SEVENTH FRAMEWORK PROGRAMME

THEME RESEARCH INFRASTRUCTURES

FP7-INFRASTRUCTURES-2007-1

Grant agreement for: Collaborative Project

Annex I – "Description of Work"

Project acronym: LAGUNA
Project full title: **Design of a pan-European Infrastructure for Large Apparatus studying Grand Unification and Neutrino Astrophysics**
Grant agreement no.:

Date of preparation of Annex I (latest version):
Date of approval of Annex I by Commission:

List of Beneficiaries

Beneficiary no.	Beneficiary name	Beneficiary short name	Country	Date enter project	Date exit project
1. (coordinator)	Swiss Federal Institute of Technology Zurich	**ETH Zurich**	Switzerland	1	24
2.	University of Bern	**U-Bern**	Switzerland	1	24
3.	University of Jyväskylä	**U-Jyväskylä**	Finland	1	24
4.	University of Oulu	**U-Oulu**	Finland	1	24
5.	Kalliosuunnittelu Oy Rockplan Ltd	**Rockplan**	Finland	1	24
6.	Centre National de la Recherche Scientifique	**CNRS**	France	1	24
7.	Max-Planck-Gesellschaft zur Förderung der Wissenschaften e.V.	**MPG**	Germany	1	24
8.	Technische Universität München	**TUM**	Germany	1	24
9.	H.Niewodniczanski Institute of Nuclear Physics of the Polish Academy of Sciences, Krakow	**IFJ PAN**	Poland	1	24
10.	KGHM CUPRUM Ltd Research and Development Centre	**KGHM CUPRUM**	Poland	1	24

11.	Mineral and Energy Economy Research Institute of the Polish Academy of Sciences	**IGSMiE PAN**	Poland	1	24
12.	Laboratorio Subterraneo de Canfranc	**LSC**	Spain	1	24
13.	Universidad Autonoma, Madrid	**UAM**	Spain	1	24
14.	University of Granada	**UGR**	Spain	1	24
15.	University of Durham	**UDUR**	United Kingdom	1	24
16.	The University of Sheffield	**U-Sheffield**	United Kingdom	1	24
17.	Technodyne International Ltd	**Technodyne**	United Kingdom	1	24
18.	University of Aarhus	**U-Aarhus**	Denmark	1	24
19.	AGT Ingegneria Srl, Perugia	**AGT**	Italy	1	24
20.	Institute of Physics and Nuclear Engineering, Bucharest	**IFIN-HH**	Romania	1	24

PART A

A1. Overall budget breakdown for the project

Copy of the A3.2 form of the GPF

A2. Project summary

Copy of the A1 form of the GPF

Key questions in particle and astroparticle physics can be answered only by construction of new giant underground observatories to search for rare events and to study sources of terrestrial and extra-terrestrial neutrinos. In this context, the European Astroparticle Roadmap of 03/07, via ApPEC and ASPERA, states:
"We recommend a new large European infrastructure, an international multi-purpose facility of 10^5-10^6 ton scale for improved studies of proton decay and low-energy neutrinos. Water-Cherenkov, Liq. Scintillator & Liq. Argon should be evaluated as a common design study together with the underground infrastructure and eventual detection of accelerator neutrino beams. This study should take into account worldwide efforts and converge by 2010..."
Furthermore, the latest particle physics roadmap from CERN of 11/06 states:
"A range of very important non-accelerator experiments takes place at the overlap of particle and astroparticle physics exploring otherwise inaccessible phenomena; Council will seek with ApPEC a coordinated strategy in these areas of mutual interest."
Reacting to this, uniting scientists across Europe, we propose here a design study, LAGUNA, to produce by 2010 a **full conceptual design** sufficient to provide policy makers and funding agencies with enough information for a construction decision.
Has Europe the technical and human capability to lead future underground science by hosting the next generation underground neutrino and rare event observatory? We aim to answer this question. Certainly construction will exceed the capacity of any single European nation - to compete with the US and Asia unification of our scattered efforts is essential. Failure to plan now risks not only that our picture of Nature's laws remain fundamentally incomplete but also that leadership in the field enjoyed by Europe for 20 years falls away. EU FP7 input now is timely and will have major strategic impact, guaranteeing coherence and stimulating national funding.

A3. List of beneficiaries

PART B

B1. Concept and objectives, progress beyond the state-of-the-art, S/T methodology and work plan

B.1.1. Concept and project objectives

There are fundamental questions in particle and astroparticle physics that can only be answered with next-generation very large volume underground observatories searching for rare events and studying terrestrial and extra-terrestrial sources of neutrinos. The great physics potentials of the new research infrastructure envisioned in this DS have been internationally recognized. In particular, ApPEC has recently stated that: *"We recommend that a new large European infrastructure is put forward, as a future international multi-purpose facility on the 100'000-1'000'000 tons scale for improved studies of proton decay and of low-energy neutrinos from astrophysical origin. The three detection techniques being studied for such large detectors in Europe, Water-Cherenkov, Liquid Scintillator and Liquid Argon, should be evaluated in the context of a common design study, which should also address the underground infrastructure, and the possibility of an eventual detection of future accelerator neutrino beams. This design study should take into account worldwide efforts and converge, on a time scale of 2010, to a common proposal."*

The need for such experiments is also recognized by CERN, the largest laboratory for particle physics in the world: high-energy accelerators like the CERN Large Hadron Collider (LHC) or the planned International Linear Collider (ILC) will not be able to answer all fundamental questions about Nature. In 2005 the CERN Council initiated a Strategy Group to produce a Draft Strategy Document (DSD) addressing the main lines of Particle Physics in Europe, including R&D for novel accelerator and detector technologies. The DSD[1] was unanimously approved by CERN Council in July 2006. In this document, Council recognised that *"A range of very important non-accelerator experiments take place at the overlap between particle and astroparticle physics exploring otherwise inaccessible phenomena; Council will seek to work with ApPEC to develop a coordinated strategy in these areas of mutual interest."* Hence, this line of investigation represents a unique way to address these otherwise undiscovered fundamental questions of particle physics.

These fields of research are at the forefront of astroparticle and particle physics and are the subject of intense investigation worldwide. What will be the European contributions in these rapidly expanding fields? Europe is currently leading deep underground science with its four long running and two emerging deep underground laboratories. This leadership is endangered by the lack of plan for a new and bigger research infrastructure, capable of hosting next generation large volume experiments. The DUSEL (Deep Underground Science and Engineering Laboratory) initiative in the USA and the Japanese plans for a large upgrade at the Kamioka site represents real competition. In order to be credible in front of the American and Asian projects, Europe must act coherently and in a unified way in deep underground science.

Can Europe aim at becoming a world leader in deep underground science by hosting the next generation very large underground neutrino and rare event detection observatory? The present DS will represent a unique opportunity to answer this question and take a leading role in research fields of fundamental importance for particle and astroparticle physics. The DS will provide the scientific and objective information to make an optimized choice of the site(s) for a European Underground Infrastructure capable of hosting large mass, underground observatories.

Designing and constructing the next major underground laboratory and building the required large-scale instruments by far exceed the capacity of a single European nation and technically non-trivial. A common approach and a coordinated international effort are required to even conceive them. This DS is the most effective tool towards achieving this goal. A substantial EU contribution will inevitably raise national funding and redirect the otherwise scattered local efforts coherently towards this common European goal.

A coherent and coordinated study group aimed towards common physics goals was formed at the ApPEC "Munich meeting" in November 2005 with the aim of developing conceptual designs for European large underground detectors, investigating physics complementarities and common R&D needs, fostering work in synergy and problem-solving activities, as well as taking into account the unique technological expertise in Europe and other existing or planned programmes in the world. It was hoped that mature designs and credible proposals could emerge around 2010. This DS will formalize, organize and very effectively provide the means for a cohesive and integrated action towards these goals.

[1] The CERN Council, in a special meeting held the 14th of July 2006 in Lisbon, agreed on the European strategy for particle physics. The strategy is defined by the 17 statements approved by Council, and contained in the Strategy Statement (available at http://council-strategygroup.web.cern.ch/council-strategygroup/).

The LAGUNA consortium includes the highest-level expertise in Europe for the required tasks. All major European underground laboratories are partners or will be consulted, and emerging candidate sites are also represented. The countries proposing the site for the facility have assigned the best companies in underground engineering as partners. All universities and institutes participating in the collaborations of the suggested experiments are taking part in the project. Our human resources include more than 60 top-level scientists, representing also the scientific community taking advantage of the results of the experiments to be performed in the laboratories. The main deliverable will be a conceptual design report (CDR), which should provide the policy makers and the funding agencies all the information for a construction decision. The deliverables include "decision factors" such as technical feasibility (underground halls and their access, safety issues, procurement of large quantity of liquid material for the detectors, related infrastructure, ...), cost optimization (digging, safety, detector design...), physics performance (*e.g.* hall depth, baseline from accelerator facilities, ...), in addition to spin-off and outreach issues.

The infrastructure, if built in Europe, will certainly attract scientists from many parts of the globe and will ensure that Europe can continue to play a leading role in the field. Europe must act coherently and in a unified way in deep underground science. The very successful history of CERN, the largest particle physics laboratory in the world, shows that this is in principle possible.

The failure to comply with the deadline set by ApPEC creates the danger that Europe falls behind other continents in underground science. Observation of Nature using very large underground experiments will be the most cost-effective way to look for physics beyond our current understanding and without them our picture of the fundamental laws of Nature will remain incomplete.

Has Europe the technical capabilities and the human and financial resources to become an international leader for future deep underground science, by hosting the next generation very large underground neutrino and rare event detection observatory? The aim of this DS is to answer to this question.

B.1.2. Progress beyond the state-of-the-art

Prepare to answer fundamental questions

The next-generation very large volume underground observatories searching for rare events and studying various terrestrial and extra-terrestrial sources of neutrinos will answer fundamental questions of particle and astroparticle physics.

Firstly, the proton, one of the main building blocks of matter, is known to be an extremely stable particle, yet many models predict that it might not live forever. A positive detection of proton decay would represent the most generic and directly verifiable consequence of the unification of the fundamental interaction (strong, electromagnetic and weak forces) of Nature. Thought by many to be as important as the search for the Higgs boson or the existence of supersymmetric particles (SUSY), the discovery of proton decay would have a tremendous impact on our understanding of Nature at the highest energies (in an energy domain in the range of 10^{16} GeV, to be compared with the energy domain up to 10^3 GeV explored by the highest energy Large Hadron Collider LHC at CERN), yielding otherwise inaccessible information on the structure of matter at extremely small scales. The new instruments envisioned in this DS will allow exploration of otherwise unreachable domains at the extreme high energies.

Secondly, the neutrino is unique among the fundamental particles in that it has no conserved quantum numbers except, perhaps, a global lepton number. The recent discovery that the neutrino changes type, or flavour, as it travels through space, a phenomenon referred to as neutrino oscillations, implies that neutrinos have a tiny, but non-zero mass, that lepton flavour is not conserved, and that the Standard Model of particle physics is incomplete. Neutrinos can travel very large distances in space and traverse dense zones of the Universe, since they only very weakly interact with matter, and provide therefore unique information on their sources. The new instruments envisioned in this DS will allow for unprecedented measurements of fundamental neutrino properties, providing us with new and deep insights into their sources, notably the Sun, the core-collapse supernovae and the Earth itself.

A very active international scientific community is discussing these scientific topics in the NNN workshop, where NNN stands for "Next generation Nucleon decay and Neutrino detectors". This series of workshops has been devoted to discussion of experiments that go beyond the reach of current projects, as well as the related theoretical work. The first NNN Workshop was held in 1999 at Stony Brook, USA. Recently, NNN05 took place in Aussois, France, and NNN06 in Seattle, USA. The next meetings will be held in Hamamatsu, Japan in 2007 and in Paris in 2008.

