resource as part of this integrating action.

The group is supported by strong technical back-up with collectively decades of experience in ultralow temperature construction and techniques. We have our own workshop facilities and also have access to the sophisticated computer-controlled 3-D milling machine facilities of the department's main workshop. We have our own helium liquefaction plant in the same building.

Services currently offered by the infrastructure

The University is located 4 km from Lancaster which is conveniently served by the main NW fast rail link to London and the M6 motorway. An approximate one-hour journey by road gives access to three international airports, Manchester, Liverpool and Leeds-Bradford.

The principle services offered in this proposal by ULANC is access to one of the three advanced dilution refrigerators and to all three of the associated nuclear stages. The dilution refrigerators are unique in all being furnished with large epoxy mixing chambers with a large internal clear volume to allow copious experimental access independently of the associated nuclear stages. These mixing chambers have a number of experimental ports for attaching experiments, sensors, small superconducting magnets, thermometry etc. The base temperatures of the the mixing chambers are 2.7 mK, 2.3 mK or 1.75 mK, respectively, and these are the world's lowest at the moment.

We also offer access to all three of the associated nuclear cooling stages. As these stages are modular and just simply attached to the dilution refrigerator by an advanced cone joint each one is built for a specific purpose. Typical performances are given below:

Cryostat 4, routinely cools superfluid ^{3}He to ~ 100 μK.

Cryostat 2, routinely cools superfluid ^{3}He to < 80 μK. Has cooled a copper sample to 10 μK.

Cryostat 5, routinely cools superfluid ^{3}He to < 80 μK. Has cooled a copper sample to 6 μK and maintained the temperature below 10 μK for several days.

The figures above represent the best performance of any suite of cryostats in the world.

The arrangement of these machines can be seen on the website:

http://www.lancs.ac.uk/depts/physics/research/condmatt/ult/facilit.htm.

Description of work

Modality of access under this proposal: **Described in NA2**

Support offered under this proposal: **In NA2**

Outreach of new users: **In NA2.**

Review procedure under this proposal: **In NA2**

Implementation plan

Short name of installation	Unit of access	Unit cost	Min. quantity of access to be provided	Estimated number of users	Estimated number of days spent at the infrastructure	Estimated number of projects
Ultralow Temperature Laboratory	Facility-month	8 945	27	18	810	14

Unit of Access:

The unit of access is facility month = visit at the facility for 1 month (30 days) by one or more researchers of the user group. The access cost covers the preparatory work with the assistance of the listed support persons, use of the listed equipment and the secretarial support in housing and travel arrangements.

Work package number	JRA1	Start date or starting event:			1.1. 2009	
Work package title	Opening the microkelvin regime to nanoscience					
Activity Type	RTD					
Participant number	1	2	3	5	7	8	10
Participant short name	TKK	CNRS	ULANC	RHUL	SAS	BASEL	BLUE FORS
Person-months per participant:	8	16	16	4	8	18	10
Participant number	11						
Participant short name	UL						
Person-months per participant:	4						

Objectives

To improve the infrastructure at the access-giving facilities at TKK, CNRS and ULANC
To open the microkelvin temperature regime to nanoscience experiments
To transfer novel microkelvin technology and good practices to new low temperature laboratories

Description of work

Task 1 The objective is to improve the cooling of nanosamples by increasing the thermal contact between the sample electron system and the refrigerant, and by reducing the external heat leak.

Task 2 The objective is to build the most compact and easy-to-use microkelvin refrigerator for cooling nanosamples, exploiting existing knowledge in the consortium and the results of Task 1.

Task 3 The objective is to build the most advanced conventional nuclear cooling facility specifically designed for nanoscience and quantum coherence measurements at microkelvin temperatures, exploiting existing knowledge in the consortium and the results of Task 1.

This JRA embodies the central integrating activity of this proposal. The main aim is to enhance the infrastructure of the core institutes and also disseminate this best practice. Not only will we integrate several laboratories in this work but also develop the necessary techniques to combine the two frontier areas of physics and technology, that is, to move into the new regime of studying nanoscience at microkelvin temperatures.

For workers in nanoscience in general the lowest electron temperature which they can reasonably contemplate using is the ~20 mK achievable in a moderate dilution refrigerator. Anything lower implies a much greater hard-to-justify investment. Meanwhile, the ultralow temperature community works routinely in the microkelvin regime and already has the techniques to cool the electron system in metals nearly four orders of magnitude colder.

Based on this existing pool of infrastructure, expertise, and insight we intend to open up the microkelvin temperature regime for the study of nanoscience. The three core laboratories are uniquely placed in this context, having collectively the best cooling facilities worldwide and each having thriving associated nanoscience sections. Thus, put briefly, with this JRA we aim to reinforce the integration of our microkelvin operations by using them to offer access to the nanoscience community to extend nanoscience experiments into the single millikelvin and sub-millikelvin temperature regime.

We should also emphasize that this will represent a unique extension of the usual access service. The technology is too complex to allow simple plug-in experiments. Rather, the combined experience of both the nanoscience users and the microkelvin providers will be needed to refine the new techniques necessary. However, the advantages in bringing nanoscience into this frontier microkelvin regime are certainly worth the extra effort necessary.

This JRA divides into three main overarching activities; two inward in supporting these new activities in the core institutes, and one outward in making the new technology available to all laboratories. First, we will advance the development and integration of nanoscale experiments intended to promote the access activities of the existing microkelvin facilities of the core institutes. Secondly, we intend to produce, in collaboration with associated institutes and SME's refrigerant-free compact automatic dilution refrigerator/nuclear cooling systems with the microkelvin capability to allow this technology to be used anywhere. Thirdly, we will develop a new major microkelvin machine embodying the cumulative experience of all the contributing laboratories.

All three activities carry long term implications. Once we have demonstrated that sub-mK nanoscience experiments are practicable, then many more workers will want research access, and once our dry cryostat systems are working, not only can many of the experiments discussed here be made in the workers' home institutions, but there will also be a demand for such techniques from workers in other branches of condensed-matter physics, technology and beyond.

Task 1. New facilitating technology for nanoscience at microkelvin temperatures (ULANC, BASEL, SAS, TKK and CNRS).

To integrate nanoscale experiments into sub-millikelvin cryostats will require new technology. The difficulties are largely those of making thermal contact to the electron gases in the nanostructures. This is especially true with semiconductor nanostructures. At ultralow temperatures such substrates become effective thermal vacua and thermal contact is restricted to the pathways via the metallic leads to the circuits

The only quantity which matters in cooling such circuits is the ratio of the heat leak into the circuit material to the thermal contact to the refrigerant. Both quantities have to be attacked in parallel. First we can make great efforts to reduce the external heat leak. With the best current refrigerators we can create enclosures which are so well insulated that the heat leak into an isolated nonconductor is already at the level set by the background radioactive heating (largely from nearby constructional concrete). Metallic samples experience additional heating from eddy currents generated by motion in stray magnetic fields. However, these can also be reduced to a level below 4 pW per mole which translates to $\sim 10^{-24}$ watts into a micron cube sample.

The real difficulties come when we attach leads, as this immediately connects the outside world. We have to take this problem very seriously and start with the best electrical filtering possible, which fortunately is being pursued with vigour in JRA2. Secondly we must enhance the thermal contact to the refrigerator. In a semiconductor 2DEG, for example, the substrate makes no contribution to thermal contact at the lowest temperatures which runs entirely via the leads. Using ideas from BASEL and ULANC we can thermally anchor each lead directly in the mixing chamber liquid with sintered silver pads and then furnish each lead with its own mini nuclear stage to absorb any final incoming energy in the nuclear bath. Finally we can envisage completely new tailor-made nanoscale structures independent of conventional semiconductors. Ideal candidates for microkelvin cooling are carbon-nanotubes and graphene structures which can be directly immersed in superfluid ^{3}He where there is a dense ^{3}He quasiparticle gas making orders of magnitude better contact directly to the structures. Finally, we should exploit the increasing scattering lengths with falling temperatures to make "macroscopic" metallic circuits which are still able to maintain electron coherence over the scale of the sample. This will make thermal contact easier, but will require high-purity materials and new features, such as electro-polishing to minimise coherence-limiting processes at the surfaces, but this is looking far ahead.

In nanostructures, cooling the phonon bath and measuring its temperature is a challenge. We propose the realization of nanoscale single crystal silicon membrane on which a S/I/N junction and a thermometer can be deposited. The purpose is to cool down the phonon thermal bath using the SIN junction as a nanocooler. Very low temperatures can be reached on such a device where the heat capacity of the membrane is very small (less than 10^{-15} J/K).

This task will be coordinated by **ULANC** with considerable input from BASEL, CNRS and TKK will provide the fabrication facilities to make the new designs of nanocircuits and substrates necessary. SAS will provide technical assistance. Much of the work of this task will involve step-by-step improvement of current technology in many directions and we anticipate a large amount of informal assistance in ideas and designs from all the members of the consortium, especially RHUL. We will also build on results generated by JRA2 and JRA4.

Milestones

M1: Advanced filtering and isolation system designed and built (18 months)
M2: High conductivity cooled links to nanocircuits designed and tested (30 months)
M3: Nanocircuit stage installed in an access machine. (36 months)
M4: Measurement of phonon temperature of nanoscale silicon membrane (36 months)

Task 2. Compact microkelvin refrigerator (CNRS, TKK, ULANC, RHUL, BASEL, BLUEFORS and UL**).**

This task aims to make low millikelvin and microkelvin experiments accessible to any laboratory whether it has the infrastructure for dealing with liquid nitrogen and helium refrigerants or not. The principal aim is to generate the knowhow leading to the production of prototype systems requiring no external support services other than power and which can be operated automatically without the operator needing any specialist millikelvin knowledge. Thus, as well as the design aim of reaching ultralow temperatures, the model needs to be compact, reliable, and simple to use.

To this end we envisage an ultimate design where the operational cool-down sequence is fully automatic with single-button initiation. Since the dilution refrigerator will operate in a cryogen-free environment we can dispense with low-temperature vacuum seals and simply open the experimental space by releasing a single room-temperature o-ring flange.

A compact dilution refrigerator, with an integrated pulsed-tube cooler, will act as the precooling stage to 10 mK temperatures. As a novel initiative, we will integrate the nuclear cooling stage, driven by a "dry" superconducting solenoid, with the compact dilution refrigerator. The whole system will be designed to be inherently vibration free which is an important consideration bearing in mind that the initial cooling is provided by a pulsed-tube cooler. We have already demonstrated that vibration amplitudes below 0.1 µm at the pulse-tube frequency are possible.

Once the concept has been successfully demonstrated we envisage that such machines will provide ready access to the milli- and microkelvin temperature regime for any laboratory without the need for any specialist knowledge or support. We also envisage that these machines will be in demand for other purposes beyond the ambit of this application.

In this task **CNRS** and **TKK** will demonstrate the new cooling concept with a conventional (> 1 kG) and miniature (<< 1 kG) nuclear cooling stages, respectively. ULANC will participate in the design of the nuclear stages, BLUEFORS in the integration of the precooling and nuclear stages and BASEL in designing the nanosample contact leads, which simultaneously serve as precooling lines, coolants and filters. LEIDEN will offer its expertise in SPMs (scanning probe microscope) and RHUL in qubits in reducing mechanical vibrations and electrical noise in the compact refrigerator, respectively.

Milestones

M5: Pulsed-tube based dilution refrigerator and conventional/miniature nuclear stage ready for integration at CNRS/TKK (12/18).
M6: The compact microkelvin refrigerator at CNRS/TKK ready for access service (24/36)

Task 3. The next-generation microkelvin facility (ULANC, SAS, TKK, CNRS, BASEL, RHUL)

Using the combined knowledge and expertise of the applicants we are also planning an entirely new advanced microkelvin refrigerator facility intended exclusively for condensed-matter and nanoscale experiments at milli- and microkelvin temperatures. This will be sited at ULANC in a purpose-built 90+m^2 laboratory hall with 7 m clearance and a 3 m dewar pit dedicated to this project, which is supported by €k400 from the UK Science Research Investment Fund. The access-giving laboratories in this consortium have a very large fraction of the world expertise and capability in carrying out experiments at sub-millikelvin temperatures. We propose to build on this unique European resource by pooling our existing knowledge along with the technology developed in task 2 above to make this the most advanced sub-microkelvin facility for nanokelvin studies that current knowledge will allow.

The project will involve the development of new designs of nuclear cooling stages and new in-mixing-chamber experimental platforms with special attention to improving thermal contact, good isolation and filtering but based on the lowest possible temperature cooling stages which can be achieved.

The task will be coordinated by **ULANC** who will provide the capital finance and laboratory space and take responsibility for the design and construction. SAS will provide technicians to contribute to the building of the machine assisting in technology transfer to the new accession states. TKK, CNRS BASEL and RHUL will provide design input. This task will also build on the outcomes of task 1 in this JRA and also build on the running outcomes of JRA4.

Milestones

M7: Complete the vibration isolation platform (6)
M8: Dilution refrigerator built, installed and tested (24)
M9: Nuclear stage, tested and running in the dilution refrigerator (30)

Deliverables

Task 1

D1: Prototype of nanocircuit stage for access service at ULANC (36)

Task 2:

D2: Prototype of compact nuclear cooling refrigerator for access service at CNRS (24)
D3: Prototype of compact nuclear cooling refrigerator for access service at TKK (36)

Task 3:

D4: Next-generation microkelvin facility for access service at ULANC (36)

Work package number	JRA2	**Start date or starting event:**			1.1. 2009	
Work package title	Ultralow temperature nanorefrigerator					
Activity Type	RTD					
Participant number	1	2	5	6	8	9
Participant short name	**TKK**	CNRS	RHUL	SNS	BASEL	DELFT
Person-months per participant:	32	12	9	18	9	15

Objectives

Thermalizing and filtering electrons in nanodevices
To develop an electronic nano-refrigerator that is able to reach sub-10 mK electronic temperatures
To develop an electronic microrefrigerator for cooling galvanically isolated nanosamples

Description of work

In this joint research activity we propose to develop ultralow temperature nanorefrigerators in which devices can be cooled to milliKelvin and sub-milliKelvin temperatures by nanoelectronic means. We will investigate nanoscale hybrid refrigerators as well as quantum dot based nano-coolers and develop the necessary filtering and thermalization methods to obtain ultralow temperatures in nano-samples. This will make use of innovative ideas, materials and optimized geometries.

Promising micro- and nanoelectronics applications include low temperature devices with unprecedented properties and functionalities as compared to conventional devices operating at room temperature. One of the main challenges of present-day cryogenics is to develop small, low-temperature refrigeration systems that provide targeted microscale cooling.

Hybrid nanostructures combining Superconductors (S) and Normal metals (N) offer a promising possibility in nanocooling. Owing to energy-selective electron tunneling, an N-I-S tunnel junction voltage-biased below the gap features a *quasiparticle cooling effect*: only electrons with an energy exceeding the gap are effectively removed from N. As a consequence, the normal metal electrons are cooled. Two tunnel junctions arranged in a symmetric S-I-N-I-S configuration routinely give a reduction of the electron temperature from 300 mK to below 100 mK. Innovative materials choices seem appropriate to improve cooler performance, but this still needs to be explored explicitly. Such coolers could provide a platform for experiments on actual quantum devices under ultra-low temperature conditions, which can hardly be reached by other means. In order to ensure a galvanic isolation of the detector from to the cooler, a membrane technology appears necessary.

The feasibility of unexplored nanocooling methods needs to be investigated. For instance, the discrete energy spectrum in semiconductor QDs can be exploited for quantum cooling at ultra-low temperatures. If a two-dimensional electron gas is coupled to two electrodes via QDs, electrons can be transmitted through the sample by resonant tunneling. The QDs quantized energy levels can be adjusted so that the transfer from the gas to one electrode depletes the electron states above the Fermi energy. Similarly, the tunneling from the other electrode to the gas can fill states below the Fermi energy. The quasiparticle distribution function in the electron gas then sharpens, leading to electron cooling.

In order to go beyond the present limitations, an important objective is to fulfill the stringent filtering and thermalization requirements in order to reach low effective electron temperatures in nanodevices. This development will be very beneficial for nanoelectronics in general. Further, to reach microKelvin temperatures in samples regardless of the cooling method (nano-refrigerators in JRA2, demagnetization for nanosamples JRA1) will require even more efficient filtering and thermalization methods, which we aim to develop here.

Role of participants: In this JRA, TKK and CNRS will develop the nanorefrigeration by superconducting tunnel junctions. SNS will build coolers based on semiconducting electron gas. BASEL will work mainly on very low temperature thermalization and filtering. DELFT and RHUL are mainly end users of the nano-coolers to be developed, as they will integrate quantum detectors and prove their compatibility with nano-cooling.

This JRA will continue the work of the presently on-going NanoSci-ERA project "NanoFridge", where a 10 mK electronic nano-refrigerator is to be developed. That project started in February 2007 and will end in January 2010. Thus the first 13 months of the present MicroKelvin project will overlap with NanoFridge. In NanoFridge there are four teams involved: CNRS, TKK, SNS and DELFT. Here we include these teams in JRA2, and, to enlarge the consortium by including BASEL in ultimate thermalization and RHUL as an end user of a nano-cooler platform.

Task 1: Thermalizing electrons in nanorefrigerators (TKK, CNRS, BASEL)

State of the art: Normally, the electronic temperature in a nano-device exceeds that of the cryostat bath, because of the insufficient thermal contact and the external noise which produces parasitic heating and photon-assisted tunneling. It is then not uncommon to have saturation of the effective electron temperature in the range of 100 mK. A thermalization down to 10 mK has been achieved in a very few places. Achieving a thermalization well below 10 mK of a nano-sample requires good thermal contact of the leads, suppression of noise background heating to about 10^{-20} W level in a typical nano-device and suppression of the out-of-equilibrium photons at the level of –200 dB.

Our project: We will build a strategy to filter and thermalize the nano-samples to the various microKelvin coolers developed in this network so that their electronic bath temperature would be as close as possible to the corresponding refrigerator temperature. We will investigate (BASEL) sintered silver heat exchangers mounted in the mixing chamber or in a separate ^{3}He cell. Each electronic wire connecting to the nano-sample would be attached to an electrically isolated sintered silver heat exchanger in order to overcome insufficient thermal contact through insulators and/or large Kapitza resistances at low temperatures (see also JRA1, task 1).

We will further develop existing ex-chip filtering techniques including lossy coaxes or strip-lines, discrete cryogenic low pass filters, copper powder and silver epoxy filters for reaching microKelvin electron temperatures in nano-samples. In particular, we will develop (TKK, CNRS) lossy filters made by lithography of resistive films. Compared to present designs, the filtering efficiency will be optimized through extensive rf propagation simulation, the miniaturization and the connectivity will be improved.

We will combine this ex-chip approach with on-chip filtering techniques. In particular, we are going to use SQUID-arrays as filters, which are known to suppress excess quasi-particle tunneling in superconducting Single Electron Transistors (SET) due to efficient noise filtering. Other on-chip filtering techniques are to be developed and perfected.

Milestones:

M1: Choice of the thermalization strategy (sintered heat exchangers, He^3 cell) (12)
M2: Choice of the ex-chip filtering technique (18)

Task 2: Microkelvin nanocooler (TKK, CNRS, SNS)

State of the art: An electron temperature down to below 50 mK can be achieved with state-of-the-art S-I-N-I-S nano-coolers, starting from a base temperature of 300 mK.

Our project: In this task, we make use of the filtering developed in Task 1, and test different strategies to realize an electronic nano-cooler to reach sub-mK electron temperatures starting at the 10 mK base cryostat temperature. The following routes will be pursued:

Normal metal – superconductor tunnel junctions-based optimized coolers (TKK, CNRS, DELFT)

A low critical temperature T_c is needed in order to enhance the efficiency of superconducting coolers at very low temperature, since the energy-selective tunneling is most efficient at a temperature approximately one third of the critical temperature. We will develop nano-coolers based on Ti (T_c = 0.4 K) and possibly other materials. The main difficulty will be to achieve a barrier quality comparable to what is routinely obtained with Al-based oxide barriers.

We will also develop strategies for trapping energetic quasi-particles in the superconductor, for instance by using ferromagnetic traps. Such a trap brings the interest of little proximity effect even in the case of a transparent interface between the superconductor and the normal metal. The problem of the inverse proximity effect (creation of quasi-particle states in the superconductor) will be taken into account.

The thermal relaxation channels in superconductors and normal metals not due to electron-phonon interaction will be investigated. There is evidence that in a superconductor, owing to sub-gap states possibly originating at magnetic impurities, recombination of quasiparticles occurs at a much faster rate than expected from the electron-phonon interaction. This study will contribute to define an improved geometry for the nano-coolers.

Quantum dot cooler (SNS)

Since a QD transmissivity can be tuned by adjusting gate voltages, a QD refrigerator can operate in different ways without modification. It can be tuned to provide larger cooling power at a certain bath temperature by lowering the barrier height, as well as being tuned to reach the lowest electronic temperature. With a $GaAs/Al_xGa_{1-x}As$ heterostructure, the prediction is to cool 1 μm^3 volume down to below 100 μK from a lattice temperature of 10 mK, i.e. a reduction in the electron temperature of more than two orders of magnitude.

We will fabricate and test such a device. The determination of both the temperature and the quasiparticle distribution function in the cooled electron gas will be based on the line shape (conductance as a function of gate voltage) of resonant tunneling through the discrete states of an additional QD. Under suitable conditions, the line shape width should provide an *absolute* thermometer at ultra-low temperatures.

Milestones:

M3: Choice of the superconductor material with a lower critical temperature (24)
M4: Precise definition of the QD cooler geometry and materials (24)

Task 3: Development of a 100 mK, robust, electronically-cooled platform based on a 300 mK ^{3}He bath (TKK, CNRS, RHUL, DELFT)

<u>State of the art:</u> Cooled platforms for radiation detectors were initially demonstrated in two experiments. These experiments were, however, each one of the kind, and no consistent technology was achieved to produce such micro-cooler platforms routinely. Thermally isolating low-stress silicon nitride membranes has in the meantime become widely available thanks to the need of such windows in TEM microscopy. Thus they can form a strong basis for a new development.

<u>Our project:</u> We will develop a technique to fabricate a 300 mK to 50 mK cooler with a sufficient heat lift to serve as a cryogenic measuring platform for such objects as bolometers, calorimeters and superconducting nano-devices including quantum bits. This platform will enable the cooling of nano-samples while keeping them galvanically isolated from the refrigerator.

N-I-S micro-refrigerators with a large cooling power (about 1 nW at 50 mK) will be fabricated on silicon nitride membranes. In order to combine the required large junctions area with the well-controlled angle deposition technique, we will make use of mechanical masks made of a lithographically patterned membrane. During the deposition, they will be separated from the substrate by calibrated spacers of 20-50 μm.

We will integrate a quantum detector on the cooled membrane and demonstrate the compatibility of the N-I-S nano-refrigeration with the quantum detector operation. Two aspects will be tested: the efficiency of refrigeration of galvanically isolated structures and the immunity of those structures to electromagnetic noise intrinsic to the refrigerator.

We will fabricate superconducting Single Electron Transistors (SET) on the refrigerator plate. At RHUL, such devices can be constructed that demonstrate both the 1e and 2e periodicity. As this behaviour is most sensitive to temperature, the SETs will be used as a nano-fabricated thermometer, able to test rather directly the temperature of the working surface. Using the same devices, we will explore the interaction of the SET under test with the operation of the refrigerator.

Milestones:

M5: Design of the membrane patterning and of the micro-coolers, based on heat and quasiparticles diffusion calculations (18)
M6: Delivery of the first membranes to the end users (36)

Deliverables
Task 1
D1: Analysis of combined ex-chip and on-chip filter performance (18)
D2: Demonstration of sub-10 mK electronic bath temperature of a nano-electronic tunnel junction device achieved by the developed filtering strategy (30)
Task 2
D3: Analysis of sub-10 mK nano-cooling techniques including (i) traditional N-I-S cooler with low T_c, (ii) quantum dot cooler (24)
D4: Demonstration of sub-10 mK nanocooling with a N-I-S junction (48)
Task 3
D5: Demonstration of 300 mK to about 50 mK cooling of a dielectric platform (36)
D6: Demonstration of cooling-based improved sensitivity of a quantum detector (48)

Work package number	JRA3	Start date or starting event:			1.1. 2009	
Work package title	Attacking fundamental physics questions by microkelvin condensed-matter experiments					
Activity Type	RTD					
Participant number	1	2	3	4	5	7
Participant short name	TKK	CNRS	ULANC	HEID	RHUL	SAS
Person-months per participant:	12	18	26	10	4	8

Objectives

To pool and apply the ultralow temperature expertise of the access-giving facilities at TKK, CNRS and ULANC in the study of wider problems in fundamental physics.

In particular to extend the use of condensed-matter analogues and techniques to further the understanding of problems in cosmology.

To develop microkelvin methods for the detection of exotic particles.

Description of work

This JRA brings together the expertise of the three core institutes in the wider context of fundamental physics for the study of cosmological analogues in the laboratory. This is a rapidly expanding field in ultralow temperature physics. There have been significant contributions from all three core institutes, which have already made the first exploratory steps towards operating as one entity in this field, with many joint Grenoble-Helsinki, Grenoble-Lancaster, and Helsinki-Lancaster publications. This is a fruitful area to foster wider collaboration and integration since there is a wealth of existing expertise although currently rather dispersed. This is a field where Europe already has a significant lead.

The motivation flows from the fact that since the evolution of the Universe cannot be repeated, cosmologists can only compare the consequences of their speculations with the current state of the Universe. This relies heavily on insight into phenomena far removed from everyday experience. Thus *any* condensed matter analogues which can be devised are of great value in validating those ideas being applied to often otherwise untestable cosmological theories.

There are five principal areas where we propose joint integrating activities:

Task 1: Investigating quantum vortices as model cosmic strings (ULANC, TKK, CNRS)

Deep analogies between the broken symmetries of superfluid ^{3}He and those of the Universe mean that quantized vortices mirror cosmic strings. Vortices are created when the superfluid transition is crossed too fast for the liquid to follow and different regions become independently superfluid. The resultant disorder in the superfluid phase cannot be completely annealed, leaving topological defects, in this case vortices. Analogous processes in the early universe should have created cosmic strings.