The need to plan even larger and better instruments

The first successful detection of neutrinos from the supernova SN-1987A by the Kamiokande experiment (Japan), recognized with the Nobel Prize in 2002, has opened the field of neutrino astronomy, a by now 20-year long tradition of incredibly rich physics with large underground detectors, the largest one being the 22.5 kton Super-Kamiokande detector. These instruments, thanks to technical breakthroughs, have achieved fundamental results like the solution of the solar neutrino puzzle and the understanding of the physics of the Sun, the discovery of non-vanishing neutrino masses. Limits on the flux of supernovae relic neutrinos have been set. The lifetime of protons has been pushed towards limits in the range of a few 10^{33} years. KamLAND has announced first evidence of so-called geo-neutrinos, emitted by radioactive elements within the Earth, opening the way to new methods of investigation of the Earth's interior. Soon the neutrino flavour oscillation mixing matrix is going to be further studied with an intense accelerator neutrino beam from the newly built J-PARC accelerator complex in Japan (T2K experiment), complementing the efforts at Fermilab in USA and at the CERN-Gran Sasso in Europe.

Further advances in low energy neutrino astronomy and neutrino astroparticle physics, as well direct investigation of Grand Unification (GU) of fundamental interactions require the construction of next-generation very large volume underground observatories. With complementary techniques, facilities on the mass scale of 50 kton to 500 kton could dramatically increase the potential of past and present underground detectors, however as expected, represent rather large extrapolations compared to current worldwide state-of-the-art, requiring advances in several fields, like underground civil engineering, mechanical engineering, large scale detector instrumentation and integration, and last-but-not-least safety and environmental issues.

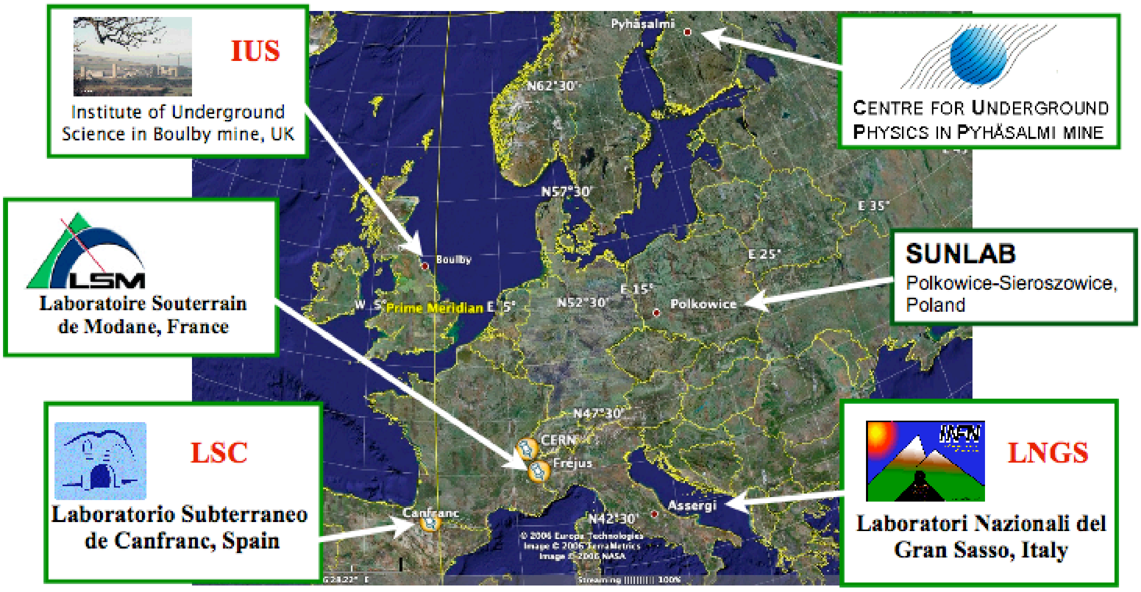


Figure 1 The existing or emerging six national underground science laboratories.

There is currently no infrastructure in the world able to host instruments of this size, although many European national underground laboratories with high-level technical expertise are currently operated with forefront smaller-scale underground experiments (see Figure 1). Very large underground laboratories are being considered in Japan in the context of the Hyper-Kamiokande[2] project and in the USA as part of the DUSEL process[3]. A pan-European research infrastructure able to host new generation underground instruments with total volumes in the range of 100'000 m^3 up to 1'000'000 m^3 would provide new and unique scientific opportunities and very likely lead to fundamental discoveries in the field of particle and astroparticle physics, attracting interest from scientists worldwide.

The present Design Study (DS) focuses on the study of feasibility and design of such a new infrastructure in Europe and on the scrutiny of the technical requirements necessary for the next generation large-scale underground observatories. This DS intends to explore different detector technologies currently being investigated by various European research institutes, and different potential underground sites in order to identify the scientifically and technical most appropriate and cost-effective strategy for future large-scale underground detectors in Europe. The main deliverable will be a report which should contain relevant information for a forward decision.

We have already mentioned that the above physics topics have historically produced very important results It is reasonable to assume that the physics programme addressed by this DS will span over 30 years and more, with the involvement of several generations of worldwide researchers. Investigating the proton lifetime up to 10^{35} years will provide a very stringent, perhaps ultimate test of the Grand Unification hypothesis. After the optical observation of supernovae (SN) by mankind during the last centuries and the SN1987A neutrino detection, the next observable event with neutrinos will occur with high probability in the next decade and with near certainty in the next 30 years. Meanwhile the background flux of neutrinos

[2] K. Nakamura, "HYPER-KAMIOKANDE: A next generation water Cherenkov detector for a nucleon decay experiment," Front. Phys. 35, 359 (2000).
[3] See http://www.dusel.org

from relic supernovae can be observed. The study of neutrino properties has shown the first indication of physics beyond the Standard Model of Elementary Particles. New discoveries, like CP-violation in the leptonic sector, are expected in this field.

Several conceptual ideas for next-generation very-massive, multi-purpose underground detectors have emerged worldwide and in Europe over the last years. All the designs consist of large volumes of liquid observed by detectors, which are arranged on the inner surfaces of the vessels. The liquid simultaneously acts as the target and as the detecting medium. The first one relies on the concept of Super-Kamiokande and uses water (MEMPHYS R&D project), the second builds on the initial experience with ICARUS and uses Liquid Argon (GLACIER R&D project), the third extrapolates experience gained in reactor experiments and BOREXINO and uses liquid scintillator (LENA R&D project). See Figure 2.

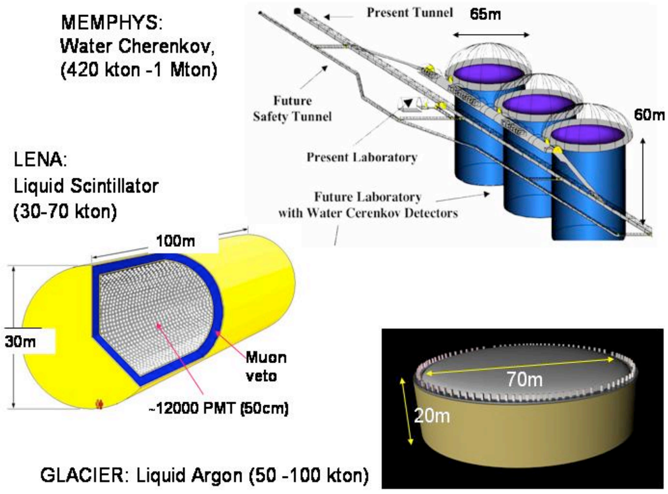


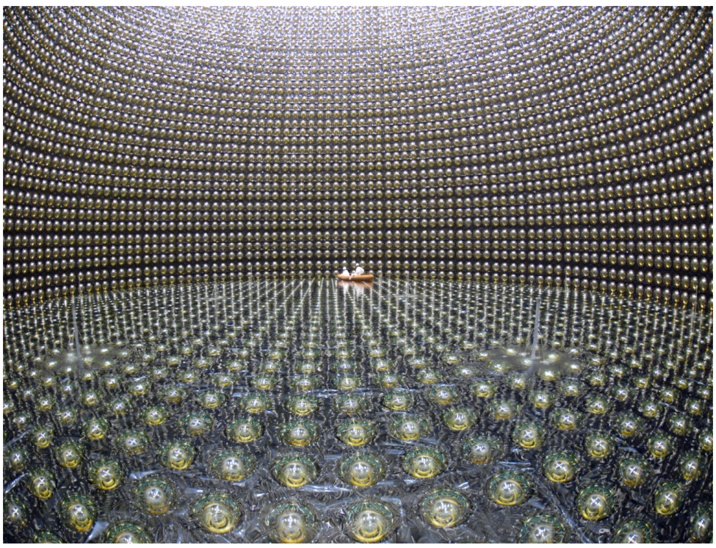
Figure 2 R&D projects being discussed in Europe as possible next generation very large volume underground detectors: MEMPHYS, LENA and GLACIER.

In this DS, we therefore evaluate these three technologies:

Water Cerenkov imaging: As the cheapest available (active) target material, water is the only liquid that is realistic for extremely large detectors, up to several hundreds or thousands of ktons. Water Cerenkov detectors have sufficiently good resolution in energy, position and angle. The technology is well proven, as previously used for the IMB, Kamiokande and Super-Kamiokande experiments (See Figure 3).

Liquid scintillator: Experiments using liquid scintillator as the active target provide high-energy resolution and offer low-energy threshold. They are particularly attractive for very low energy particle detection, as for example solar neutrinos and geo-neutrinos. Also liquid scintillator detectors feature a well-established technology, already successfully applied at relatively large scale in the Borexino and KamLAND experiments.

Liquid Argon Time Projection Chambers (LAr TPC): This detection technology has among the three the best performance in the identification of the topology of interactions and decays of particles, thanks to the bubble-chamber like imaging performance. Liquid Argon TPCs are very versatile and work well with a wide particle energy range. Experience with such detectors has been gained within the ICARUS project.



The three technologies have in common similar requirements for their design, installation and operation in the future underground facilities. They have similar (high) discovery potential and exhibit some interesting elements of complementarity. In addition, the three proposed solutions are backed by rather large and active European communities. This DS will create the opportunity for a concerted effort towards a global optimization of the projects, increasing the probability of success with the elaboration of shared strategies.

Figure 3 Inside view of the Superkamiokande detector in Japan. The large volume of water is seen by 11000 photo-detectors for a total sensitive mass of 22.5 ktons.

From a practical point of view, the most straightforward liquid is water, where the detection is based on the Cherenkov light emission by the final state particles. This faint light is detected by a very large number of photomultipliers positioned on the surface of the container. The technology has been pioneered by the IMB and Kamiokande projects (USA and Japan, respectively) and successfully extended to Super-Kamiokande during many years of operation. Super-Kamiokande has a fiducial mass of 22.5 kton observed by about

11,000 large-size photomultipliers. The possibility of building a water Cherenkov detector with a fiducial mass of about 500 kton observed by about 200,000 photomultipliers is currently being investigated by different groups around the world, and for different underground sites. While water is a cheap medium, the size of such detectors is limited by the cost of excavation and of the photomultipliers. The MEMPHYS project is being discussed for deployment in an extended Frejus laboratory (France/Italy). In the US, the UNO detector is being proposed for a future underground facility in North America. In Japan Hyper-Kamiokande will provide an extension of Super-Kamiokande, using a new cavern to be excavated near Super-Kamiokande. Hyper-Kamiokande could serve as the far detector for the T2K experiment. Water-Cerenkov detectors are ideally matched for neutrino energies below 1 GeV. They have also a high sensitivity for proton decays with two isolated Cherenkov rings like for example the channel $p \rightarrow e^{+}\pi^{0}$.