The analogy is only complete near absolute zero where there is no normal fluid to mask the properties of the condensate. Here the creation of vortices, after local heating by neutron irradiation, shows behaviour suggesting competition between the two superfluid phases as the liquid recools. Such processes shed light on similar but elusive competing quantum vacua in the early Universe. At low temperatures vortices can only decay by radiation. It is thought that kinks left after reconnections propagate rapidly, leading to the decay of the vortex by radiation of quasiparticles

M

from broken pairs. A cosmic string network should decay analogously by the radiation of gravitational waves.

We intend to study the energy processes involved in vortex tangles, both the energy released on setting up the network and that released on the final decay at microkelvin temperatures in the pure condensate. ULANC will attempt the measurement in the high-resolution quasiparticle energy detector by observing the decay of a vortex tangle generated inside the bolometer. TKK will observe the heat released in the inverse process when a previously stationary condensate in a rotating container is suddenly converted to a vortex lattice. Both methods will require high-sensitivity energy detection. CNRS will investigate the effect of pressure on the dynamics associated with the competition between the two superfluid phases as the vortices are created.

Milestones

M1: Determination of the energy released by a vortex tangle with known line density (12 month).
M2: Measurement of the dissipation when a vortex tangle is established (24).
M3: A precise determination of the effect of pressure on vortex creation via the dynamics of the second-order phase transition (30).

Task 2: Investigating condensate-condensate phase boundaries as analogue branes (ULANC, CNRS)

The several coherent phases of superfluid ^{3}He provide us with phase boundaries which are absolutely unique in being boundaries between two fully-ordered condensates with different symmetries. The smooth transformation of the order parameter across the boundary yields the most highly ordered 2D structure to which we have experimental access. In Lancaster phase boundaries are studied as analogues of branes in the early Universe. The motivation being that brane interaction and annihilation is thought of as a possible trigger for inflation. Preliminary work has shown that brane-annihilation (mutual annihilation of two phase boundaries) leads to the generation of topological defects, validating those braneworld scenarios where such defects are predicted. Oscillating branes have been studied in all three core institutes in the search for the various aspects of Schwinger pair production.

ULANC will devise methods to identify the topological defects left after boundary ("brane") annihilation. CNRS will investigate the direct interaction of a micromechanical oscillator with the recently observed 2D "cosmological defect" and investigate the conditions of its creation and destruction, and the dissipation mechanism.

Milestones:

M4: Identification of the topological defects left after brane (phase boundary) annihilation (24).
M5: Observation of several "cosmological defects" in a microkelvin multi-cell detector (30).

Task 3: Horizons, ergo-regions and rotating Black Holes (TKK, CNRS)

There is great current interest in condensed-matter analogues where aspects of Black Holes and their associated horizons can be simulated. The pure superfluid ^{3}He condensate can throw light on several Black-Hole processes.

In the superfluid the Landau critical velocity plays the role of the velocity of light, marking the threshold where excitations can be created with zero energy. Any scattering object moving through the condensate at this velocity freely creates excitations (costing no energy) with the consequent destruction of the condensate. In the absence of scatterers, when the liquid exceeds this critical velocity, some quasiparticles develop negative energies. This is the analogue of the ergoregion around a Black Hole where the negative-energy quasiparticles clearly cannot escape. This property of the excitation gas provides a whole range of Black-Hole analogue behaviours. For example, an excitation injected into the "ergoregion" can pair break, leaving a trapped negative-energy daughter particle and ejecting the other with energy above that of the parent, thus extracting energy from the "Black Hole". This is closely related to the phenomenon of Hawking radiation where the high energy particles can emerge spontaneously.

Other phenomena which can be studied include; the analogue of cosmological particle production during expansion simulated by the rapid change say, of the magnetic field; the analogue of the Unruh effect of particle creation, simulated by a potential gradient moving rapidly in the superfluid; the radiation of fermionic quasiparticles by a moving vortex in turbulent flow of ^{3}He simulating the radiation of gravitational waves by evolving cosmic strings in early Universe, and many more.

Several experimental configurations can provide such scenarios. At TKK instabilities at the interface between the A and B phases of the superfluid, where one phase is in relative motion, mimic several features of Black-Hole behaviour. With a suitable choice of the superfluid layer thickness, the spectrum of excitations on the interface takes the relativistic form with the governing equations mimicking those for the event horizon of a black hole.

The A-B transition can be triggered by neutron absorption where the "new" B phase destroys the existing metastable A phase, in an analogy with various models of inflation. Preliminary work at CNRS suggests a mechanism working through percolation between B-phase seeds created by the absorption, which will give information on the fundamentals of the phase transition dynamics.

Milestones

M6: Realization of a Black-Hole analogue in a rotating system with an A-B boundary (24).
M7: Test of the Unruh effect from rapid motion of a phase boundary (30).
M8: Test of the percolation theory of the A-B transition (36).

Task 4: Q-balls in superfluid ^{3}He (CNRS, ULANC, TKK, SAS, RHUL)

Q-balls can be thought of as bubbles trapping the "wrong" phase after phase transitions in the early Universe. In one scenario the Q-ball represents a bunch of supersymmetric particles trapped in the surrounding "normal" matrix. If such a Q-ball were to enter a neutron star, for example, it would convert the neutrons to their boson equivalent and lead to the disintegration of the star.

The Q-ball can modify its surroundings. A powerful analogy is the long-lived domains seen in superfluid ^{3}He where the spin superfluid precesses coherently over a limited region of space back-reacting on the surroundings to perpetuate its own potential well both in the stationary and in the rotating superfluid. At microkelvin temperatures, dissipation processes become very weak and the deflection of the magnetization becomes the conserved quantity in analogy with the conserved Q-ball charge "Q". In ^{3}He we can observe the deflected spin directly by NMR thus probing the inner structure of the ball. Where two such coherent but independent domains can be formed we can also bring them into contact and watch the inner workings of the Josephson effect between them by NMR. The domain lifetime also provides thermometry at the lowest temperatures.

Milestones:

M9: The observation of the interaction between two independent precessing Q-balls (30).
M10: Creation of excited modes of a "Q-ball" under radial squeezing by rotation (36).
M11: Realization of microkelvin thermometry based on "Q-ball" behaviour (42).

Task 5: ULTIMA-Plus: Dark matter search with ultra-low temperature detectors (CNRS, ULANC, HEID)

The ^{3}He condensate provides a "scintillator" material for dark-matter detection and other ultrasensitive energy measurements. A conventional scintillator produces optical photons with eV scale energies. The ^{3}He condensate behaves similarly, but the quasiparticles produced (by pair breaking) have energies of order 10^{-7} eV, potentially yielding orders of magnitude more sensitivity. This provides a large advantage over current dark-matter detectors based on the nuclear recoil in large (>100 g) semiconductor single crystals cooled typically to 10 mK (e.g. CDMS, Edelweiss, CRESST, etc). However, the use of superfluid ^{3}He as a detector naturally requires state-of-the-art ultralow temperature techniques, currently only accessible in two laboratories worldwide. The possibility of detecting astroparticles with a sensitivity of less than 1 keV using superfluid ^{3}He at 100 µK (two orders of magnitude colder than current experiments) has been demonstrated in Lancaster and CNRS-Grenoble.

A prototype particle detector showing extreme sensitivity and high discrimination has been successfully tested in Grenoble (Projects MacHe3 and ULTIMA). Current results of ULTIMA, achieved with a small-sized detector, have been widely acclaimed by both the low-temperature and the cosmo-particle communities. In a few months the prototype detector will be the first ^{3}He system to run under the stringent astrophysical conditions of very low muon flux in the Canfranc underground laboratory.

Along with several European groups, we are now in a position to undertake the even more ambitious research project, ULTIMA-Plus, taking advantage of the expertise available in the MICROKELVIN Collaboration. The detector cell containing superfluid ^{3}He cooled to 100 µK is arranged in a matrix of bolometers which, by correlation and pulse-shape discrimination, provide background-event rejection. We intend to develop the first operational superfluid ^{3}He neutralino detector with the first measurements at Canfranc. A 100 cell detector (100 grams of ^{3}He) would provide an ideal starting point for non-baryonic Dark-Matter searches. In particular ^{3}He, with one neutron, should provide a clear advantage for detecting that class of WIMPs thought to interact only with unpaired neutrons.

We have the expertise needed to cool large quantities of ^{3}He to the temperatures required for such a unique detector. However, further techniques must be developed to exploit fully the potential of superfluid ^{3}He, including thermometry, mechanical resonators, low noise signal detection, low radioactivity cryogenic materials, etc.

Such microkelvin devices could also provide the basis for more universal bolometric particle detectors applicable to several different types of cosmic particles, especially those with axial interactions. Since many different WIMP candidates have been proposed to account for the Dark Matter excess (neutralinos and axions being currently very popular), we need to develop a range of different types of detector.

Milestones:

M12: Microfabricated silicon vibrating wires tested in superfluid ^{3}He below 100 microkelvin in underground laboratory conditions (30).

M13: Superfluid ^{3}He microkelvin underground multicell particle-detector operating underground (42).

Deliverables

D1: Report on microfabricated silicon vibrating wires tested in superfluid ^{3}He at 100 µK (12).
D2: Publication on vortex creation in superfluid ^{3}He (24, 36).
D3: Publication on 2D defects (36).
D4: Publication on Black Holes (36)
D5: Publication on Q-balls in superfluid ^{3}He (48)
D6: Report on ULTIMA multicell particle-detector operating underground (48).

Work package number	JRA4	Start date or starting event:			1.1. 2009	
Work package title	Novel methods and devices for ultra low temperature measurements						
Activity Type	RTD						
Participant number	1	2	4	5	8	11	12
Participant short name	TKK	CNRS	**HEID**	RHUL	BASEL	UL	PTB
Person-months per participant:	6	12	27	30	10	12	8

Objectives

To develop contactless measurement techniques for microkelvin temperatures
To develop low noise SQUID-amplifiers for measurements at the quantum limit
To develop novel ultra low temperature thermometers

Description of work

Many standard methods in low temperature physics are not directly suited for use at ultralow temperatures. The main reasons is the strong thermal decoupling and the requirement of extremely low parasitic heating. This is especially true in studies of small nanosamples near their quantum mechanical ground state. Fundamentally new approaches are needed to overcome these obstacles to open up new frontiers in this field of research. The ultimate goal is to develop measurement techniques limited only by the laws of quantum mechanics. They are useful at sub-mK temperatures where the thermal noise of environment becomes smaller than the quantum noise at relatively low frequencies of f > 20 MHz.

One line of development will be based on the idea of transforming conventional measuring methods into contactless setups by utilizing inductive, capacitive and optical coupling methods. Avoiding direct contact of wires and measuring cables at the samples can reduce parasitic heat flow by many orders of magnitude. Therefore we will design and demonstrate ultra sensitive techniques to measure specific heat, thermal conductivity and sound velocity by consequent implementation of contactless methods. In addition, we will utilize new types of filtered leads developed in JRA2 to suppress high frequency noise.

Another general requirement for many experiments at ultralow temperatures is the use of ultra sensitive low temperature amplifiers. For many applications the optimal choice are SQUID amplifiers. Therefore we intend to develop SQUID amplifiers for various low and high frequency applications, which can be operated at mK temperatures with an energy sensitivity close to the quantum limit.

Finally, thermometry is an essential part of any microkelvin experiment. Studies on nanosize samples at ultra low temperatures are, however, hampered by the lack of convenient thermometers. We intend to make a serious effort to solve this problem by developing suitable nanothermometers for ultra-low temperatures. We will transfer our knowledge on SQUID amplifiers to develop noise thermometry of nanosamples. Coulomb blockade thermometry, invented already in 1994 by some of the consortium partners (TKK), will be further developed to work also at sub-mK. Microkelvin experiments in nanosamples in semiconductor materials (pursued in JRA1) require on-chip thermometry measuring directly, in-situ the temperature of the electrons in the sample. We will develop a suitable quantum dot thermometer to allow temperature measurements at sub-mK temperatures in semiconductor nanosamples. In addition, a compact ultralow temperature ^{195}Pt NMR thermometer will be realized.

Task 1: Contactless measurement of thermal, dielectric, magnetic and acoustic properties (HEID, CNRS, TKK, PTB)

Development of new techniques for measuring dielectric, magnetic, acoustic and thermal properties of samples at ultralow temperatures. Optical heating techniques, scanning SQUID probes as well as inductive and capacitive coupling schemes will be investigated for designing contactless measuring methods. As one example we mention here a new idea to measure heat capacity of amorphous solids at ultra low temperatures. The understanding of the low temperature properties of amorphous solids is of vital importance for many cutting edge technologies like solid state qubits and kinetic inductance detectors. At very low temperatures it is possible to generate polarization echoes in amorphous dielectrics. For this the sample is located in a microwave cavity and the microwave pulses are coupled in inductively. Since the echo amplitude is a steep function of temperature it can be used to determine the internal temperature of the sample without any leads. Combining this with an optical heating system allows the measurement of specific heat of such samples without electrical contacts to the sample. Many other properties can be measured in a similar way.