A second possibility is a very large liquid scintillator volume observed by photomultipliers. The scintillator technology is based on the developments within the BOREXINO and DoubleCHOOZ projects. The total light yield of a scintillator is much larger than that of water, resulting in a much better energy resolution and lower detection threshold. A high efficiency can be achieved in the search for the proton decay via $p \rightarrow \bar{\nu} K^{+}$, as the Kaon and its decay products can be observed directly. In addition to the detection of Supernova neutrinos and the diffuse Supernova neutrino background, the very low threshold allows measuring different contributions to the solar neutrino spectrum at high statistics. Moreover, due to the delayed coincidence signal of electron antineutrinos liquid scintillator is the only proposed technology able to detect geo-neutrinos. LENA is a European proposal for such a detector. Already with a mass of 50 kt, the detector would provide interesting physics. This mass could be enlarged as the main costs are due to the price of the scintillator and the photomultipliers. There is a growing interest in the technique in North America, with the SNO+ experiment and the proposed deep ocean geo-neutrino observatory HanoHano.

A third possibility is the liquid Argon Time Projection Chamber developed under European leadership over many years of ICARUS R&D programme. This technology is able to image rare events with the quality of bubble-chambers, which are famous for having led to important discoveries in particle physics. The liquid Argon TPC is fully electronic and can be extrapolated to very large masses, possibly beyond many tens of kilotons. The Liquefied Natural Gas (LNG) technology developed by the petrochemical industry has proven that the storage of very large volumes of cryogen is safe. The ionization charge produced by charged particles when they traverse the medium and the associated scintillation light can be independently readout to provide a tracking-calorimetry detector. Thanks to their imaging capability, these detectors provide improved sensitivity to the proton decay channels where backgrounds are the limiting factor in Water Cherenkov detectors, such as the channel $p \rightarrow \bar{\nu} K^{+}$. GLACIER is a European design for a new generation liquid Argon TPC, eventually scalable up to at least 100 kton, and dedicated R&D for the extrapolation of the liquid Argon TPC to very large scales is been pursued. Interest in the technology has recently also grown in the USA in the context of a second generation long-baseline experiment at Fermilab.

The three mentioned detector types represent a variety of complementary aspects (see Table 1): MEMPHYS would collect the largest statistics, GLACIER would have the best pattern recognition, LENA would have the lowest energy threshold. MEMPHYS and LENA are superior in anti-neutrino detection while GLACIER is best in neutrino detection. Neutrinos and anti-neutrinos together provide the full information to study supernovae. MEMPHYS has complementary sensitivity to LENA and GLACIER on proton decay flavour signatures.

Table 1 Overview of the physics potential of the three types of instruments considered

Topics	**GLACIER** (100 kt)	**LENA** (50 kt)	**MEMPHYS** (400 kt)
proton decay, sensitivity (years) decay mode $e^{+}\pi^{0}$ decay mode anti-ν K^{+}	 $0.5 \cdot 10^{35}$ $1.1 \cdot 10^{35}$	 TBD $0.4 \cdot 10^{35}$	 $1.0 \cdot 10^{35}$ $0.2 \cdot 10^{35}$
SN at 10 kpc, # events CC NC ES	 $2.5 \cdot 10^{4}$ (ν_e) $3.0 \cdot 10^{4}$ $1.0 \cdot 10^{3}$ (e)	$9.0 \cdot 10^{3}$ (anti-ν_e) $3.0 \cdot 10^{3}$ $5.0 \cdot 10^{3}$ (p) $6.0 \cdot 10^{2}$ (p)	 $2.0 \cdot 10^{5}$ (anti-ν_e) - $1.0 \cdot 10^{3}$ (e)
Diffuse SN # Signal/Background events (after 5 years)	 60/30	 (10-115)/4	 (40-110)/50 (with Gadolinium)
Solar neutrinos # events, 1 year	^{8}B ES : $4.5 \cdot 10^{4}$ Abs: $1.6 \cdot 10^{5}$	^{7}Be: $2.0 \cdot 10^{6}$ pep: $7.7 \cdot 10^{4}$ CNO: $7.6 \cdot 10^{4}$ ^{8}B(CC): $3.6 \cdot 10^{2}$ ^{8}B(NC): $5 \cdot 10^{3}$	^{8}B ES: $1.1 \cdot 10^{5}$
Atmospheric ν # events, 1 year	 $1.1 \cdot 10^{4}$	 TBD	 $4.0 \cdot 10^{4}$

Geo-neutrinos # events, 1 year	Below threshold	$1.5 \cdot 10^3$	Below threshold

Towards a proposal around 2010

Without any doubt, a very large underground detector facility has an extremely rich physics programme. The construction and operation clearly represents a difficult technological challenge and a significant investment on the scale of several hundred millions of Euros. It is intimately connected to the question of large underground infrastructures. The choice of the most appropriate technology, of the site and of the designs of such super-massive detectors should be carefully optimized taking into account the technical feasibility and predicted costs, the multiple physics goals, and also the possible existence of accelerator neutrino beams. To set the scale, the Hall B at the LNGS underground laboratory (See Figure 4) is one of the largest volumes available today for underground experiments. It has an instrumentable volume of about 15'000 m^3. In comparison, this DS foresees total instrumentable volumes ranging from 100'000 to 1'000'000 m^3. The technical and economical feasibility of an underground observatory of this magnitude, perhaps ultimate in size, requires a strong coordinate and coherent European strategy and will be heavily reliant on the possibility to contain costs compared to today's state-of-the-art by a careful optimization of all elements involved in the project: (1) the excavation and preparation of the underground space, (2) the design and construction of the tank, (3) the instrumentation and (4) the safety aspects. This implies that cost is optimized at all level of the project, and must heavily rely on careful design and engineering.

At the ApPEC "Munich meeting" held in November 2005, a coordinated effort among the 3 "liquid" technologies was proposed and accepted. Large detectors like Water Cherenkov, Liquid Scintillator and Liquid Argon TPC present, in addition to the above mentioned physics complementarities, a lot of common needs for R&D studies that will be fostered by synergies and task sharing.

The purpose of this proposal is to develop a conceptual design report for a pan-European infrastructure capable of hosting large-scale liquid detector(s). This study will allow a coherent and well-coordinated EU-wide design effort towards a large infrastructure, solving common problems together, taking into account the unique technological expertise in rare event detection technologies, underground excavation and construction, such that mature designs and credible scenarios can be proposed around 2010.

Figure 4 The Hall B at the LNGS underground laboratory. This hall is one of the largest volumes available today for underground experiments.

An important point is the possibility to eventually couple the research instruments that will be studied in this DS with existing or future neutrinos produced with accelerators. In Europe, the CERN Council at its December 1999 meeting has approved the CNGS project. Construction started in September 2000, and the first beam was obtained in the Fall 2006. This beam will serve the OPERA experiment at LNGS for the next five years. The further improvement of knowledge of neutrinos oscillation parameters requires precise measurements of parameters governing neutrino oscillations, which will require new high intensity neutrino oscillation facilities in which neutrino beams are generated using new and highly challenging concepts. Whatever the kind of beam that will be technically realisable, it will require a massive underground detector as a far detector. Therefore, our present DS addresses a fundamental point in the feasibility of future long baseline neutrinos programme, since it will assess where in Europe, very large underground detectors could be conceivable and at what cost.

B.1.3. S/T methodology and associated work plan

B.1.3.1. Overall strategy and general description

The main goal of the DS is to bring together on one hand the scientific community interested in this kind of research infrastructure and on the other the industrial and technical experts able to help assess its feasibility. The DS is subdivided into 4 workpackages (WP), interconnected with each other. The list of WP is the following:

WP1 = Management, coordination and assessment
WP2 = Underground infrastructures and engineering
WP3 = Safety, environmental and socio-economic issues
WP4 = Science impact and outreach

WP1 – Management, coordination and assessment

The management WP will coordinate the contractual, financial and administrative aspects of the Design Study and will oversee the technical and scientific work of the other WPs. It will be responsible for ensuring the project milestones are achieved and the deliverables produced on time. Furthermore, this WP will be responsible for knowledge management for the Design Study, coordinating the protection, use and dissemination of the knowledge generated during the project.

Task 1 **Development of a management framework**

The first task is to outline a management structure to allow efficient coordination of all contractual, financial and administrative aspects of the Design Study. This will be completed within the first 4 months of the project, although the management network created will continue, through the various WP leaders, to monitor milestones, ensuring that deliverables are produced on time.

Task 2 **First year report**

To be completed in the 12th month, this document will summarize the work done in all WP, and will compare progress against milestones and deliverables, and outlining any conclusions that can be drawn.

Task 3 **Final year report**

To be completed in the 24th month of the project, this report will describe the achievements of the Design Study and will include a detailed comparison of all sites and experiments considered. Based on the findings, a recommendation will be made for the feasibility of the project with respect to scientific performance, underground construction, engineering infrastructure, and cost.

WP2 – Underground infrastructures and engineering

The WP focuses on the technical issues of underground large-scale civil engineering needed to host large volume instruments considered in the DS. The purpose of this WP is to assess the feasibility of large underground caverns in seven potential European sites to host large volume detectors of each target liquid. The main deliverable will be a feasibility document containing the scientific and technical information related to excavation of large caverns in those sites, addressing the technical and legal feasibility, the total associated cost (±30%) of the infrastructure and total time of technical realization (±1 year). It is foreseen that each site will receive a lump sum in order to perform its study.

A report, subject to commercial confidentiality where appropriate, with conceptual designs of the underground cavities will be delivered, recommending the sites that are technically suitable for large excavations and if relevant which target liquids can be envisaged in a particle location. Estimates for costs of cavern and access excavations will be included. A critical comparison of these costs, pointing out potential relative and absolute cost differences, will be included in the report.

In each site involved there will be two partners: a scientific institute and a technical (engineering) partner. The role of the technical partner is to prepare the technical part of the design and to study the feasibility of the rock construction. The role of the scientific partner is to provide scientific expertise for the design, particularly outlining the requirements and preferences of the experiments and acting as a link between the technical partner and the scientific community. All countries need their own local participants for the site studies, because the local conditions are very specific and different in each participating country (See for example Figure 5 to illustrate difference in bedrock), considering both geology and default host and access.

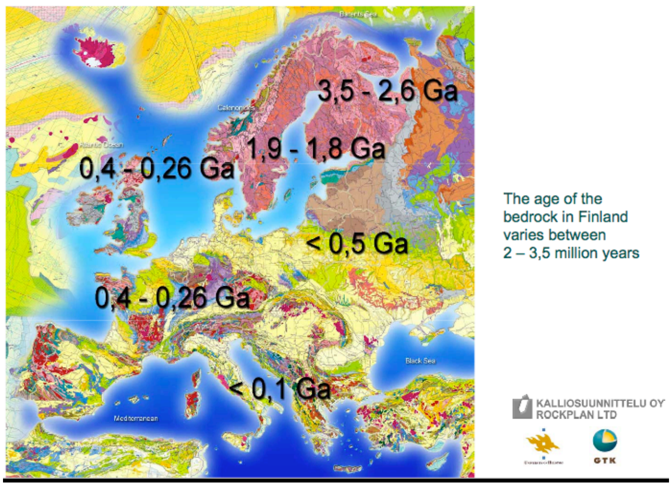


Figure 5 Bedrock conditions in Europe. Conditions vary substantially from one location to another.

All partners of DS will work cooperatively and share data whenever possible, experience and expertise. The work is started with the underground sites shown in Table 2. The goal of the DS is to investigate each of the seven sites to a similar level of detail. It is important to allow a coherent and fair comparison of the pros and cons of the potential sites. Hence, in a feasibility study phase all sites will be investigated in order to reach the same level of understanding of their potential for very large excavations. This DS will include special requirements of the experiments, as well as plans for normal insulation, ventilation, power and other building technical tasks. The interface to the local host infrastructure (mine, tunnel) and the access from the surface will also be studied. The scientific preferences and requirements will be studied in parallel with the technical studies by scientists in the community in the other WPs. Detailed executive designs are out of scope of this DS, since it is a normal practice to include them in the construction budget.

Table 2 Sites to be explored during the DS.

Name	*Country*	*Region*	*Host institute*	*Site type*
1) Boulby mine	United Kingdom	Boulby	Sheffield Univ.	Mine/salt (potash) or rock
2) Fréjus	France	Fréjus	CNRS	Road tunnel / hard rock
3) CERN CNGS off-axis location	Italy	Along CERN CNGS neutrino beam	Not yet defined	Soft rock/shallow depth
4) LSC	Spain	Pyrenees	MEC/Regional Aragon Governm./ Zaragoza Univ.	Soft rock
5) Pyhäsalmi	Finland	Pyhäjärvi	Oulu Univ.	Mine / hard rock
6) SUNLAB	Poland	Polkowice - Sieroszowice	Not yet defined	Mine / salt & rock
7) IFIN-HH	Romania	Prahova	IFIN-HH	Salt / shallow depth

Engineering companies will perform the main part of this WP. There will be a separate local company for each laboratory, as specific knowledge of the local conditions is mandatory.

The feasibility studies will include geological studies of the sites, analysis of available rock samples and simulations of rock mechanics. As a guideline, the topics to be addressed for each seven sites are summarized in Table 3:

Table 3 Guidelines that will be given to the various sites during their feasibility study.

Basic topic	**Foreseen study**
Basic rock studies	Rock structural studies including bore holes and analysis Rock water content and issues of removal and disposal of water (pumps and pipes) Rock activity analysis Rock environmental issues including dust or other hazards
Main excavation design issues	Optimum size for vertical cylindrical tanks Requirements for rock bolting or other extra structures within caverns Design of ancillary caverns, rooms and access roadways Stability over 30 years Optimal access methods for cavern excavation and tank construction Requirements and costs of interaction with tunnel companies or mine Limitations to rate of rock removal from site Environmental restrictions to rock excavation and disposal Provision of power and services required during excavation Special requirements during excavations such as dust control Procedures and timescale for excavation, type of excavation (horizontal, vertical)
Excavation outfitting	Treatment and securing of cavern walls (rock bolting etc)

	Provision of general support structures, internal buildings and walls
Services to underground facility	Power provision Ventilation Radon control costs Other services: humidity, temperature and air conditioning, communications (internet), water.
Special services	Provision of secondary containments (dump) for water, liquid noble gases or scintillator (in connection with WP3) Provision of pumps, special ventilation and structures for cryogenic liquid handling Provision of water treatment facilities Assessment for use of magnetic fields Investigation of underground assembly of the tanks, by assessing construction strategies as a function of underground access methods
Surface buildings and support	Outline requirements for surface facilities, restrictions and costs New build or extension/mods to existing facilities
Safety during and after excavation	(in connection with WP3)
Suitability for other applications	Any restrictions of use for science – suitability for microbiology, environmental science, engineering etc
Level of impact	What added value – from education and school links, exchanges with local industry and mine/tunnel companies (e.g. CPL, Cuprum, KGHM, etc.) Economical and social impact
Political issues	What level of local and regional support and contributions (financial and in kind)
Legal and land ownership issues	Legal issues of environment Local and national political issues or restrictions Planning permissions and lease agreements
Operating costs	Operating and power costs Access costs, including cost of separate access roadways and/or shafts or tunnels to allow independence from operators Mine operating costs after closure (if relevant)
Decommissioning	Implications and costs for decommissioning the sites if any
Risk analysis	

Task 4 **<u>Start-up phase</u>**
The first task is to agree on a common framework to the different site studies. In order to compare the results at an equal basis, we define the standards to be used in all studies and set up the template for the interim reports. We also ensure that all partners have similar starting points, agree on intercommunication and introduce all technical partners to each other to share data and knowledge. This task is to be completed during the first six months of the project.

Task 5 **<u>Feasibility study for CUPP/Pyhäsalmi</u>**
For CUPP a pre-feasibility study for a deep laboratory was done in 2002, with two drill holes . The rock was found to be very good, though the rock pressure was high. Although the study did not consider as large cavities as in LAGUNA, it did not show any evident obstacle for such cavities. The feasibility of large underground constructions in a new underground laboratory located by the Pyhäsalmi mine will be further

studied in this DS. The integration into the infrastructures and operation of an active mine will be specifically studied.

Task 6 Feasibility study for Fréjus

In Fréjus a pre-feasibility study for excavation of very large cavities in the context of the MEMPHYS project was done 2005[4]. It included rock mechanical analysis using the existing data of the rock in the road tunnel. No technical obstacles for caverns of the kind needed by the MEMPHYS project were discovered so far. Using the general rock properties the optimal shape of the cavity for MEMPHYS was found to be individual cylinders (3 to 5) of ca 250 000 m^3 each. The cavity for GLACIER in its preferred form was found to be infeasible, but another form was suggested (e.g. 2 modules of 50 ktons each). The programme of this DS will consist of a more advanced and precise study including the basic equipments of the laboratory, as needed by each target liquid. The main task could be subcontracted to the SETEC[5] and LOMBARDI[6] companies. Fine-tuning of the shape of the cavities will be an important point of the study. In addition, a study of compatibility between the excavation operations for a megaton-scale laboratory at the Fréjus site and the running conditions of the future safety tunnel at the Fréjus (with a diameter = 8 m) will be assessed: need of ventilation, of excavated rock evacuation, etc.

Task 7 Feasibility study for Boulby mine

The Boulby mine, a working salt and potash mine in north east England, at 1100m deep, is the deepest mine in Britain with over 1000km of tunnels excavated over the last 40 years. The potential for expansion is a priori excellent and there is already interest from the mine operators Cleveland Potash Ltd (CPL) in excavating deeper to exploit polyhalite ore. Whereas excavations in the salt seam are limited to 8m wide by 5m high, polyhalite is thought to be a far more competent rock, which is expected to be self-supporting over large areas. Based on a core sample taken from the polyhalite seam 200m below the salt and potash layers, CPL predicts that labs as large as those seen in existing hard rock locations are possible, and that cavities 30m wide and high are potentially feasible. In its current form LENA appears to be viable, and based on the cavity geometry permitted by the surrounding rock, GLACIER and potentially MEMPHYS could also be adapted to fit. The concept of a new underground science facility in this seam is strongly supported by CPL. The study in this DS would involve strategic exploration to identify the economic viability of mining the deeper polyhalite resources, and a full appraisal of the feasibility of establishing a full laboratory with all associated services required for underground science including specific reports for each proposed experiment and their requirements both above and below ground. CPL would act as a professional engineering consultant and would liaise with Sheffield University, the scientific institute. The main aim for CPL would be to undertake a detailed scientific environmental study of the polyhalite deposit to assess suitability for a deep laboratory for the science intended, and hence to inform critical areas of the facility design. Boulby mine is a fully functioning salt and potash mine, and as such it is only correct that the mine operators CPL have the final decision on the making public of any and all facts concerning Boulby mine and CPL deemed to be of a private, proprietary, or sensitive nature for whatever reason by way of a confidentiality agreement. This will provide written assurance from the Principle Investigators, before any feasibility study is carried out, and is seen as an essential first step of the design study.

Task 8 Feasibility study of a shallow site along the CERN NGS neutrino beam

The CERN CNGS project, approved by the CERN Council in 1999, has been commissioned in the Fall 2006. This high-energy beam, using the CERN accelerator complex, is directed towards the Gran Sasso Underground Laboratory and will serve the underground OPERA experiment located in Hall C of LNGS for a period of about five years. The current optimization of the CNGS beam is tuned to the particular physics programme of the OPERA project and exhibits limited interest for the physics addressed in the present DS. The physics potential of an intensity upgraded and energy re-optimized CNGS neutrino beam coupled to an "off-axis detector" of very large mass could offer interesting physics opportunities. Within this DS, possible shallow depths sites will be investigated taking into account the expected profile of the CNGS beam and possible upgrades its intensity, in agreement with CERN long term plans.

Task 9 Feasibility study for SUNLAB

The Sieroszowice Underground LABoratory (SUNLAB) is planned to be located in the Sieroszowice mine, which belongs to the KGHM holding of the copper mines in the west-southern Poland. The site is placed 70 km from the airport in Wroclaw and 40 km from the motorway A4 crossing the southern Poland in the west-east direction. At a depth of 900-1000 meters below the surface there is a layer of salt about 70 meters thick. Over and under the salt deposit, layers of high stiffness and strength parameters (anhydrite, limestone and dolomite) are observed, often water saturated. So far, the cavities executed at such depths in the Polish rock salt formations were of a smaller scale. One of existing caverns, 100 m long, 15 m wide and

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[4] "Cavernes de 1 Million de metres cubes : Étude préliminaire de faisabilité" STONE (Juin 2005) http://www.apc.univ-paris7.fr/APC_CS/Experiences/MEMPHYS/ and "Étude préliminaire de faisabilité de puits de grande dimension (au Fréjus) : Méthodes de réalisation Coûts et Délais SETEC-TPI (12 octobre 2005)"

[5] SETEC-TPI, Tour Gamma D 58, Quai de la Rapée, 75583 Paris (France)

[6] LOMBARDI SA, Ingegneri Consulenti, Via R. Simen 19, CH-6648 Minusio Locarno, Switzerland.

15 m high, is located in Sieroszowice at 950 m below the surface. It serves now for measurement purposes. The movements of the salt walls have been monitored since 1997 in order to better understand a viscous creep of salt at big depths. A very large underground infrastructure for the LAGUNA project would be an innovating enterprise. In Sieroszowice an initial study was done in 2004/2005, showing prospects to host a large detector for GLACIER Liquid Argon detector. The preliminary conclusion of finite elements analyses showed that very large caverns in the salt layers could be potentially considered. The full pre-feasibility study for SUNLAB will be performed by KGHM Cuprum in close collaboration with IGSMiE PAN and the Sieroszowice mine's personnel. It will embrace all mining and geological aspects of large salt cavern design, from its location selection to water and energy supply. 3d stability analysis performed using the finite differences numerical tool (Flac3d) will permit determining the optimum cavern's shape constituting the main objective of the overall study. This feasibility study will focus particularly on salt-rock creep behaviour as well as the appropriate strength hypothesis assessment based on mechanical tests performed in KGHM Cuprum laboratory site, validated later on by field measurements in the existing underground salt chambers. During the computation procedure, salt-rock and surrounding hard rock mass will be scanned out whether the values of stability measures expressed by so called safety margins are maintained within a given safe bounds. This kind of numerical modelling will include the multi-phase and time-dependent excavation process and salt-rock creep behaviour in long-term horizon as well.

Task 10 Feasibility study for LSC

The Canfranc laboratory is located at 1080 m over the sea level and has a natural rock shielding amounting up to 2450 meters water equivalent. The lab originally consisted of two small halls (known as Lab1 and Lab3) located 780m and 2500m away from the Spanish entrance of the tunnel, respectively. A new lab was recently constructed. It consists of a main hall with an area of $45x15m^2$ and has a height of 10 meters. In addition, there are storage corridors, workshops, clean rooms, etc. for a total surface exceeding 1000 m^2.