Milestones:

M1: Realization of a contactless setup to investigate decoherence (18) and specific heat (36) in solids at ultra-low temperatures

M2: Realization of a high resolution μSQUID scanning magnetometer (42)

Task 2a: SQUID amplifiers for microkelvin measurements (RHUL, HEID, TKK, CNRS, ULANC, PTB)

Development of novel SQUID systems with micro-coil input circuits as local probes of quantum matter and nanosystems at millikelvin and microkelvin temperatures. The pick-up loop may be integrated with the SQUID loop as in a miniature SQUID susceptometer or be located remotely and transformer coupled to the SQUID. The major gain from the micro-circuit is that high inductive coupling between the coil and the sample or region of interest (of comparable dimensions) can be achieved. If a mechanical actuator is implemented to move the coil the system would act as a NMR microscope, with spatial resolution limited by coil dimensions. In addition, we wish to develop SQUID amplifiers operated at mK temperatures with energy sensitivity approaching the quantum limit, using conventional pick-up coils. We also wish to approach the quantum limit at relatively low frequencies (of order 1 MHz). Our approach will be threefold. First the SQUID will be miniaturized to reduce the energy corresponding to a given flux amplitude. Secondly, the cooling of the resistive element inherent to the SQUID will be given special attention, while finally the power dissipated in the resistive element will be minimized by using an inductive detection scheme of the flux in the SQUID.

Task 2b: High frequency SQUID amplifiers at the quantum limit (UL, PTB, RHUL, HEID, TKK)

The quantum regime of SQUID amplifiers is an open problem. Is a SQUID operated at sufficiently high frequency and sufficiently low temperatures a quantum-limited amplifier? We need to understand the back action of the SQUID on the input circuit. SQUID amplifiers operating into the several hundred MHz region in flux-locked loop mode are on the immediate horizon. Clearly the first thing would be to try and observe quantum-limited noise from a resistor at low mK temperatures. The longer term objective is to achieve quantum limited SQUID amplifiers into the GHz regime for quantum computing applications.

Milestones:

M3: Demonstration of SQUID-NMR detection of nanoscale ^{3}He samples at sub-millikelvin temperatures (12)

M4: Demonstration of NMR signals from sample regions of characteristic dimensions from 10 to 100 microns (36)
M5: Demonstration of NMR at frequencies up to 100 MHz with wide bandwidth SQUID amplifiers (42)

Task 3a: Noise thermometer (RHUL, UL, HEID, PTB, TKK)

To develop current sensing noise thermometry for the temperature range 50 microkelvin to 10 K (5 orders of magnitude in temperature, one calibration point, no cross calibration, precision independent of temperature). One way to achieve this is by the use of a high-purity noble metal as a temperature sensor, whose current fluctuations are measured inductively by a DC SQUID.

Task 3b: Ultra low temperature ^{195}Pt NMR - Thermometer (PTB, TKK)

To develop a compact ^{195}Pt NMR -Thermometer for temperatures down to 10 microkelvin. At the high temperature end (10 mK) of the scale this thermometer will be calibrated against a current sensing noise thermometer. Below 1 mK a new superconducting fixed-point device will be developed to provide calibration points. Here the rhodium transition will be utilized, for example.

Task 3c: Coulomb blockade thermometer for nanosamples (TKK, CNRS, BASEL)

Coulomb blockade thermometry (CBT) is based on detecting the non-linear conductance of a semiconductor quantum dot or of an array of tunnel junctions: the width of the conductance peak or dip around zero bias voltage is measured, and this width can be related directly to absolute temperature without calibration. We wish to develop Coulomb blockade thermometry for nano samples at the lowest possible temperatures, including both tunnel junction CBT sensors as well as GaAs quantum dot temperature sensors in semiconducting nanosamples.

Milestones:
M6: Realization and measurement of a 10 mK CBT sensor (15)
M7: Design and testing to 200 μK of a current-sensing noise thermometer optimized for metrological measurements (24)
M8: Operation of GaAs quantum-dot thermometer at 10 mK (24)
M9: Design and testing of a ^{195}Pt-NMR thermometer down to temperatures of 10 microkelvin (36)
M10: New temperature scale for ultralow temperatures (42)

Deliverables
Task 1
D1: Report on the contactless decoherence and heat-capacity measurement method (18, 36)
D2: Report on the performance of high resolution μSQUID scanning magnetometer (48)
Task 2
D3: Report on the performance of microcoils coupled to low inductance SQUIDs (12, 24)
D4: Report on the performance of wide bandwidth SQUIDs (18, 36)
Task 3
D5: Report on current sensing noise thermometer for ultra low temperature (12, 24)
D6: Report on ^{195}Pt-NMR thermometer for ultralow temperatures (18, 36)
D7: Report on metrologically compatible CBT sensor (12, 24)
D8: Report on 10 mK (12, 24) and on 100 μK (36, 48) GaAs quantum dot thermometer

B.1.3.6 Efforts for the full duration of the project

Project Effort Form 1 – Indicative efforts per beneficiary per WP

Project number (acronym) : 228464 (MIRCOKELVIN)

Participant no./short name	**NA1**	**NA2**	**NA3**	**NA4**	**JRA1**	**JAR2**	**JRA3**	**JRA4**	**Total person months**
1. TKK	**20**	**1**			8	**32**	12	6	79
2. CNRS		1	**2**	1	16	12	**18**	12	62
3. ULANC		1		**1**	**16**		26		44
4. HEID							10	**27**	37
5. RHUL					4	9	4	30	47
6. SNS						18			18
7. SAS					8		8		16
8. BASEL					18	9		10	37
9. DELFT						15			15
10. BLUEFORS					10				10
11. UL					4			12	16
12. PTB								8	8
Total	20	3	2	2	84	95	78	105	389

Project Effort Form 2 - Indicative efforts per activity type per beneficiary

Project number (acronym): 228464 (MICROKELVIN)

Activity Type	TKK	CNRS	ULANC	HEID	RHUL	SNS	SAS	BASEL	DELFT	BLUE FORS	UL	PTB	TOTAL ACTIVITIES
RTD													
JRA1	8	16	16		4		8	18		10	4		84
JRA2	32	12			9	18		9	15				95
JRA3	12	18	26	10	4		8						78
JRA4	6	12		27	30			10			12	8	105
Total 'RTD'	58	58	42	37	47	18	16	37	15	10	16	8	362
COORD													
NA2	1	1	1										3
NA3		2											2
NA4		1	1										2
Total 'COOR'	1	4	2										7
Consortium management activities: MGT													
NA1	20												20
Total ' management MGT'	20												20
TOTAL BENEFICIARIES	79	62	44	37	47	18	16	37	15	10	16	8	389

B.1.3.7 List of milestones and planning of reviews

List and schedule of milestones					
Milestone number	**Milestone name**	**WPs no's**	**Lead beneficiary**	**Delivery date From Annex I**	**Comments**
M1	MICROKELVIN kick-off meeting	NA1	TKK	1	Web-site news
M2	Management Committee email meetings	NA1	TKK	1, 4, 8,..	Web-site news
M3	General Assembly and Advisory Board meetings	NA1	TKK	1, 12, 24, 36	Web-site news
M4	Mid-term review	NA1	TKK	30	Web-site news
M1	Appointment of SP	NA2	TKK	1	Web-site news
M2	Meetings of Selection Panel (email meetings)	NA2	TKK	1, 13, 37 (6, 12, 18…)	Web-site news
M1	Meetings of Dissemination Committee	NA3	CNRS	1, 13, 37	Web-site news
M1	Meeting for the creation of ECS	NA4	CNRS	10	Web-site news
M2	Formal creation of Third-Countries Associated Low Temperature Network	NA4	CNRS	10	Web-site news
M3	Statutes of Distributed European Microkelvin Laboratory	NA4	ULANC	48	Report
M1	Advanced filtering and isolation system designed and built	JRA1, Task 1	ULANC	18	Prototype ready
M2	High conductivity cooled links to nano-circuits designed and tested	JRA1, Task 1	ULANC	30	Prototype ready
M3	Nanocircuit stage installed in an access refrigerator	JRA1, Task 1	ULANC	36	Prototype running flawlessly
M4	Phonon temperature on nanoscale silicon membrane measured	JRA1, Task 1	ULANC	36	Demonstrator
M5	Pulsed-tube based dilution refrigerator and conventional (miniature nuclear) stage ready for integration at CNRS (TKK)	JRA1, Task 2	CNRS (TKK)	12 (18)	Prototypes running flawlessly
M6	The compact microkelvin refrigerator at CNRS (TKK) ready for access service	JRA1, Task 2	CNRS (TKK)	24 (36)	Prototypes ready
M7	Complete the vibration isolation platform	JRA1, Task 3	ULANC	6	Prototype ready
M8	Dilution refrigerator built, installed and tested	JRA1, Task 3	ULANC	24	Prototype running flawlessly
M9	Nuclear stage tested and running in dilution refrigerator	JRA1, Task 3	ULANC	30	Prototype running flawlessly
M1	Choice of the thermalization strategy	JRA2, Task 1	BASEL	12	Tests completed
M2	Choice of the ex-chip filtering technique	JRA2, Task 1	BASEL	18	Tests completed
M3	Choice of the superconducting material with a lower T_C	JRA2, Task 2	CNRS	24	Tests completed
M4	Precise definition of the QD cooler geometry and materials	JRA2, Task 2	SNS	24	Tests completed
M5	Design of membrane patterning and microcoolers	JRA2, Task 3	TKK	18	Report
M6	Delivery of the first membranes to the end users	JRA2, Task 3	TKK	36	Prototype running flawlessly
M1	Determination of the energy released by a vortex tangle with known line density	JRA3, Task 1	ULANC	12	Test completed
M2	Measurement of the dissipation when a	JRA3,	ULANC	24	Report

	vortex tangle is established	Task 1			
M3	A precise determination of the effect of pressure on vortex creation via the dynamics of the second-order phase transition	JRA3, Task 1	ULANC	30	Report
M4	Identification of the topological defects left after brane (phase boundary) annihilation	JRA3, Task 2	ULANC	24	Report
M5	Observation of several "cosmological defects" obtained in a microkelvin multi-cell detector	JRA3, Task 2	ULANC	30	Test completed
M6	Realization of a Black-Hole analogue in a rotating system with an A-B boundary	JRA3, Task 3	TKK	24	Report
M7	Test of the Unruh effect from rapid motion of a phase boundary	JRA3, Task 3	TKK	30	Test completed
M8	Test of the percolation theory of the A-B transition	JRA3, Task 3	TKK	36	Test completed
M9	The observation of the interaction between two independent precessing Q-balls	JRA3, Task 4	CNRS	30	Report
M10	Creation of excited modes of a "Q-ball" under radial squeezing by rotation	JRA3, Task 4	CNRS	36	Test completed
M11	Realization of microkelvin thermometry based on "Q-ball" behaviour	JRA3, Task 4	CNRS	42	Report
M12	Microfabricated silicon vibrating wires tested in superfluid ^{3}He below 100 μK in underground laboratory conditions	JRA3, Task 5	CNRS	30	Prototype functioning flawlessly
M13	Superfluid ^{3}He microkelvin underground multicell particle-detector operating underground	JRA3, Task 5	CNRS	42	Prototype running flawlessly
M1	Contactless setup to investigate decoherence (specific heat) of solids	JRA4, Task 1	HEID	18 (36)	Prototype running flawlessly
M2	Realization of a high resolution μSQUID scanning magnetometer	JTA4, Task 1	CNRS	42	Prototype running flawlessly
M3	SQUID NMR detection of nano-scale 3He samples at sub-mK temperatures	JRA4, Task 2	RHUL	12	Prototype running flawlessly
M4	Demonstration of NMR signals from 10 x 100 micron 3He samples	JRA4, Task 2	RHUL	36	Prototype running flawlessly
M5	Demonstration of NMR at frequencies up to 100 MHz with wide bw SQUID amplifier	JRA4, Task 2	RHUL	42	Prototype running flawlessly
M6	Realization and measurement of 10 mK CBT sensor	JRA4, Task 3	TKK	15	Prototype running flawlessly
M7	Design and testing to 200 μK of noise thermometer optimized for metrological measurements	JRA4, Task 3	RHUL	24	Prototype running flawlessly
M8	Operation of GaAs quantum dot thermometer at 10 mK	JRA4, Task 3	BASEL	24	Prototype running flawlessly
M9	Design and test of a ^{195}Pt-NMR thermometer down to temperatures of 10 μK	JRA4, Task 3	PTB	36	Prototype running flawlessly
M10	New temperature scale for ultra low temperatures	JRA4, Task 3	PTB	42	Prototype running flawlessly

Tentative schedule of project review			
Review no.	**Tentative timing**	***planned venue of review***	***Comments , if any***
1	After project month: 30	Helsinki University of Technology	Mid-term review

B.2 Implementation

B.2.1 Management structure and procedures

The management of the MICROKELVIN consortium will focus on six aspects: organization, time, budget, quality, communications, risks and knowledge, as outlined here.