So far no plans for possible extensions of this laboratory have been considered. Within this DS, possible extension of the laboratory either near the current site, which offers a dedicated entrance via the abandoned train tunnel, or in the neighbouring sites, will be investigated.

Task 11 Feasibility study for IFIN-HH

The Unirea salt mine in the slanic mine of the Prahova region (Romania) is an interesting potential site for the design study. The mine is administrated by SALROM SA, (Romanian National Salt Society). The salt exploitation ended in 1971. For the time being the mine is used for tourism and medical purposes. The access into the mine is assured by an elevator able to carry up to 65 tons. The network of galleries of Unirea salt mine are very large. The current area is 70000 m^2 and 2.9 million m^3 have already been excavated. The salt lens is about 5km x 3 km x 0.5 km. A gallery of about 1,000,000 m3 could be dug at a depth of 450 m. The costs are about 30€/ton, 1 m3 ~ 2.2 tons. The price of 1 ton of salt on the market is about 40€.

Task 12 Site specific impact of assembly of large underground tanks

An assessment will be made of the feasibility of underground construction and assembly of large tanks, and the strategies required based on the underground access route and local infrastructure. In an above-ground scenario the large storage tanks are usually constructed using common civil construction techniques. As there is no restriction on headroom the use of large cranes is normal. In the underground scenario it is less likely that there will be enough headroom to allow the use of large cranes. The domed roof is normally constructed on the bottom of the tank and then raised and welded in place using air pumped into the vessel. This technique is commonly used when manufacturing these types of tank and does not present a problem underground. The only requirement being a supply of electricity to power the air fans needed to raise the roof. An alternative technique could then to be employed where the roof is built first together with the top ring of the shell. The assembly would then be jacked up about 3m and the next lower ring installed. Successive ring welding / jacking operations would be performed until the shell is completed without the use of a large crane. This is a common technique for large diameter oil storage tanks. The order of construction of the tank would be as follows: (a) base (b) roof and deck (c) outer shell (d) base insulation (e) inner shell base (f) inner shell (g) insulation. This task will generally investigate the impact on the site of the assembly and operation of the large tanks.

WP3 – Safety, environmental and socio-economic issues

The safety and environmental issues for large underground research infrastructures must be tackled from the beginning of the project and taken into account in the DS. This work package will identify both general and specific hazards for the underground sites and will establish associated safety protocols and additional infrastructure to mitigate the risks.

Task 13 Start-up and definition of common language

This WP will determine the relevant safety considerations for each experimental site and assess the potential impact on the local environment both due to normal operation of the facility, and as the result of an accident. Studies carried out within this WP will include a description of the underground safety systems, protocols, and training, and will identify site specific requirements from a legal and environmental viewpoint, in accordance with directives from the site hosts. Various safety aspects related to the handling of very large quantities of liquids, at room or at cryogenic temperature, with a particular focus on assessing the necessary legal authorization requirements at each promising site will be studied. In this context, it is important to define the interface and the sharing of responsibilities in terms of safety between the research infrastructure and the host. The host can be either the company owning or running the nearby road tunnel or the company exploiting the mine. In this case the access will have to be operated in "shared" mode and the coordination of the activities of research infrastructure will have to be tightly coordinated. In the case of a dedicated site (e.g. new site at shallow depth) the interface with the local political authorities and security community (fire brigades, …) will be addressed. For each site and experiment a distinction will be made between internal risks i.e. hazards associated with the running of the experiment, and external risks i.e. hazards connected with the local area such as earthquake, fire, or rock collapse and will identify systems which must be employed to mitigate damage to the workforce, the equipment, the cavern, and the environment in accordance with local law. Definition of the interface between the installation safety and the overall safety strategy of the host including coordination with the host's safety experts will also be made.

Task 14 __**Definition of dedicated services and general safety and environmental issues**__

Irrespective of the location of the site, it is vital that the underground environment is suitable for both the needs of the science and personnel. In addition to the main target area, control rooms and ancillary systems, the cavern will feature meeting rooms, kitchens, offices, communication studios, electrical and mechanical workshops, storage facilities, clean rooms and decontamination and wash areas. Surface facilities will include clean rooms, workshops and lab space required to pre-assemble and test equipment prior to transfer underground. The geothermal gradient at each site coupled with the requirements of the individual experiments will determine the extent of ventilation, air conditioning, air humidity and purification required. The report will detail all site specific requirements and will include a detailed analysis of the local power distribution from the national power grid, through the substation and distribution network, to the local system transformers and switchgear, estimating the power requirements of the laboratory and the requirements this imposes on the cavern supply, the underground power supply system, and the national grid. Irrespective of the location of each experiment, compliance with all applicable environmental regulations is a legal requirement. Included in the proposal for each scientific site will be a detailed appraisal of the local environmental impact, including waste disposal procedures, environmental protection and potential risk due to accidental chemical release. Each report will document specific procedures, administrative controls and review processes required to mitigate each risk and the techniques employed to render any exhaust products released into the atmosphere benign in compliance with local law. The report will detail the consequences to the local transport infrastructure and surrounding communities due to increased commercial road traffic and personnel. It will also identify final decommissioning and decontamination procedures at the conclusion of research. Construction will use recycled materials where possible, all electrical equipment will be selected for the best energy efficiency, and all wood, paper, plastic, and electronic waste will be separated for recycling.

Task 15 __**Studies on long-term cavern stability and assessment of sources of instabilities**__

The fundamental concern of any underground excavation is the integrity of the cavity. Geologists, rock engineers, and mining experts over many years have created large caverns that have demonstrated excellent long-term stability. Geotechnical advances such as rock creep monitoring, and simulation studies coupled with improvements in machinery and mining techniques, have led to further improvements both in the size of cavern possible, and its longevity. However frequent evaluation must be made of the condition of the rock either by the mining corporation or professional rock engineering contractors.

Task 16 __**Assessment of hazards events and risk analysis**__

The implications of a serious incident in a LAGUNA site are profound and depending on the severity could result in the closure of all facilities. In many countries it is a legal requirement that all accidents resulting in injury or having the potential to cause harm be reported. In addition to the publication of a document detailing the safety policies and protocols required to ensure safety of LAGUNA staff, general underground personnel, and visitors, health and safety awareness of employees would be improved through continuous laboratory safety appraisals, equipment inspections, training, and courses. The minimum standards would be determined by the individual codes and rules set out by the specific site owners, the local law, and the governmental site inspectorate, and would include appropriate training, safety equipment, emergency procedures, and protocols. Mine sites have different issues compared to tunnel sites with regard to emergency egress, ventilation systems, fires, large volume liquid gas emergencies, production of liquid cryogens and air quality monitoring. Appraisal of each site will reflect this. A risk management consultant or in some cases mining and safety experts employed on site by the facility owners, will identify potential failures or unexpected incidents and their effect on the project. In addition to leaks, fire, engineering delays and scientific underperformance, these should include discovery of unacceptable rock properties during cavern excavation, major underground rock collapse in either the cavern or the access routes, and closure of the host site should it become economically unviable. Although catastrophic rupture of a liquid or liquid noble gas tank in an underground site is by far the worst-case scenario, the technologies involved in large tank production coupled with many decades of incident free operation belie concern. Throughout the world cryogenic tanks of similar design are operated without problem and have been designed to withstand earthquakes and subsidence. Leaks are far more likely to occur due to thermal expansion of liquid scintillator or during transfer from the storage facility to the main experimental tanks. In this case total liquid containment is essential and the report will detail ancillary equipment, procedures, control systems, and environmental monitors required to achieve this. The report will also investigate commercial solutions for tank monitoring and environmental control such as pumps to circulate noble liquids to avoid stratification – liquid fractionation producing thermoclines within the volume possibly due to pockets of impurities – potentially leading to rapid evolution of gas on turnover. In the event of a total power failure, emergency power would be provided to vital scientific support systems such as liquid scintillator cooling, purification of both liquid scintillator and liquid noble gas, and noble gas boil off compression via diesel generators. These generators would also supply power to life support systems such as emergency lighting, ventilation of toxic gases or smoke and the underground communication network. The report will identify in detail the total power demands for each system and the requirements imposed by the site hosts due to integration of an additional power generating system within the overall local grid. Fibre optic cabling will enable communication and small-scale data transfer, although the report will also include potential upgrades for an improved transfer network, and will detail proposed environmental monitoring and control devices. Each LAGUNA experiment represents a significant investment and, in today's global climate, must be viewed as a potential terrorist target. The report will identify security measures both to limit site access to those approved and qualified and to safeguard the underground systems from attack.

Task 17 Safety and monitoring of large-scale underground tanks

Safety of large systems can benefit greatly if existing and proven solutions are identified and utilized whenever possible. We mention as an example the case for LNG tanks: for over 40 years, WHESSOE S.A.[7] has developed instrumentation and safety shut-off valve systems for LNG / LPG storages, ensuring that all hazardous aspects are known and controllable. In close cooperation with leading gas companies, new technologies have been extensively tested for endurance, accuracy and reliability in harsh environments. WHESSOE'S Total LNG Storage tank Instrumentation Solution® consists of one single, totally integrated tank instrumentation package and integrated SCADA platforms. All instrumentation such as process level gauges, LTD gauge, in-tank temperature sensing and transmission devices as well as leak detection and cool-down monitoring system are designed and built at their manufacturing facilities. All system components are to be interconnected in a fully redundant communications loop. Information obtained from all tank instrumentation is displayed, using clear and concise displays, at the control system. WHESSOE is the only company worldwide, supplying a single source, total LNG storage tank instrumentation complete with LNG MASTER® Stratification and roll-over predictive software[8].

Task 18 Site specific impact of liquid procurement and tank filling

In parallel to the site impact of the tanks in WP2, this task will evaluate the methods of procurement in large quantities of each target liquid and the consequence for each specific site. To set the scale, a single truck can typically transport ≈30 m^3 of liquid. In comparison, the total volumes are typically 3 to 4 orders of magnitude larger, requiring the use of many thousands of trucks. This is not without causing significant technical and safety issues and potentially creates interference with local activities of the site. Strategies to bring very large quantities of liquids into the underground tanks will be discussed and an optimization of the liquid procurement methods will be attempted. Availability nearby the sites will be investigated and costs for transport will be estimated taking into account purity at delivery. Methods of local production and their impact on the site will be assessed. For cryogens, local liquefaction of air will be considered. The liquids will not be produced *ab initio* with the required purity, so a trade-off between initial purity versus in-situ purification systems will be studied taking into account costs. The filling techniques of deep underground tanks avoiding recontamination will be defined. In addition, methods to further purify and maintain high purity levels of the liquids will be designed by extrapolation to large scale of existing methods employed in currently operating projects. The definition of the purification methods will be based on input from the senior physicists and industrial partners involved in the business. All methods of storage and liquid transfer will be considered in terms of the impact on laboratory space, cost, safety, speed of transfer, and implications on the science. In the case of liquid Argon this will include both the cryogenic cooling requirements within the detector tank, and the boil off rate induced by auto-refrigeration. Although unlikely to occur more than once in the lifetime of the experiment, the emptying of the tanks will be addressed.

Task 19 Final report on safety and environmental issues

[7] Whessoe S.A. - 135, Rue de Bitche - 62100 Calais Tél.: +33 (0)3 21 96 49 93 - Fax : +33 (0)3 21 34 36 12 - contact@whessoe.fr

[8] LNG MASTER® is developed and owned by Gaz de France.