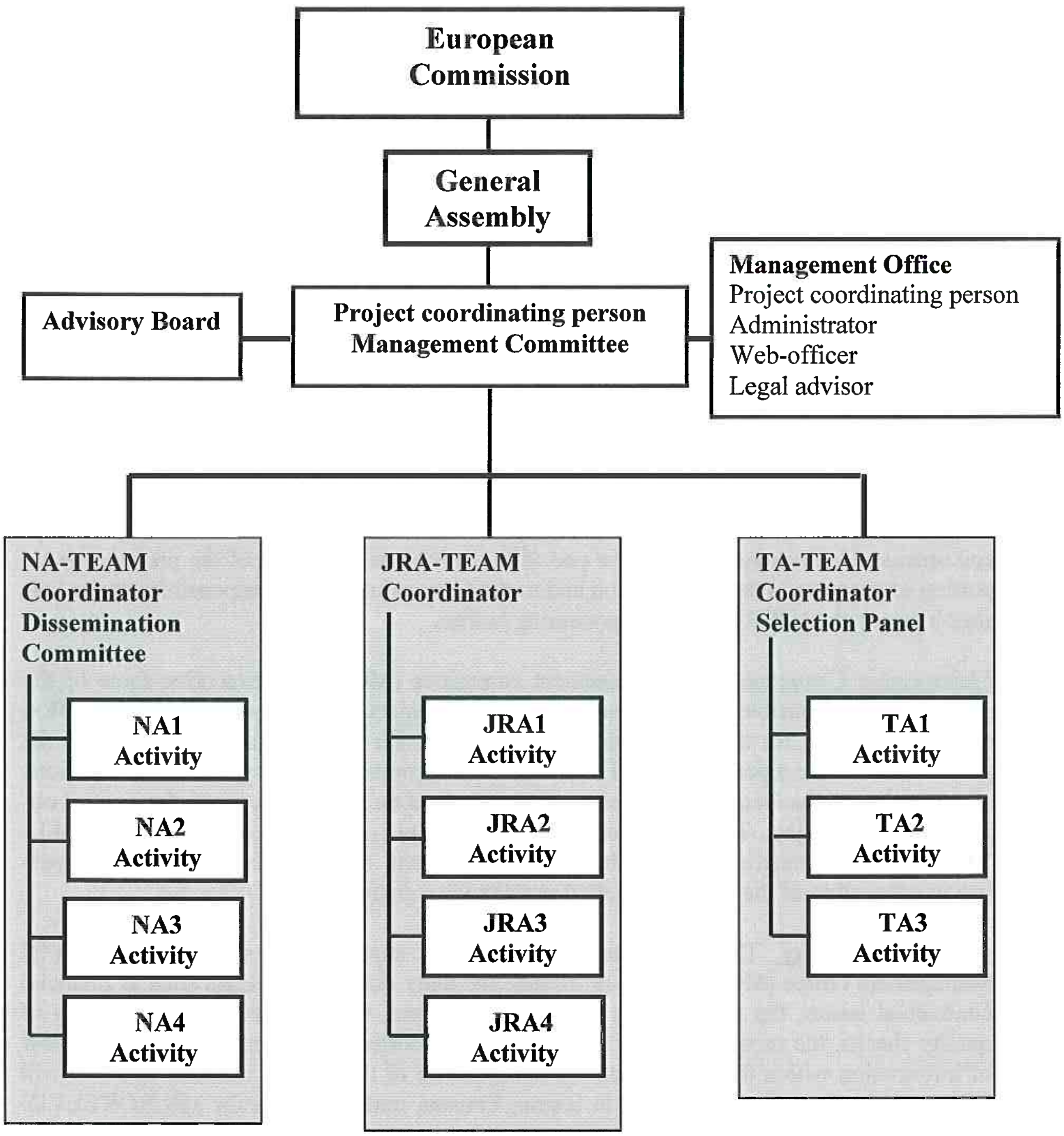

Figure 1: Management organisation within the MICROKELVIN project and its relation to the EC.

B.2.1.1 Organization

The MICROKELVIN consortium consists of 12 partners executing 11 different activities. There are 4 networking activities, 4 joint research activities and 3 activities concerning transnational access. Each activity is managed by an activity leader who is fully responsible for the quality and timely delivery of the deliverables in his/her activity. For each cluster of activities (NA, JRA or TA) an activity coordinator, appointed among the activity leaders, is responsible for the coordination among the activities and for the management of the interfaces. The activity coordinators report to the project management on progress, results and bottlenecks. The management structure is shown in Figure 1. Below is a short explanation of the duties, responsibilities and composition the different bodies.

The *Coordinator* is the legal entity, TKK, acting as the intermediary between the Parties and the European Commission.

The *General Assembly* is the decision-making body of the Consortium. The General Assembly will consist of one representative per partner, each having one vote, with the Project Coordinating Person acting as secretary with no voting right. Among other things, the General Assembly will elect the Project Coordinating Person and members of Advisory Board, manage intellectual property rights, decide on publishing results and decide on possible changes to the project plan. The General Assembly will conduct email meetings and meet in person three times in connection of the kick-off and two User meetings, together with the MC, the AB and the SP. Users' feedback is formalised in the stakeholders representation offered by the Consortium members and by the SP. The details of decision making and voting rules will be described in the Consortium Agreement.

The *Project Coordinating Person* is the executive director of the project, representing the Coordinator (TKK), and the single contact person for the project toward the Commission and outside. He is responsible for the execution and the management of the project, the reporting of progress to the Commission and to the Consortium, and is responsible for the liaisons between the MICROKELVIN governing bodies.

Management Committee. The management committee (MC) is the executive force of the project. It is responsible for the management of the project, for the monitoring of NA, JRA and TA activities, for the development of the project, for the information flow within the project and for the reporting to the EC and the Consortium. It may propose major revisions of the project to the General Assembly, if new solutions are required to reach the general objectives of the project. The MC consists of the 3 activity coordinators and the MICROKELVIN Project Coordinating Person who acts as a chairman. The MC meets three times in person in connection of the GA, and every 4 months via a email meeting.

Management Office. The management committee is supported by the MICROKELVIN Management Office (MO), which will execute the daily management tasks such as financial contractual issues, the management of budget and time, the monitoring and execution of quality checks, the reporting to the EC and to the consortium, the communication and flow of information within the project and the maintenance of the project website. The MO will be located in the LTL at the TKK in Espoo, Finland, under contract for MICROKELVIN and will consist of the Project Coordinating Person, one part-time administrator and one part-time web-officer. When necessary, legal advice on the contractual and IPR matters will be obtained at the Otaniemi International Innovation Centre (OIIC) of the TKK. The MO will follow the daily activities of the whole MICROKELVIN project and provide assistance to the Management Committee and to the Activity Coordinators.

Advisory Board. The Advisory Board (AB) monitors the progress of the project and advises the Management Committee and the consortium on all issues of the general scientific and managerial policy. The Advisory Board has no power to make decisions concerning the project. It represents the interests of the wider scientific community and of the key stakeholders in various sectors of society not covered by the Consortium. Its 5-7 members, elected by the General Assembly, include key research figures in low temperature physics and cryoengineering, representatives from international organisations (IUPAP C5), large low temperature facilities worldwide (ISSP or Riken in Japan, Cornell University or University of Florida in US) and also from industry. The AB meets three times in person in the connection of the GA.

Activity Leaders. Activity leaders manage their activity as an individual task. They are fully responsible for the quality and timely delivery of the deliverables of the activity and the control of the interfaces and interconnectivity with other activities as well as the assessment and response to external developments. The activity leaders confirm their progress on all issues every half year to the activity coordinator.

Activity Coordinators. For each cluster of activities an activity coordinator will be appointed from the activity leaders. The activity coordinator is responsible for the coordination between the activities and the management of interfaces. The activity coordinator confirms every half year to the project management the progress, results and bottlenecks.

Selection Panel. In the access activity, the common Selection Panel (SP) selects the visitors to all three access giving sites. The SP consists of the 3 managers of the access giving sites and 5 other members, representing the user community and elected by the General Assembly. The meetings of the SP are conducted via email. The SP meets three times in person in the connection of the GA.

Dissemination Committee. Knowledge and technology transfer will be organized by a Dissemination Committee, formed by the NA3 Leader and representatives of the Partners (one identified person per partner), in liaison with the Management Committee and the Project web-officer. The DC meets in person three times in the connection of the GA.

B.2.1.2 Management of time and budget

Each year the activity leader will make an 18 month activity schedule based on the schedule of the project. The progress per activity will be confirmed 2 times per year by the activity leaders to the activity coordinator and the project office. The budget of the project will be managed with a project control system, defining the original cost baseline, the actual cost baseline and the estimate to completion. The project office will report the overall progress of the project to the project coordinating person every half year identifying the value obtained for the money spent.

B.2.1.3 Management of quality

To control the quality of the project, several tools will be implemented. For each activity in the working plan a quality procedure will be defined stating:

- The quality requirements of the deliverables
- The activity-specific risks and the remedial actions
- The monitoring of the work, bottlenecks and risks by the activity leader

MA

- A timetable of the deliverables including the interconnection and interfaces with other activities
- The reviewer and the reviewing procedure for each deliverable and milestone

The activity leader confirms every half year to the project coordinator and the activity coordinator the progress of the project in relation to the time schedule and the budget, the bottlenecks and risks, the extent to which the requirements are going to be met and the results of the reviews. The exchange of deliverables through the internal project web-site facilitate the execution of the quality checks and reviews and make it easier for the project coordinator and the project officer to monitor progress.

The project coordinating person is responsible for the monitoring and execution of the quality assurance procedures. Before the delivery to the EC all the deliverables have to be approved by the project coordinating person. The project coordinator will describe the quality assessment of the daily management in the project handbook as part of the working plan.

B.2.1.4 Management of the communication and information

One of the pitfalls of working with a large consortium is communication and the flow of information. The Project Office at TKK will deal with this problem by creating a novel project website with an internal and external interface. The internal interface facilitates the up- and downloading of documents and deliverables, communication and discussion per activity, per group of activities, and for the whole project, the communication with the partners and the execution of quality checks.

Apart from regular email meetings a schedule of meetings will be held. The Management Committee, the Advisory Board and the Selection Panel will meet in kick-off and User Meetings in person to discuss the progress of the project, the impact of external events and the feedback of users.

B.2.2 Beneficiaries

1. Helsinki University of Technology (TKK) http://ltl.tkk.fi/

Helsinki University of Technology (TKK) is the oldest and largest engineering school in Finland. TKK has an annual budget of 230 million, 250 professors and in total 3400 persons employed. The Low Temperature Laboratory (LTL) of TKK, founded in 1965, is one of the world centers in ultra low temperature physics. The LTL has served in FP4, FP5 and FP6 as an EC-funded single-site infrastructure in low temperature physics (ULTI, Ultra Low Temperature Installation), giving annually access to about 25 European scientists. The LTL organized in 1975 LT14 and in 1999 LT22, the main International Conference on Low Temperature Physics attended by over 1000 participants.

The leading position is based on vigorous in-house development and construction of sub-mK refrigerators. In 2000 the laboratory reached the present low temperature world record of 10^{-10} K. The in-house research is organized in 5 experimental and 1 theory groups, which employ altogether 5 professors, 5 senior scientists, 5 post doctoral researchers, 15 graduate and 4 undergraduate (part-time) students. Altogether two sub-mK and four 20 mK cryostats, located in a 500 m^2 cryohall, are available for experimental work at ultra low temperatures. The LTL operates a mechanical workshop and an in-house semi clean room. Access to nearby Micronova clean room, the largest clean room complex in Scandinavia offering equipment, assistance and expertise for fabrication of both nanoelectronic and micromechanical samples, will be limited to most experienced visitors.

The TKK will coordinate the consortium and Access Activities, and host the Management Office. It will operate one of the three access giving sites (TA1), lead JRA2 and participate in all other JRAs and all NAs.

Prof. Mikko Paalanen will coordinate the Microkelvin consortium and TA activities, and lead NA1 and NA2. He has been the director of the LTL and the coordinator of the ULTI projects since 1996. In 1977-92 he served as a research scientist at AT&T Bell Laboratories, Murray Hill, New Jersey, US. He has served as chairman of LT22 in 1999, and IUPAP C5 (International Union of Pure and Applied Physics, Commission on low temperature physics) in 2006-2008, and PE3, the ERC Starting grant panel in condensed matter physics in 2007-09. He is a member of Fritz London (2002-2008) and Simon Prize (2007-) Committees.

Prof. Jukka Pekola will serve as the activity leader in JRA2. He has expertise in low temperature physics, cryoengineering and nanoelectronics. Current research interest include thermometry, refrigeration, and nanoscale superconducting electronics. He has over 140 refereed scientific publications, 8 patents. He received InnoFinland Prize in 2001. He is the founder of Nanoway Ltd (1997).

2. Centre National de la Recherche Scientifique (CNRS) http://neel.cnrs.fr/

The Centre National de la Recherche Scientifique (CNRS) is a government-funded research organization, under the authority of France's Ministry of Research. Founded in 1939, CNRS, the largest fundamental research organization in Europe, carries out research in all fields of knowledge. Its annual budget represents a quarter of French public spending on civilian research. CNRS research units are located throughout France, and employ a large body of tenured researchers, engineers, and support staff.

Located in Grenoble, the Institut Néel is a proprietary laboratory of the CNRS, associated with the University of Grenoble. It arose from the reorganization of 4 CNRS laboratories, the 'Centre de Recherche sur les Très Basses Températures' (CRTBT), 'Laboratoire de Cristallographie', 'Laboratoire d'Etudes des Propriétés Electronique des Solides' and 'Laboratoire Louis Néel'. Research at the Institute is organized in 3 departments: Low Temperatures, Nanosciences, and Functional Materials. The Institut Néel (415 people) has 19 research groups and a dozen technical support groups. It is the largest European centre dedicated to the investigation of low temperature science and technology. Its technical staff in cryogenics, electronics, and nanofabrication (50 engineers and technicians) is highly trained and competent. The equipment available at the Intitut Néel includes about 30 dilution refrigerators (3 of them with nuclear demagnetisation stages) and a large number of standard cryostats.