The report, subject to commercial confidentiality where appropriate, will include an assessment of site specific power requirements such as the installation of additional transformers for air conditioning, ventilation, atmospheric purification, pumping and chiller systems, underground workshops, surface buildings, experimental areas, cranes and associated heavy duty equipment required during construction. It will identify alternative ventilation and cooling schemes for tailored cooling of sensitive components such as the heat exchange on compressors. It will assess the redundancy amongst vital components such as the cooling and purification systems of LENA and the boil off compressors for GLACIER. Although it is envisaged that the ventilation system for the majority of sites will allow air to pass directly from the experimental areas into the general underground site, the report will also outline options to redirect the air flow in the event of a toxic release or fire through a secondary ventilation pipe directly to the surface, thereby limiting contamination of the site and ensuring safe egress of personnel. The report will outline the requisite skills and qualifications for all personnel and will detail the mandatory safety requirements at each site including the local building fire protection codes for fire prevention and containment, noise control, and electrical safety. The report will identify safety considerations specific to each proposed site in addition to emergency response equipment, air monitoring, and egress procedures, such as hazardous material handling, dedicated ventilation piping for the removal of boil off noble gas, cryogenic coolants, and toxic scintillator vapour, and containment systems for scintillator and liquid noble gas spillages. It will detail an emergency management plan, fire containment procedures and evacuation route. It will identify training required for the underground rescue and emergency response teams relevant to the specific experimental target material, and will detail the steps required to contain and dispose of hazardous laboratory materials, and subsequent decontamination in accordance with local law. It will consider the possible failure modes for each experiment, making an assessment of the severity of each, the potential costs involved, and ways in which each can be mitigated.

Task 20 <u>Socio-economic impact of the research infrastructure on the sites</u>

In contact with the local governments at each site, a report on the potential socio-economic impact of the construction and operation of the research infrastructure will be produced. It is a priori expected that local communities will generally directly or indirectly benefit from the presence of this unique research infrastructure yet it could also be affected by the construction and operation of the laboratory. This task will attempt to quantify this impact and propose solutions to mitigate any possible negative aspects.

WP4 – Science Impact and Outreach

This WP will explore different detector technologies and different underground laboratory sites in order to identify the best strategy for future large-scale detectors.

Task 21 <u>Theoretical activities supporting experimental programme</u>

The main focus of the LAGUNA proposal is to investigate the best strategy for a large underground detector, aiming at measuring proton decay and a rich neutrino physics program. Proton decay is a process of fundamental importance for an understanding of the basic laws of particle physics, which has so far eluded detection. The most promising channel for proton decay depends on expectations from a larger theoretical picture. These expectations evolve due to new theoretical insights as well as due to experiments, which will be carried out in future years. Theoretical expertise is therefore included in this task, in order to study the most promising decay channels, lifetimes and the corresponding search strategies. In the same way, theoretical expertise is needed in order to optimally connect the R&D being done towards a large underground detector with theoretical expectations and new insights from other experiments. Examples how theory may play an important role in this project is given by new results from lepton flavour violation (LFV) experiments and from LHC. New LFV experiments should see a signal in the years to come and the type of signal has profound consequences for the flavour structure of physics beyond the Standard Model. In the same way, LHC-experiments may or may not find supersymmetry, which has immediate consequences for the expected lifetimes, decay channels and search strategies for proton decay.

Task 22 <u>Education and Outreach</u>

In the LAGUNA project, all the European leading experts on underground laboratories are involved. The interdisciplinary character and non-standard problems of this research create unique opportunities for teaching and outreach. Students of physics, astrophysics, geology, civil engineering, geo-mechanics and hydrology can mix, make first class research in their field and learn much about the other fields. An important aspect is attracting good students to scientific careers. The goals for outreach are:

- A document for the general public explaining all the aspects of underground science and its achievements and prospects in Europe.
- A public web site popularising the research done in the framework of LAGUNA.
- Hands-on displays related to underground science.
- Advertising the LAGUNA project during the "open doors" days of the participating institutions.
- Popularising LAGUNA via the European newspapers, radio and TV.
- Contacts with local communities and, in the case of mines, with the mine personnel.

In addition, specific actions at particular sites will be considered: for example, at Boulby the idea to build on this foundation by carrying out a viability and funding study for a dedicated surface building featuring a visitors centre illustrating underground science and mining, a video conferencing studio, scientific workshops and conference rooms suitable for public lectures was proposed. One would investigate potential sources of funding from the local education authority, through local and national government grants, the tourist board, and CPL. In addition one would evaluate the use of internet education technologies such as interactive online study courses, and the value of recruiting summer students. Finally, meeting with senior scientists from earth sciences, engineering, and geological disciplines would be organized. The developments of links with, and the formulation of letters of intent from potential collaborators in the fields of bio-science, geo-physics, environmental sciences, geo-chemistry, and microbiology to study for example microbial evolution, population, and diversity could be considered. In addition one would foster links with geological and engineering groups to identify potential research topics such as the interaction of mechanical, thermal, chemical, and hydrological processes on the nature of underground rock, and would investigate the potential for long-term studies using novel geophysical imaging technologies to measure pressure and stress changes, and hence the long-term stability of large cavern excavations.

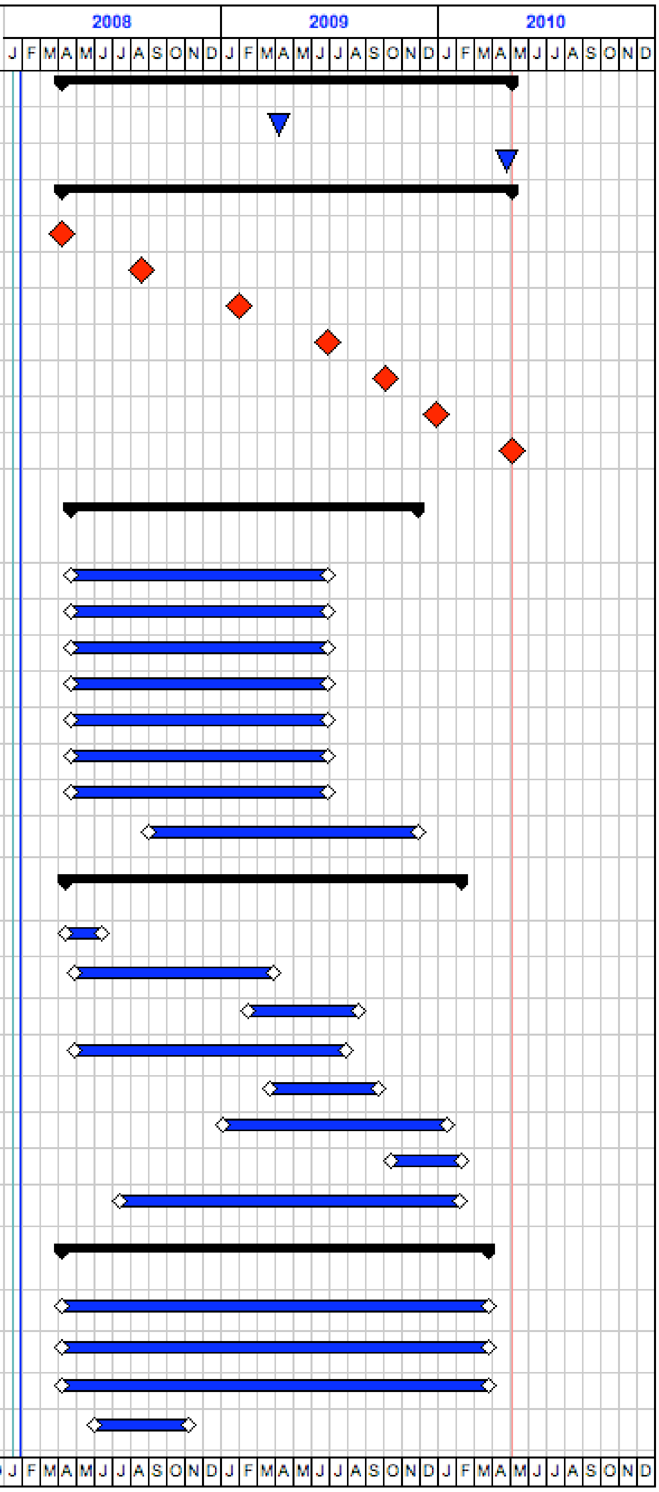
Task 23 Investigation of synergies with the European Strategy for Particle Physics and the CERN laboratory

As was pointed out in the ESR, the LAGUNA DS must proceed in symbiosis and synergy with the recommendations and roadmaps developed within the realm of the European Strategy for Particle Physics and CERN. This task will initiate and conduct technical and strategical discussions with CERN, in particular for what concerns the feasibility of future neutrino facilities from CERN and directed towards the sites investigated in this DS.

B.1.3.2. Timing of work packages and their components

Assumed starting date : April 2008; Anticipated duration: 24 months

Activity Name	Start Date	Finish Date	Duration (Work Days)
WP1 – Management	**4/7/08**	**5/3/10**	**540.00**
First year report	4/6/09	4/6/09	0.00
Final report	4/26/10	4/26/10	0.00
LAGUNA general meetings	**4/7/08**	**5/3/10**	**540.00**
Kickoff meeting	4/7/08	4/7/08	0.00
General meeting 1	8/18/08	8/18/08	0.00
General meeting 2	2/2/09	2/2/09	0.00
General meeting 3	6/29/09	6/29/09	0.00
General meeting 4	10/5/09	10/5/09	0.00
General meeting 5	12/28/09	12/28/09	0.00
Final meeting	5/3/10	5/3/10	0.00
WP2 – Underground infrastructures and engineering	**4/21/08**	**11/26/09**	**419.00**
Feasibility study for CUPP/Pyhäsalmi	4/21/08	6/26/09	310.00
Feasibility study for Fréjus	4/21/08	6/26/09	310.00
Feasibility study for Boulby	4/21/08	6/26/09	310.00
Feasibility study for CNGS off-axis	4/21/08	6/26/09	310.00
Feasibility study for SUNLAB	4/21/08	6/26/09	310.00
Feasibility study for IFIN-HH site	4/21/08	6/26/09	310.00
Feasibility study for LSC	4/21/08	6/26/09	310.00
Site impact of underground assembly of large undeground tanks	9/1/08	11/26/09	324.00
WP3 – Safety, environmental and socio-economic issues	**4/14/08**	**2/10/10**	**478.00**
Startup and definition of common language	4/14/08	6/13/08	45.00
Definition of dedicated services and general safety and environmental issues	4/28/08	3/27/09	240.00
Studies on long term cavern stability	2/16/09	8/18/09	132.00
Assessment of hazards events and risk analysis	4/28/08	7/27/09	326.00
Safety and monitoring of large-scale tanks	3/23/09	9/22/09	132.00
Site impact of liquid procurement and tank filling	1/5/09	1/15/10	270.00
Final study on safety and environmental issues	10/12/09	2/10/10	88.00
Socio-economic impact of the research infrastructure on the sites	7/14/08	2/5/10	410.00
WP4 – Science impact and Outreach	**4/7/08**	**3/26/10**	**515.00**
Theoretical activities supporting experimental investigations	4/7/08	3/26/10	515.00
Optimization of the physics potential of the research infrastructure	4/7/08	3/26/10	515.00
Education and Outreach	4/7/08	3/26/10	515.00
Synergy with European Strategy for Particle physics and with CERN	6/2/08	11/7/08	115.00
			5,797.00



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
WP1	Management, coordination and assessment	MGT	ETHZ	26.5	1	24
WP2	Underground Infrastructures and Engineering	RTD	U-Oulu	160	1	24
WP3	Safety, environmental and socio-economic issues	RTD	U-Sheffield	42	1	24
WP4	Science Impact and Outreach	RTD	IFJ PAN	47.5	1	24
	TOTAL			**276**		

B.1.3.4. Deliverables list

List of deliverables – to be submitted for review to EC							
Del. No.	**Deliverable Name**	**WP No**	**Lead bene-ficiary**	**Estimated indicative person-months**	**Nature (Report, Prototype, Demonstrator, Other)**	**Dissemination Level (Public, PP, RE, CO)**	**Delivery date (month)**
1.1	First year report	1	ETHZ	5	Report	Public	12
1.2	Final report on European underground research infrastructure and its science	1	ETHZ	10	Report	Public	24
2.1	Interim report for CUPP/Pyhäsalmi	2	U-Oulu	18	Report	Public	16
2.2	Interim report for Fréjus	2	CNRS	18	Report	Public	16
2.3	Interim report for Boulby	2	U-Sheffield	18	Report	Public	16
2.4	Interim report for CNGS off-axis	2	U-Bern	10	Report	Public	16
2.5	Interim report for SUNLAB	2	IFJ PAN	18	Report	Public	16
2.6	Interim report for LSC	2	LSC	18	Report	Public	16
2.7	Interim report for IFIN-HH	2	IFIN-HH	10	Report	Public	16
2.8	Final joint report on potential European sites	2	U-Oulu	20	Report	Public	24
3.1	Site specific safety overview report	3	U-Sheffield	20	Report	CO	12
3.2	Final report on safety	3	U-Sheffield	20	Report	CO	24
3.3	Report on liquid procurement	3	U-Sheffield	10	Report	RE	20
3.4	Report on socio-economic impact	3	U-Sheffield	10	Report	RE	20
4.1	Deep science paper for general audience	4	IFJ PAN	20	Report	Public	24
4.2	Scientific paper for the physics community	4	IFJ PAN	20	Report	Public	24
			Total	245			

B.1.3.5. Work packages description

Description of Work package:

<table>
<tr><td>Work package number</td><td>1</td><td colspan="2">Starting date or starting event:</td><td>Contract start date</td></tr>
<tr><td>Work package title:</td><td colspan="4">Management, coordination and assessment</td></tr>
<tr><td>Activity type:</td><td colspan="4">MGT</td></tr>
<tr><td>Participants number:</td><td colspan="2">1-24</td><td colspan="2" rowspan="2">All participants in the Governing Board will devote approx. 1 person x month, while all other participants will devote 0.5 person x month.</td></tr>
<tr><td>Person months per participant:</td><td colspan="2">0.5-1</td></tr>
<tr><td colspan="5">Objectives: Coordinate the contractual, financial and administrative aspects of the Design Study and oversee the technical and scientific work of the other work packages. Ensure that the project milestones are achieved and the deliverables produced on time. Take care of the knowledge management for the Design Study, coordinating the protection, use and dissemination of the knowledge generated during the project.</td></tr>
<tr><td colspan="5">Description of work (possibly broken down in tasks), and role of participants:
Coordination task: coordination of the contractual, financial and administrative aspects of the Design Study, including delivery of annual reports and control of the funds.
Oversight task: oversight of the technical and scientific aspects of the Design Study, including the monitoring of milestones and ensuring that deliverables are produced on time.
Knowledge task: management of the knowledge generated by the Design Study, including its protection, use and dissemination.
Promote international contacts with Europe, North America and Asia. Develop outreach activities in Europe.</td></tr>
<tr><td colspan="5">Deliverables (brief description and month of delivery):
Report of 1st year activities in month 12, summarizing the work done by all the WPs and comparing progress against milestones and deliverables.
Final report, submitted in month 24, describing the achievements of the Design Study, including the design of the facility, checking that all deliverables have been delivered. The report includes: (a) comparison chart of all sites (b) recommendation of the feasibility of the sites for a particular set of experiments (c) cost predictions (d) preliminary plans for the cavities and supporting underground infrastructures (e) drawings.</td></tr>
</table>

Description of Work package:

Work package number	2	**Starting date or starting event:**	1
Work package title:	Underground infrastructures and engineering		
Activity type:	RTD		

Participant number:	1	2	3	4	5	6	8	9	10	11	12	13	16	17	18	19
Person months per participant:	8	2	2	3	22	18	1	2	17	12	16	3	20	14	2	10

Objectives:

- To assess the feasibility of large underground caverns in seven potential European sites to host large volume detectors of each kind.
- To provide the technical information, including cost estimates, needed for potential construction decision and site selection.
- To assess the site impact of the construction of underground tanks on the facility and estimate time of underground realization

Description of work:

The technical issues of the construction of large-scale underground cavities are studied. The studies include general geological studies of the sites, preliminary designs for the cavities, simulations of rock mechanics, analyses of local rocks, planning of the cavity construction and cost optimisation.

This WP consists of the following tasks:

- Start up by defining the common basis so that all studies are comparable.
- Feasibility studies made separately and competitively but coherently for each site, sharing experiences.

For each site there is a scientific partner and a technical partner. The technical partner (en engineering company) will do the technical studies and designs, while the scientific partner sets the goals and acts as a link between the technical partner and the scientific collaborators. All sites need their own partners that know well the local conditions.

- Generic designs of underground tanks will be developed using as a starting point the specifications for large volume above-ground tank EUROCODES 3 (Part 4-2, BS EN 1993-4-2 Silos, tanks and pipelines – Tanks) to allow the understanding of the site impact of their construction and safe operation.
- The investigation of an underground assembly will be performed via partnership and/or subcontracting to specialized industries and with contact and/or partnership with companies exploiting mines or road tunnels
- Regular meetings among senior physicists, industry and specialized engineers will be held in order to address the implications of the design choices to the science, and to balance the benefits to engineering aspects against the impact they may have on the physics

Deliverables (brief description and month of delivery):

- Interim reports for each site will be delivered within the first 16 months.
- The main deliverable is a final report in month 24 on the feasibility of constructing large-scale underground research infrastructures. The report includes: (a) comparison chart of all sites and experiments considered (b) recommendation of the feasibility of each experiment on the sites (c) cost predictions (at 20-25 % accuracy) for underground construction (d) preliminary plans for the cavities and supporting underground infrastructures (e) visual outline drawings.

Description of Work package:

Work package number	3	**Starting date or starting event:**								1			
Work package title:	Safety, environmental and socio-economic issues												
Activity type:	RTD												
Participant number:	1	2	3	4	5	6	8	9	10	12	13	16	17
Person months per participant:	8	1	1	4	4	1	1	1	4	3	1	6	6

Objectives:

- Identify potential safety and environmental risks for each target liquid
- Assess legal authorization requirements for each target liquid
- Define interface and the sharing of responsibilities in terms of safety between the research infrastructure and the host (road tunnel or mine)
- Evaluate the methods of the procurement of large quantities of each target liquid and the local safety impact and cost associated to the in-situ procurement of a given quantity of each target liquid
- Define tank filling techniques maintaining the specifications during the process and their impact on the site
- Assess the socio-economic impact of the research infrastructure in the different sites

Description of work (possibly broken down in tasks), and role of participants:

- Investigate commercial solution for monitoring of large scale tanks and assess their applicability to each target liquid
- Define needed services (ventilation system, electrical power requirements, liquid spill containment infrastructure, radon filter, etc…)
- Subcontract studies of risk analysis with safety experts
- Perform a seismic analysis of the tanks in the underground site
- Assess the procurement of the cryogenic liquids via contacts with leading European companies in the market. The study will involve estimation of costs and transport methods.
- In contact with local governments, develop a the socio-economic impact report for the local communities and other interested parties

Deliverables (brief description and month of delivery):

- In month 12, a confidential report will be produced from each underground site in which the pertinent safety considerations are addressed. In addition to generic factors such as an appraisal of the underground safety protocols and the safety and support infrastructure, the document will detail regional environmental issues, transportation infrastructure and relevant local laws. Finally the report will identify key safety considerations specific to the type of experiment, which might be located at each site.
- The final confidential report in month 24 will define all safety and environmental issues of selected sites, and will include the additional infrastructure required for safe operation, in conjunction with the overall safety strategy of the host (road tunnel or mine). This will include the possible failure modes of each experiment, methods by which this risk can be mitigated, and a risk analysis for each site.
- In month 20, a restricted report on the liquid procurement will be completed.
- In month 20, a restricted report on the socio-economic impact of the research infrastructure at each site will be completed.

Description of Work package:

Work package number	4	**Starting date or starting event:**										1	
Work package title:	Science Impact and Outreach												
Activity type:	RTD												
Participant number	1	2	3	4	6	7	8	9	13	14	15	16	18
Person months per participant:	8	2	2	0.5	1	5	3	7	1	5	5	5	3

Objectives:

- Optimization of the physics potential of the research infrastructure
- Multi-disciplinary and assessment of "other" sciences (biophysics, geophysics, geo-engineering)
- General public education and outreach concerning potential large underground research infrastructure in the Europe and in the world

Description of work (possibly broken down in tasks), and role of participants:

- Develop tools for physics reach simulations and parameters fitting
- Prepare document for general public, a website and hands-on displays, outreach activities
- Synergy with European Strategy for Particle Physics and CERN laboratory

Deliverables (brief description and month of delivery):

- Deep science paper for general audience in month 24
- Technical paper for the particle, astroparticle and astrophysics or other physics community, in month 24
- Website, in month 12

B.1.3.6. Efforts for the full duration of the project

Proposal number (acronym): 212343-CP (LAGUNA)

Participant no./shortname	WP1	WP2	WP3	WP4	Total MM 1FTE = 24
1. ETHZ	15	8	8	8	39
2. U-Bern	0.5	2	1	2	5.5
3. U-Jyväskylä	0.5	2	1	2	5.5
4. U-Oulu	1	3	4	0.5	8.5
5. Rockplan	0.5	22	4	0	26.5
6. CNRS	1	18	1	1	21
7. MPG	0.5	0	0	5	5.5
8. TUM	0.5	1	1	3	5.5
9. IFJ PAN	1	2	1	7	11
10. KGHM CUPRUM	0.5	17	4	0	21.5
11. IGSMiE PAN	0.5	12	0	0	12.5
12. LSC	0.5	16	3	0	19.5
13. UAM	0.5	3	1	1	5.5
14. UGR	0.5	0	0	5	5.5
15. UDUR	0.5	0	0	5	5.5
16. U-Sheffield	1	20	6	5	32
17. Technodyne	0.5	14	6	0	20.5
18. U-Aarhus	0.5	2	0	3	5.5
19. AGT	0.5	10	0	0	10.5
Sub-total					266.5
20. IFIN-HH	0.5	8	1		9.5
Total					**276**
Total per WP	**26.5**	**160**	**42**	**47.5**	**276**

To be compiled as soon as possible

Template: Project Effort Form 2 - indicative efforts per activity type per beneficiary[31]

Project number (acronym) : ………………………………

Activity Type	Beneficiary 1 short name	Beneficiary 2 short name	Beneficiary 3 short name	Beneficiary 4 short name	Beneficiary 5 short name	etc	TOTAL ACTIVITIES
RTD/Innovation activities							
WP name							
WP name							
Etc							
Total 'research'							
Demonstration activities							
WP name							
WP name							
Etc							
Total 'demonstration'							
Consortium management activities							
WP name							
Etc							
Total ' management'							
Other activities							
WP name							
Etc							
Total 'other'							
TOTAL BENEFICIARIES							

Note: This is a new table, with a breakdown of efforts per beneficiary to activity type level, which was not requested in the proposal