Technical facilities include a national nanofabrication platform (NANOFAB), several mechanical, welding, electronics workshops, etc. The laboratory runs in addition the Grenoble cryogenic fluids liquefaction plant, the second largest in Europe (after CERN). The Institut Néel (http://neel.cnrs.fr) is located in the Grenoble Scientific Polygon, together with important research centres such as CEA, HMFL, ILL, ESRF and EMBL.

Dr. Henri Godfrin will coordinate the Networking Activities and lead TA2, NA3 and JRA3. He has worked since 1976 in the Grenoble low temperature laboratory (CNRS); he served as Director of this centre (2002-2005). He worked for 3 years in the Centro Atómico Bariloche, 5 years at the Institut Laue-Langevin, and 1 year at AT&T Bell Laboratories. He has co-authored 150 scientific publications, organised international conferences. He received the Helmholtz Award and the Silver Medal of CNRS. He coordinates the Marie Curie European Advanced Cryogenics School ..

Dr. Yu. Bunkov will participate in JRA3 as a leading scientist. He worked at the Moscow Kapitza Institute (1974-1995). Since 1995 he has worked at the CNRS Low Temperature laboratory in Grenoble. He has co-authored 150 publications in condensed matter and ultralow temperature physics. He received the 1993 Lenin Award (Moscow) and in 2008 the Fritz London Memorial Prize.

3. Lancaster University (ULANC)

http://www.lancs.ac.uk/depts/physics/research/condmatt/ult/index.htm

Lancaster University was founded in Northwest England in the sixties. It has rapidly established itself as one of the leading research-led institutions in the region. Research and Teaching in the university cover the major fields of science, technology, the arts, social sciences and management. The university has an annual income of €M200. The university this year appeared in the top 150 of world universities as ranked by THES-QS.

The Department of Physics has three main groupings, high energy physics and cosmology, theoretical physics, and condensed matter physics. The theory group performs leading research on carbon nano-structures, nanotubes and graphene. The Ultralow Temperature Laboratory has been at the forefront of milli- and microkelvin research since the eighties. The group holds a number of low-temperature world records, including attaining the coldest sustained temperature of 6 μK for a solid. The group was recently ranked by Thomson-ISI as the most prolific group in superfluidity publications worldwide over the last decade. The group has excellent technical back-up built up over many years and builds its own dilution refrigerators including that with the current world best performance of 1.75 mK. The group has three nuclear cooling cryostats with sub-100 μK performance. All three machines would be available for access in the current initiative.

The ULT group is the world leader in the study of quantum fluids at the lowest accessible temperatures. It plays a leading role in the study of quantum fluids as model systems for looking at cosmological phenomena and has organised the COSLAB 2004 conference on this subject. The group also performs leading research in quantum turbulence at ULT and on dirty superfluidity in aerogel nanostructures. In nanoscience, the group has the support of the Lancaster theory group which specializes in the theory of carbon nanostructure (nanotubes and graphene).

Prof. George Pickett, will coordinate the JRA activities and serve as the activity leader of TA3 and NA4. He is a world leader in the field of experimentation at the lowest attainable temperatures. He has been Professor of Low Temperature Physics since 1988. He is a Fellow of the Royal Society of London and a foreign member of the Finnish Academy and the Russian Academy of Science. He has over 175 refereed scientific publications (including 35 Physical Review Letters). He served as the chairman of the Council of Scientists of INTAS 2001-3. He sits as UK representative on IUPAP C5 (International Union of Pure and Applied Physics, Commission on low temperature physics), and on the Condensed Matter panel of the ERC. He received the 1998 Simon Memorial Prize.

Prof. Shaun Fisher, will serve as the activity leader JRA1. He has expertise in quantum fluids research at ultralow temperatures and has pioneered research using sensitive "black-body radiator" techniques to tackle a wide variety of problems including quantum turbulence, gapless superfluidity in nano-structures, and cosmological analogues. He has been Professor of Low Temperature Physics since 2006. He is a Fellow of the UK Institute of Physics. He has over 110 refereed scientific publications. He received the U.K. Institute of Physics' Charles Vernon Boys medal and prize for distinguished research in experimental physics in 1998.

4. **Ruprecht-Karls-Universitaet Heidelberg (HEID)** (http://www.kip.uni-heidelberg.de)

Universität Heidelberg is the oldest university in Germany. It was founded in 1385 and has just received the status of an official elite university in Germany. Research and education at Universität Heidelberg covers a wide range of subjects including all traditional university fields. It has an annual budget of over 400 million Euro, 600 professors and in total over 11000 persons employed. The Kirchhoff-Institut für Physik (KIP) of Universität Heidelberg, founded in 1999, is one of the leading centers of low temperature physics in Germany. Altogether one sub-mK and five sub-20 mK cryostats are available for experimental work at ultra low temperatures. The in house mechanical workshop and clean room facilities are important infrastructures. Universitaet Heidelberg will participate in JRA1, JRA3 and in NA2, NA3 and NA4.

Prof. Christian Enss will serve as the activity leader in JRA4. He has expertise in low temperature physics, solid state physics and low temperature particle detection. Current interests include atomic tunneling states in amorphous solids, development of magnetic calorimeters, thermometry and refrigeration. He has been the director of the Kirchhoff-Institut für Physik and has taught physics at the Universities Heidelberg, Konstanz, Bayreuth and Brown. Since 2004 he has held the chair for experimental physics at the university. Over 80 refereed scientific publications. Author of two textbooks on low temperature physics. Organizer of several international workshops and symposia.

Dr. Andreas Fleischmann has expertise in low temperature physics, solid state physics and low temperature particle detection. Current interests include atomic tunneling states in amorphous solids, development of magnetic calorimeters, thermometry and refrigeration. Over 30 refereed scientific publications. Geiger prize 1999 and Ruprecht-Karls prize 2004.

5. Royal Holloway and Bedford New College (RHUL) (http://www.ph.rhul.ac.uk)

Royal Holloway University of London (RHUL), legal name Royal Holloway and Bedford New College, is one of five centres for scientific research in the University of London. In 2006-7 the annual budget was £104m. The Low Temperature Laboratory at RHUL was founded in 1986, and is an international centre in low temperature physics. The condensed matter physics group consists of two strongly inter-linked subgroups, Nanophysics and Low Temperature physics with thirteen academics (professors, readers, lecturers), two senior scientists, five postdoctoral researchers and nineteen graduate students. Two sub-mK cryostats, six dilution refrigerators, two adiabatic demagnetization refrigerators are available for experimental work at low temperatures. This research is supported by a modern helium liquefier, and mechanical and electronic workshops. Nanofabrication laboratories comprise five class 100 clean rooms containing two e-beam lithography machines, UHV evaporation and laser ablation, reactive ion etching and sputtering capabilities. RHUL will participate in NA2, NA3, NA4, JRA1, JRA2 and JRA4.

Prof. John Saunders will act as node leader at RHUL. He is director of the Low Temperature Laboratory and Head of the Department of Physics. Over 100 scientific publications on superfluid ^{3}He, low dimensional helium, solid helium, and SQUID applications to NMR and noise thermometry.

Dr Phil Meeson will participate in JRA2. He has more than 20 years' experience in low temperature physics at the University of Bristol and presently as Reader in Quantum Information Processing at RHUL. Current research focuses on nano-fabricated quantum devices, including the implementation of a solid-state single photon microwave source, superconducting quantum computing devices and single-electron quantum physics using electrons supported on helium.

6. Scuola Normale Superiore di Pisa (SNS)

http://www.nest.sns.it

The NEST laboratory in SNS, founded in 2001, is one of the 10 Centres of Excellence of the Istituto Nazionale per la Fisica della Materia (INFM), a CNR (Consiglio Nazionale delle Ricerche) division devoted to condensed matter physics and technological applications. It is an interdisciplinary research and training centre where teams of computational, experimental, and theoretical physicists together with chemists and biologists investigate scientific issues at the nanoscale. This knowledge is exploited to develop innovative biotechnological tools, nanoelectronic and photonic devices, and architectures. The in-house research is organized in several experimental and theoretical groups, which employ altogether 8 full professors, 6 associate professors, 5 senior scientists, 16 scientists, 3 technologists, 16 post doctoral researchers, 27 graduate and 6 undergraduate (part-time) students. Two 20 mK and four 300 mK cryostats, and magnetic fields up to 16 T are available for experimental research at low and ultra-low temperatures. The NEST operates a mechanical workshop and a clean room, the latter equipped also with a MBE and a CBE facilities for the growth of high-mobility GaAs 2DEGs and heterostructured semiconductor nanowires. NEST is one of the top research centres in Europe for nanoscience, as demonstrated by the number of publications in high-quality international journals (see www.nest.sns.it). Some of these publications are a result of the close collaboration between NEST and Scuola Normale Superiore (SNS), a nearby high-level university for education and research, a co-founder of NEST jointly with INF. NEST will participate in NA2, NA3 and NA4, and JRA2.

Dr. Francesco Giazotto has expertise in low-temperature physics, UHV technology, and mesoscopic transport on the nanoscale. Current research interests: electronic refrigeration, spintronics, non-equilibrium phenomena in solid-state systems, electron and heat transport in mesoscopic nanostructures. Over 40 refereed publications, 1 patent.

7. Ustav Experimentalnej Fyziky Slovenskej Akademie Vied (SAS) (http://ofnt.saske.sk/)

The Institute of Experimental Physics of the Slovak Academy of Sciences (IEP SAS) in Košice was established in1969. Currently the institute has 10 scientific departments. The Department of Low Temperature Physics, established in 1980 is one of the most important departments of the institute. The department owns a complete cryogenic base and unique experimental facilities and various measurement methods and techniques are also implemented. Amongst our unique experimental facilities are an in-house built nuclear demagnetisation refrigerator capable of cooling samples down to 100 μK and a commercial dilution refrigerator with a top-loading system. Another small dilution refrigerator, a ^{3}He refrigerator with STM and several ^{4}He cryostats together with commercial devices as MPPS SQUID and PPMS are also available. In 2002 the department received the status of the Centre of Low Temperature Physics (CLTP) - Centre of Excellence of the Slovak Academy of Science and since 2007 it is also a Centre of Excellence of Slovak Academy of Sciences and P.J. Safarik University. Research at CLTP is conducted by two cooperating institutions. The first is IEP SAS, where there are 4 experimental groups employing altogether 4 senior scientists (directors of research), 5 post doctoral researchers, 3 engineers, 3 technicians and 4 graduate students. The second is the Faculty of Science of P.J. Safarik University with one group employing 1 professor, 2 senior scientists, 3 post doctoral researchers and 4 graduate students. The CLTP in Kosice will participate in NA2, NA3, NA4, JRA1, JRA3.

Dr. Peter Skyba is the head of the Department of Low Temperature Physics of IEP SAS. He has expertise in low and ultra low temperature physics, cryo-engineering, and electronics. Current research interest covers physics of the superfluid helium-3 and its application as model system for cosmology, thermometry and refrigeration. He has published over 40 referred scientific publications. Holder of the prize of Slovak Academy of Science (2000) and the prize of Ministry of Education of Slovak Republic (2005).

8. Universitaet Basel (BASEL) http://physik.unibas.ch

The University of Basel, founded 1460, is the oldest University in Switzerland. Physics has been an active area of research and teaching since the late 17th century. The Department was the center of the activities of the Bernoullis and Euler was educated there. Today, research and education broadly cover the academic spectrum including the humanities, natural sciences, economics, medicine, psychology and law. Basel University has an annual budget of about 320 million €, over 11 000 students, 330 professors and a total of over 2 000 persons employed. It is one of the major academic and research centers of Switzerland.

The focus of the Department of Physics in Basel is on nanophysics and on astro / nuclear / particle physics. With 13 departmental chairs and a total of about 20 active research groups, the Department hosts the Swiss Nanoscience Institute, the national Nanoscience excellence center of the Swiss National Science Foundation, and also hosts the Basel QC2 Center for Quantum Computation and Quantum Coherence. The combined low-temperature effort includes four dilution refrigerators, two ^{3}He cryostats, several 1 K and 4 K cryostats and a Helium and Nitrogen liquefier. The nano-physics groups share and operate a quasi clean room facility including several scanning electron microscopes and writers, including all facilities necessary to produce gated nanostructures for GaAs 2D electron gases. Basel will participate in JRA1, JRA2, JRA4, NA2, NA3, and in NA4.

Prof. Dominik Zumbühl obtained his PhD at Harvard University and subsequently was a postdoc at the Massachusetts Institute of Technology. Since 2006 he has been a tenure track assistant Professor in Basel, and has set up a low temperature quantum transport laboratory and independent research group. He has expertise in spin qubits in coupled, laterally gated GaAs quantum dots, topological quantum phases in the fractional quantum Hall effect and in mesoscopic electron transport in semiconducting nanostructures. Recently, he won one of the highly contested Starting Grants from the European Research Council (ERC).

9. Technische Universiteit Delft (DELF) http://www.tudelft.nl/

Delft University of Technology (TUD) is the oldest and largest engineering school in the Netherlands. It was founded in 1842 and received the right to grant PhD degrees in 1905. Education at TUD covers the major fields of engineering and it has a particular strong research profile in the nanosciences. The Department of Nanoscience has become the Kavli Institute of Nanoscience to acknowledge its leading position in many areas of nanoscience such as molecular biophysics, quantum information processing, nanoelectronics for space research, physics of nano-electronics and theoretical physics. It has a commonly run nanofacility equipped for various general processes and for specific research groups. The facility is used by industries such as MAPPER, a multi-electronbeam lithography development company. Research is funded through a variety of national, European and US research organisations. Delft will participate in JRA2 and in NA2, NA3, and in NA4.

Prof. Teun M. Klapwijk, received his PhD in 1977 on a thesis on nonequilibrium superconductivity. He has worked extensively on superconductor-semiconductor mesoscopic physics and collaborated with astronomers on instruments to detect THz radiation. He worked as a post-doc at Harvard University from 1979-1980, at IBM Yorktown Heights in 1983. He was a professor at Groningen University from 1985-1998. He has been a professor at Delft since 1999. In 2001 he was elected a Fellow of the American Physical Society and in 2008 an Outstanding Referee. His current interest is on nanoelectronics for space research, including quantum cascade lasers, as well as mesoscopic superconductivity.

10. BlueFors Cryogenics (BLUEFORS)

http://bluefors.com/index.php?option=com_content&task=view&id=14&Itemid=49

BlueFors Cryogenics is a spin-off company from the Low Temperature Laboratory of Helsinki University of Technology. It was founded at the beginning of 2008. BlueFors Cryogenics specializes in dry (pulse-tube driven) dilution refrigerator systems. The aim of the company is to deliver robust, easy-to-operate refrigerators that hardly require any cryogenic experience of the user. Some standard features on all systems are: no low-temperature vacuum seals (including measurement wiring), fully automated cool down from room to base temperature, and a mechanically decoupled pulse tube to assure low vibration levels. All systems can be optimized and/or customized to meet the requirements of the customer. Some examples are: optimization for placement of the refrigerator system inside a shielded room, design of high-current leads and experimental magnets, integrated magnetic shielding and optimization of the system for use with SQUID's (remote motor of pulse tube). BlueFors will participate in JRA1 in building the pulsed-tube-based compact nuclear refrigerator. BlueFors will participate in JRA1, NA2, NA3 and in NA4 .

Dr. Rob Blaauwgeers earned his M.Sc. degree in 1996 in Leiden University, in the Kamerlingh Onnes Laboratory and his Ph.D. degree in 2002 in the Low Temperature Laboratory of Helsinki University of Technology. In his thesis work he studied properties of superfluid 3He. In 2008 together with Pieter Vorselman, he founded the company BlueFors Cryogenics. He is an expert in ultra low temperature refrigeration and techniques.

11. Universiteit Leiden (UL) http://www.physics.leidenuniv.nl

Leiden University (UL) was founded in 1575 and has approximately 17,000 students and 4,000 staff members. With this aim of promoting fundamental research Leiden University in alliance with eleven other leading universities in Europe has formed the *League of European Research Universities (LERU).*

Leiden Institute of Physics is part of Leiden University and consists of approximately 25 permanent academic staff members and a total of 140 postdocs and PhD students. Research is mainly fundamental with a strong focus in solid state physics.

Since the time of the achievements of Kamerlingh Onnes who first liquefied helium and discovered superconductivity in the early twentieth century, the Kamerlingh Onnes laboratory has been world famous for its expertise in cryogenic equipment. The UL organized in 2008 LT25, the main International Conference on Low Temperature Physics attended by nearly 1500 participants.

An important strength of the physics department is the knowledge base of the Fine Mechanics and Electronics departments. While in many institutes technical support has been decimated by budget cuts, the Leiden institute has actively maintained a strong fine mechanics and electronics department. Some 30 skilled technicians are employed in active instrumentation design bringing in their knowledge of materials, tools and components. This has been an important factor in making the physics department so successful in building state-of-the-art equipment.

Dr. T.H. Oosterkamp received his masters and PhD in engineering physics at the TU Delft in 1999 where he has optimized a dilution refrigerator working at 20 mK for transport experiments in semiconductor quantum dots, co-authoring several papers in Nature and Science. He spent a period as a postdoc in the group of Charles Lieber at Harvard University, researching carbon nanotubes applied to scanning probe microscopy and electron transport. In 2000 he moved to Leiden as an assistant professor. Oosterkamp coordinates an FP6-STREP project on scanning probe microscopy entitled Tips4Cells and recently received the prestigious ERC starting grant to develop magnetic resonance force microscopy at sub-mK temperatures.

12. Physikalisch-Technische Bundesanstalt (PTB) http://www.ptb.de/

The Physikalisch-Technische Bundesanstalt (PTB), Braunschweig and Berlin, is the national institute of natural and engineering sciences and the highest technical authority for metrology and physical safety engineering of the Federal Republic of Germany. PTB cooperates closely with a large number of industrial firms, one focal point at present being the field of nanotechnology. In accordance with the organizational structure of PTB, there are 10 divisions which are subdivided into 52 departments and about 100 working groups. The *Department Low-temperature thermodynamics and technology* accommodated in the Berlin institute consists of the *Working Group Cryosensors* which develops and manufactures SQUIDs and SQUID systems for various applications and the *Working Group Behaviour of Materials and Quantum Phenomena* which investigates the experimental and thermodynamic fundamentals of low-temperature thermometry. 5 scientists are currently working in the department which has a total staff of 19 employees. About 25% have non-permanent positions financed by national or European third party projects. The department is headed by Dr. Thomas Schurig who leads the *Working Group Cryosensors.*

The *Working Group Cryosensors* uses superconductor (Nb) thin-film technology for developing and fabricating complex multilayer sensor chips. Special superconducting and conventional bonding techniques allow complete custom designed sensor packages and sensor systems to be manufactured. The SQUID control electronics, required for operating the sensors, are also developed. PTB SQUID developments have been made commercially available by the company Magnicon (see www.magnicon.com) in the framework of licence agreements. Very sophisticated electronic equipment including very heavily magnetically shielded rooms are available for sensor characterization and measurements.

The *Working Group Behaviour of Materials and Quantum Phenomena,* headed by Prof. Peter Strehlow, operates a nuclear demagnetization cryostat for studies of condensed-matter phenomena at ultralow temperatures. A superconducting double-stage magnet not only allows ultra-low temperatures to be achieved with the copper nuclear stage but also facilitates the investigation of samples in high magnetic fields up to 9T. At this enormous polarisation, macroscopic quantum effects of great importance for physical fundamental research and quantum metrology are studied.

B.2.3 Consortium as a whole

The MICROKELVIN consortium has 12 carefully selected partners whose collective expertise and equipment matches well the objectives of the proposal. The achievement of the objectives of the consortium in access service quality and in technology development relies on two main elements; ultralow temperature refrigeration and nanofabrication. Expertise in both of these key areas is strong in the consortium.

The MICROKELVIN partners are the world leaders in developing microkelvin refrigeration and thermometry for sub-mK research. Seven of the partners (#s 1, 2, 3, 4, 5, 7 and 12) have microkelvin refrigerators and in-house experience and technology to build them. TKK, CNRS and ULANC are among the largest low temperature laboratories in the world, and pioneers in microkelvin refrigeration. They have developed a strong in-house technology base for building new refrigerators. CNRS has made and patented a novel pulse-tube based dilution refrigerator, for instance.

Several partners of the MICROKELVIN consortium have also considerable expertise in nanofabrication: four of the partners (#s 1, 2, 6 and 9) have access to a professional level clean room and six to well-equipped in-house clean-rooms 1, 2, 4, 5, 8 and 11). TKK, CNRS, SNS and DELFT are pioneers in low temperature microrefrigeration, with a long history of successful collaborations which will continue in JRA2 and JRA4.

In addition to refrigeration and nanofabrication, the successful completion of MICROKELVIN goals demands special expertise in ultra-low temperature measuring methods. One of our main objectives is the opening of the microkelvin temperature regime for nanoscience. It requires gentle and sensitive characterization of nanosamples, *e.g.* temperature, with new measurement techniques. HEID, and RHUL are pioneers in ultra-sensitive SQUID-measurement techniques, which will be further developed under their leadership in JRA4. Coulomb-blockade thermometry, invented by some of the partners at TKK, and ideal for nanosamples, will be further developed in JRA4 by TKK, CNRS, PTB and BASEL. PTB will strengthen MICROKELVIN in metrology and network it to the metrological community.

One of the objectives of MICROKELVIN is to reach out to small university research groups and companies. BASEL and UL are small but dynamic partners, each led by a single young professor. Both of these professors have won the prestigious ERC Starting Grant in 2007 in condensed matter physics. BlueFors is a promising start-up company, founded as a spin-off of LTL in 2008. It will specialise in building He-free pulsed-tube based refrigerators, including the first commercial nuclear cooling refrigerator. It has already received its first order for the He-free dilution refrigerator. Basel, UL and BlueFors will offer fresh research ideas and innovations to the consortium.

The success of MICROKELVIN will depend not only on the excellence of its partners, but also their ability to collaborate with each other and form networks to the nearby research communities. The core partners TKK, CNRS and ULANC have over 10-year-long track record in collaboration documented in many publications. They have experience in coordinating international research and training projects, in hosting visitors and organizing large conferences. They will collectively

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provide the leadership needed not only in the Transnational Access but also in the Networking and Joint Research activities.

B.2.4 Resources to be committed

The total budget of the MICROKELVIN Collaboration is 4,965 357 € over 48 months. The budget is covered by the EU and Collaboration partners with 4 200 000 and 765 357 € contributions, respectively. The EU contribution is carefully balanced between the Transnational Access (26,7%), Networking (18,6%, includes management cost) and Joint Research Activities (54,7%).

The total cost of Transnational Access Activities is 1 122 000 €. A major part, 908 000 €, will provide access for 54 visitors for 81 months at TKK, CNRS and/or at ULANC. In addition, 318 000 € will be allocated to the travel (150 trips), housing and living expenses (81 months) of the visitors. The estimate of access time offered and the practicality of the budget is based on the long experience of the Coordinator in similar ULTI projects in 1994-2008. One should note that the planned access volume does not exceed the 20% limit of total access in any of the access giving sites.

The budgets of the Networking and Joint Research Activities take into account the overall size of the MICROKELVIN consortium. On one hand, these activities mobilize 389 months of manpower, which is less than 10% of the total manpower of the consortium and can certainly be delivered. On the other hand, the manpower requests of NA1-4 (54 mo) and JRA1-4 (413 mo) are fully adequate to achieve the objectives in 4 years time.

The main instrument in the Networking Activities is the organization of workshops. The Consortium will use nearly 500 000 € to organize several large meetings in Europe with the widest possible participation: 2 User Meetings (3 days, 100 participants), 4 LT-X meetings with nearby research communities (3 days, 40 participants) and 2 industry-academy meetings (2 days 60 participants). In addition, several smaller meetings, concerning the consortium management, will take place annually. By our estimate the MICROKELVIN budget on Networking Activities, which is mostly used for workshops and meetings, is adequate to foster better collaboration in the European low temperature community of about 1000 people.

In the Joint Research Activities the MICROKELVIN consortium is investing 3 060 800 € to improve the services and equipment in the 3 access infrastructures at TKK, CNRS and ULANC. This figure should be compared with their annual combined budgets (5 000 000 €) and total value of their equipment (10 000 000 €). The budget of the MICROKELVIN JRAs is fully adequate to improve the quality of the services and the infrastructure at TKK, CNRS and ULANC.

Finally, MICROKELVIN will spent 260 800 € in management costs which is less than 7% of the total budget. This is a necessary but adequate expenditure in a consortium of 12 partners.

B.2.4.1 Access costs:

The access costs contain 2 parts: the travel and subsistence costs of the visitors and their access cost to infrastructure. The travel and subsistence costs are estimated to be similar in all three access giving sites and calculated below.

Calculation of the total **Travel and Subsistence costs for TKK, CNRS and ULANC**

			€ /4 year
Travel and subsistence for users from EU			
50 research visits with a total number of 27 person-months.			
It is assumed that 100% of their costs are covered by this programme			
-	average cost of a round trip to the infrastructure	500 €/visit	25 000
-	daily allowance + accommodation	3000 €/month	81 000
			106 000

The travel and subsistence costs, presented in the above table, are transferred to the following access cost sheets of the individual sites.

TKK is giving access to two installations: Cryohall and TKK Micronova. The unit cost of of Cryohall is slightly over 10 000 €/facility-month and TKK Micronova 150 €/hour. The cost of the access to ultra low temperatures turns out to be very similar in all the 3 access giving sites. It contains the cost of cryogenic liquids, consumables and the salaries of technical staff. In case of TKK, the rent of the Cryohall is not included in the indirect costs of TKK and therefore included in the cost calculation. At CNRS and ULANC it is included in the indirect cost of the partner and therefore cannot be charged in the unit cost.

Participant number	1	Organisation short name		TKK	
Short name of Infrastructure	LTL	Installation number	1	Short name of Installation	Cryohall
Name of Installation	Cryohall			Unit of access	facility-month

A. Estimated direct eligible costs of providing access within the project life-time excluding personnel costs	Describe the direct eligible costs for providing access to the installation over the project life-time (e.g. maintenance, utilities, consumable costs). All contributions to capital investments of the infrastructure are not eligible .			Eligible Costs (€)
	Consumables (200 000 liters of liquid He, 5 €/l)			1 000 000
	Consumables (120 000 liters of liquid nitrogen, 0.50 €/l)			60 000
	Consumables (electronics and vacuum components, machineshop materials)			100 000
	Rent of cryohall, semi clean room and machineshop (820 m^2, 15 €/m^2/month)			590 400
	Total A			**1 750 400**
	of which subcontracting (A')			***0***
B. Estimated personnel direct eligible costs needed to provide access within the project life-time	**Category of staff (scientific and technical only)**	**Nr. of hours (1)**	**Hourly rate (2)**	**(3) = (1) x (2)**
	3 technicians	18 876	25,00	471 900
	1 chief engineer	6 292	43,00	270 556
				0
				0
				0
				0
				0
	Total B			**742 456**
C. Indirect eligible costs = 7% x ([A-A']+B)				174 500
D. Total estimated access eligible costs = A+B+C				2 667 356
E. Total estimated quantity of access provided to all normal users of the infrastructure (i.e. both internal and external) within the project life-time				260
F. Fraction of the Unit cost to be charged to the proposal [1]				100 %
G. **Estimated Unit cost charged to the proposal** = F x (D/E)				**10259,06**
H. Quantity of access offered under the proposal (over the whole duration of the project)				27
I. Access Cost = G x H				**276 995**

Travel and subsistence for users supported under the grant agreement and for selection panel members	
J. T&S direct eligible costs [2]	**106 000**
K. T&S indirect eligible costs = 7% x J	**7 420**

To report in the "Support" column of the administrative forms [3]	L. ***Other direct costs = J***	**106 000**
	M. ***Indirect costs = K***	**7 420**
	N. ***Access costs***	**276 995**
	P. ***Total budget = L+M+N***	**390 415**

Participant number	1	Organisation short name		TKK	
Short name of Infrastructure	LTL	Installation number	2	Short name of Installation	TKK Micronova
Name of Installation	TKK Micronova			Unit of access	Hour

A. Estimated direct eligible costs of providing access within the project life-time excluding personnel costs	Describe the direct eligible costs for providing access to the installation over the project life-time (e.g. maintenance, utilities, consumable costs). All contributions to capital investments of the infrastructure are not eligible .			Eligible Costs (€)
	Maintenance services (ebeam writer, focused beam system, pumps)			124 000
	Consumables and spare parts (gases, chemicals, clean room materials, parts)			744 000
	Clean room infrastructure services (purchased from VTT)			1 008 000
	Rent (cleanroom, laboratories and machineshop)			2960000
			Total A	4 836 000
			of which subcontracting (A')	*0*
B. Estimated personnel direct eligible costs needed to provide access within the project life-time	Category of staff (scientific and technical only)	Nr. of hours (1)	Hourly rate (2)	(3) = (1) x (2)
	2 technicians	13 050	30	391 500
	1 clean room engineer	6525	45	293625
	1 senior technology expert	6525	50	326250
				0
				0
				0
				0
				0
				0
			Total B	1 011 375
C. Indirect eligible costs = 7% x ([A-A']+B)				409 316
D. Total estimated access eligible costs = A+B+C				6 256 691
E. Total estimated quantity of access provided to all normal users of the infrastructure (i.e. both internal and external) within the project life-time				41 664
F. Fraction of the Unit cost to be charged to the proposal [1]				100 %
G. Estimated Unit cost charged to the proposal = F x (D/E)				**150,17**
H. Quantity of access offered under the proposal (over the whole duration of the project)				100
I. Access Cost [2] = G x H				**15 017**

Participant number	2	Organisation short name		CNRS	
Short name of Infrastructure	CNRS	Installation number	1	Short name of Installation	CNRS-MICROKELVIN
Name of Installation	CNRS-Institut Néel-MICROKELVIN			Unit of access	facility-month

A. Estimated direct eligible costs of providing access within the project life-time excluding personnel costs	Describe the direct eligible costs for providing access to the installation over the project life-time (e.g. maintenance, utilities, consumable costs). All contributions to capital investments of the infrastructure are not eligible .	Eligible Costs (€)
	Consumables (60 000 liters of liquid He, 3 €/l)	180 000
	Consumables (120 000 liters of liquid nitrogen, 0.25 €/l)	30 000
	Consumables (electronics and vacuum components, machineshop materials)	140 000
	Nanofabrication and machineshop	60 000
	Total A	410 000
	of which subcontracting (A')	*0*

B. Estimated personnel direct eligible costs needed to provide access within the project life-time	Category of staff (scientific and technical only)	Nr. of hours (1)	Hourly rate (2)	(3) = (1) x (2)
	3 technicians	18 000	28,00	504 000
	1 chief engineer	6 000	41,00	246 000
	2 senior scientists DR1	12000	72,00	864 000
	1 scientist CR2	6000	35,5	213 000
				0
				0
				0
	Total B			1 827 000

C. Indirect eligible costs = 7% x ([A-A']+B)	156 590
D. Total estimated access eligible costs = A+B+C	2 393 590
E. Total estimated quantity of access provided to all normal users of the infrastructure (i.e. both internal and external) within the project life-time	260
F. Fraction of the Unit cost to be charged to the proposal [1]	100 %
G. **Estimated Unit cost charged to the proposal** = F x (D/E)	9206,12
H. Quantity of access offered under the proposal (over the whole duration of the project)	27
I. **Access Cost = G x H**	248 565

Travel and subsistence for users supported under the grant agreement and for selection panel members	
J. T&S direct eligible costs [2]	106 000
K. T&S indirect eligible costs = 7% x J	7 420

To report in the "Support" column of the administrative forms [3]		
	L. *Other direct costs = J*	106 000
	M. *Indirect costs = K*	7 420
	N. *Access costs*	248 565
	P. *Total budget = L+M+N*	361 985

Participant number	3	**Organisation short name**		**ULANC**	
Short name of Infrastructure		**Installation number**		**Short name of Installation**	**MicroKLab**
Name of Installation	**MicroKelvin Laboratory**			**Unit of access**	**facility-month**

A. Estimated direct eligible costs of providing access within the project life-time excluding personnel costs	Describe the direct eligible costs for providing access to the installation over the project life-time (e.g. maintenance, utilities, consumable costs). All contributions to capital investments of the infrastructure are not eligible .			**Eligible Costs (€)**
	Consumables (70 000 liters of liquid He, 6 €/l)			420 000
	Consumables (180 000 liters of liquid nitrogen, 0.30 €/l)			54 000
	Consumables (electronics and vacuum components, machineshop materials)			120 000
	Total A			**594 000**
	of which subcontracting (A')			***0***
B. Estimated personnel direct eligible costs needed to provide access within the project life-time	**Category of staff (scientific and technical only)**	**Nr. of hours (1)**	**Hourly rate (2)**	**(3) = (1) x (2)**
	2 technicians	13 200	25,00	330 000
	1 senior scientist	6 600	50,00	330 000
				0
				0
				0
				0
	Total B			**660 000**
C. Indirect eligible costs = 7% x ([A-A']+B)				87 780
D. Total estimated access eligible costs = A+B+C				1 341 780
E. Total estimated quantity of access provided to all normal users of the infrastructure (i.e. both internal and external) within the project life-time				150
F. Fraction of the Unit cost to be charged to the proposal [1]				100 %
G. **Estimated Unit cost charged to the proposal** = F x (D/E)				**8945,20**
H. Quantity of access offered under the proposal (over the whole duration of the project)				27
I. **Access Cost = G x H**				**241520,40**

Travel and subsistence for users supported under the grant agreement and for selection panel members	
J. T&S direct eligible costs [2]	**106 000**
K. T&S indirect eligible costs = 7% x J	**7420**

To report in the "Support" column of the administrative forms [3]	L. ***Other direct costs = J***	**106 000**
	M. ***Indirect costs = K***	**7420**
	N. ***Access costs***	**241520,40**
	P. ***Total budget = L+M+N***	**354 940**

Summary of transnational access provision

Partici-pant number	*Organisa-tion short name*	*Short name of infrastruc-ture*	*Installation*			*Opera-tor coun-try code*	*Unit of access*	*Esti-mated unit cost (€)*	*Min. quan-tity of ac-cess to be provided*	*Access costs charged to the GA*	*Estimated number of users*	*Esti-mated number of pro-jects*
			number	*Short name*	*Esti-mated costs*							
1	TKK	LTL	1	Cryohall	2667346	FI	Facility-month	10259	27	276995	18	14
1	TKK	LTL	2	TKK Micronova	6256691	FI	Hour	150,17	100	15017	5	5
2	CNRS	CNRS	1	CNRS MI-CROKELVIN	2393590	FR	Facility-month	9206,12	27	248565	18	14
3	ULANC	MicroKLab	1	MicroKLab	1341780	UK	Facility-month	8945,20	27	241520,40	18	14

B.3 Potential impact

B.3.1 Strategic impact

Traditionally, low temperature research work has been small-scale table-top science, conducted in isolated university laboratories which have evolved around a single professor. The research was focussed on a narrow topic and each group has developed its own refrigeration and measurement techniques. The community still continues to operate on this way. A young professor is exhausting his/her energy when setting up alone his ultra-low temperature laboratory, which usually takes up to 4-5 years. The community is fragmented into sub-critical units, which alone lack the capacity to offer services to other fields or to attack large-scale cross-disciplinary problems. At the same time emerging topics in nanophysics, material science and quantum information processing demand novel low temperature equipment, methods and services.

Today there are perhaps 10 ultralow temperature laboratories in the world with large concentrations of microkelvin refrigerators and technology, and the potential to provide and develop services beyond the low temperature community. Three of these facilities are in Europe (TKK, CNRS and ULANC). One of these, TKK, has served as a single-site access-given facility in 1995-2008 (ULTI projects). Most of the users (70%) of TKK facilities came from the traditional quantum fluids and solids community. During the last 5 years, however, the fraction of nanoscientists among the users has steadily increased.

The MICROKELVIN Collaboration has to be seen as the next evolutionary step in the integration and restructuring of European ultralow temperature infrastructure. This next step cannot be realized on national level, taking into account the small number of large low temperature facilities in Europe. MICROKELVIN will take into account the present potential of its partners, restructuring their infrastructure and optimising their operation on a European scale, to attack both traditional and new problems. The impacts of MICROKELVIN will be several, both in terms of improved infrastructure and access services, improved knowledge dissemination, better practices, new products and scientific outputs. We can list the main outcomes as follows:

The Impact on European infrastructure:

a) Improved European infrastructure in the microkelvin field for higher capacity and quality services, both in the access-giving units and those jointly involved. This is the prime aim of our integrated action.
b) A better educated workforce in the access-giving centres with enhanced microkelvin skills and new capabilities.
c) Restructured and stronger ERA by founding the Virtual European Low Temperature Laboratory by 2012.

The Impact on wider community:

d) Increased number of scientists and engineers using advance microkelvin technology, through the dissemination of both knowledge and infrastructure-independent machines to university laboratories and SMEs.
e) Increased number of low temperature laboratories using He-saving user-friendly cooling methods.
f) A better educated workforce in the peripheral regions where such experience would otherwise be difficult or impossible to acquire.

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The Impact on new knowledge and its exploitation:

g) The focus on nano- and material sciences at microkelvin temperatures as the themes of the integration will lead to the production of novel materials, material production techniques arising from the imperatives of the new temperature regime.
h) The same focus will also lead to novel nanoscale refrigerators and quantum devices with capabilities which are only realized at microkelvin temperatures.
i) The same focus should also lead to new discoveries being revealed in this new temperature regime.

On a more specific level, the MICROKELVIN Collaboration will improve the European infrastructure by demonstrating novel methods for ultra low temperature refrigeration, thermometry and characterization of nanosamples and new materials. The new methods will be added not only to the access services, provided by the access giving sites, but also disseminated beyond our consortium. In addition, MICROKELVIN will restructure the existing infrastructure by creating by 2012 a Virtual European Low Temperature Laboratory. This restructuring will include at least the three access giving partners of the consortium. The Virtual laboratory requires the acceptance of the host institutes and the degree of integration will depend on their internal rules. At least the integration of their machine- and electronics shop services is possible.

B.3.2 Plan for the use and dissemination of foreground

MICROKELVIN is designed to benefit the whole low temperature research community and nearby basic research communities, such as the astrophysics, cosmology, high energy physics, material physics, quantum information processing and nanoelectronics communities. It will benefit indirectly large sectors of society relying on cryoengineering, such as medical imaging, metrology, security and the space industry. A comprehensive knowledge dissemination plan will be devised by a dedicated Dissemination Committee to enlarge the participation of the wider research community in MICROKELVIN (NA3), to disseminate MICROKELVIN knowledge (NA3), and to ensure the follow-up of MICROKELVIN by embedding the MICROKELVIN results in the existing European infrastructure. MICROKELVIN is structured as a time-limited and goal-oriented project, based upon the existing European infrastructures to achieve a long-standing structural improvement (NA4). At the end of MICROKELVIN, the existing infrastructures will inherit and implement the developments of MICROKELVIN.

The JRAs are expected to produce patents and prototypes. Concerning Intellectual Property, the Management Committee, relying on the recommendation of the Otaniemi International Innovation Centre, will

- inform all participants on their legal responsibilities and rights on the Background and Foreground Knowledge within the guidelines of 7FP.
- decide the terms and conditions of ownership or joint ownership of the prototypes and
- ensure the review of Foreground knowledge and take measures in connection with their industrial protection, defence and use.

In MICROKELVIN it is expected that we will publish about 400 scientific and technical publications, of which about 300 articles in international reviewed journals and about 100 meeting reports and abstracts.