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**
1.1	Establish management and final consortium agreement	1	ETHZ	1	Kickoff meeting
1.2	First year report	1	ETHZ	12	First year report released
1.3	Final report	1	ETHZ	24	Final report is submitted
2.1	Feasibility study for all sites	2,3	U-Oulu	16	An interim report on the feasibility of all sites
3.1 (a-f)	Site specific safety protocols	2,3	U-Sheffield	12	An interim restricted report on the underground safety and support infrastructure
3.2 (a-f)	Site specific environmental and legal factors	3	U-Sheffield	12	An interim restricted report on the legal and regional considerations
3.3	Liquid procurement and handling for each target	3	U-Sheffield	20	A report on the procurement and filling of each liquid
3.4	Report on socio-economic impact	3	U-Sheffield	20	Restricted report
4.1	Deep science general audience paper	4	IFJ-PAN	24	
4.2	Scientific paper for the physics community	4	IFJ-PAN	24	

Tentative schedule of project reviews			
Review no.	**Tentative timing, i.e. after month X = end of a reporting period**	**Planned venue of review**	**Comments**
1	After project month: 10		General meeting #2
2	After project month: 19		General meeting #4
3	After project month: 24		Final meeting

Implementation

B.1.4. Management structure and procedures

The structure of the DS foresees in addition to the coordinator and the deputy coordinator, the existence of the governing board (GB) and a joint secretariat (JS). Their tasks are defined below:

The **coordinator** is responsible for the overall legal, contractual, ethical, financial and administrative management of the consortium, the co-ordination of knowledge management and other innovation-related activities, overseeing the promotion of gender equality in the project and overseeing science and society issues related to the research activities conducted within the project. He will ensure general liaison between the contractors and the Commission. He will submit financial statements, will receive in trust for the consortium all payments from the Commission and will distribute them among the contractors according to their decisions. He will represent the Design Study to the public and especially to partner councils inside and outside the EU not yet participating in the network. He will be accountable for keeping all contract commitments, for submitting all reports and financial records required from the Commission, for overlooking the joint secretariat, for supervising the implementation of the decisions of the Governing Board. The deputy coordinator whose main task is the scientific secretariat of the GB assists him.

The coordinator is Prof. André Rubbia. The deputy will be nominated during the first month of the DS.

The **governing board** (GB) comprises 1 representative from each LAGUNA participant. It is responsible for all management decisions of the network and for the approval of all documents results and approaches related to the LAGUNA activities. It has overall responsibility for monitoring the work performed, reviewing the objectives and progress achieved towards sustained co-operation and the specific objectives set and discussing corrective actions where necessary. The GB also has a general responsibility for the dissemination of information. Decisions are taken when more than 2/3 of the members are present or have proposed a proxy, by simple majority. It will meet at least once per year.

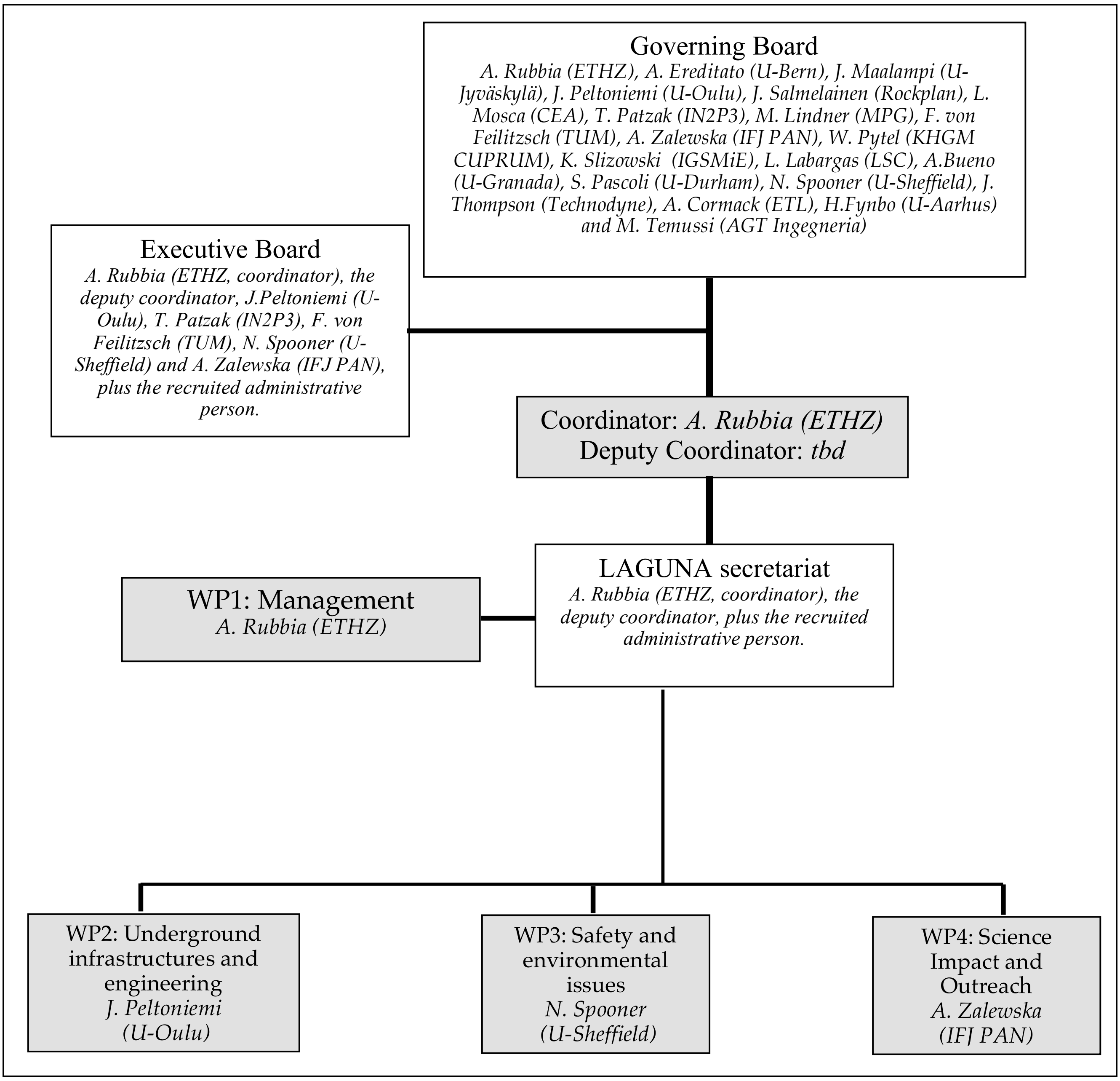
- The members of the Governing Board are: A. Rubbia (ETHZ), A. Ereditato (U-Bern), J. Maalampi (U-Jyväskylä), J. Peltoniemi (U-Oulu), J. Salmelainen (Rockplan), L. Mosca (CEA), T. Patzak (IN2P3), M. Lindner (MPG), F. von Feilitzsch (TUM), A. Zalewska (IFJ PAN), W. Pytel (KHGM CUPRUM), K. Slizowski (IGSMiE), L. Labargas (LSC), A. Bueno (U-Granada), S. Pascoli (U-Durham), N. Spooner (U-Sheffield), J. Thompson (Technodyne), A. Cormack (ETL), H. Fynbo (U-Aarhus) and M. Temussi (AGT Ingegneria).

The **executive board** (EB) assures the day-to-day follow-up of the program and it is formed by the coordinators, the 6 workpackage leaders plus the administration responsible members. It will be responsible for the co-ordination and harmonization of all LAGUNA actions and particularly for the administrative and co-operative support of all transnational research activities. It will follow up all important horizontal issues and will prepare the GB meetings of the LAGUNA consortium. It will also be responsible for public relation issues and for the contents of the LAGUNA website. It will meet every two months, and decisions will be taken on a unanimity basis. On exceptional cases differences may be resolved by qualified majority rule (2/3 of the members) or can be directed to an exceptional GB meeting.

- The members of the Executive Board are: A. Rubbia (ETHZ, coordinator), the deputy coordinator, J.Peltoniemi (U-Oulu), T. Patzak (IN2P3), F. von Feilitzsch (TUM), N. Spooner (U-Sheffield) and A. Zalewska (IFJ PAN), plus the recruited administrative person.

The **LAGUNA Secretariat** assures the day-to-day follow-up of the programme and it is formed by the coordinator and its deputy, the administration plus invited members of the LAGUNA consortium, like for example the leaders of the workpackage, depending on the session. The close interaction of the consortium partners in the joint secretariat belonging to different national institutes will improve coordination and internal quality control, but will most notably increase the acceptance and transparency within the LAGUNA consortium. All relevant quality control information within the six work packages will be collected within the project management. The division of labour between the partners is explained in the Workpackage description. The joint secretariat will be responsible for the coordination and harmonisation of all LAGUNA actions (electronic communication tools, …), and particularly for the administrative and cooperative support of all transnational research activities. The joint secretariat will keep contact with all participants of the consortium. It will follow all important horizontal issues and will prepare the meetings of the LAGUNA consortium: the Governing Board, and the LAGUNA general meetings. It will also be responsible for public relation issues and for the contents of the LAGUNA website. The GB and LAGUNA meetings of the joint secretariat will be held at the different capitals of the countries participating in the network. Each major meeting will be accompanied by a joint secretariat meeting, while independent meetings will also be organized.

- The members of the LAGUNA Secretariat are: A. Rubbia (ETHZ, coordinator), the deputy coordinator, plus the recruited administrative person. When necessary, WP coordinators will be asked to joint for particular meetings.



B.1.5. Beneficiaries

ETH Zürich – Swiss Federal Institute of Technology Zurich, Physics Department

The ETH Zurich, often called Swiss Federal Institute of Technology, is a science and technology university in the city of Zurich, Switzerland. Its full name is Eidgenössische Technische Hochschule Zürich, with ETHZ also being a common unofficial abbreviation. The ETH is an internationally oriented university. It is a member of the IDEA League and the International Alliance of Research Universities IARU.

The Institute for Particle Physics (IPP) belongs to the Physics Department. The Institute's main research projects address fundamental questions in the following three research fields:
(1) experiments at the frontier of high-energy interactions between fundamental particles, (2) experiments in neutrino physics and 3) experiments in Astroparticle Physics.

Profile of staff members who will be undertaking the work:

- Prof. Dr. A. Rubbia, head of the institute of particle physics, group leader, leading the ArDM and GLACIER R&D efforts. Chairman of CHIPP (Swiss Institute for Particle Physics. Elected member of the T2K executive board. Attended CERN course of management. Experimental high-energy particle and astro-particle physics, Search for neutrino flavor oscillations, Search for proton/neutron decay, Physics with positron/positronium, Detector R&D, Direct search for dark matter in the Universe, Phenomenology, Physics computing. Present and past international research projects: NA61, T2K, OPERA, ArDM, ICARUS, NOMAD, L3.
- Dr. A. Badertscher, senior researcher, detector construction, liquid Argon TPC detectors
- Dr. M. Laffranchi, PostDoc researcher, detector design and assembly, liquid Argon TPC detectors
- Dr. A. Marchionni, PostDoc researcher, neutrino beams and neutrino physics, expertise in detectors and accelerators, detector development, liquid Argon TPC detectors, electronic and readout systems

[U-Bern] University of Bern, Laboratory for High Energy Physics (LHEP)

The University of Bern is one of the most important Swiss Universities. Already in 1528 it was structures as a " Hohe Schule". Today therre are about 20000 students subdivided in 8 faculties: Theology, Law, Economics and Social Sciences, Medicine, Veterinary Medicine, Human Sciences and Science. The faculty of Science provides teaching and researches in the fields of Mathematics, Physics astronomy and phylosophy, Chemistry and Biochemistry, Biology, Geology and Geography. Physics is subdivided into three institutes (Physics, Applied Physics and Theoretical Physics). The laboratory for High Energy Physics (LHEP) is one of the three departments of the
Physics Institute. More information can be found in: http://www.unibe.ch/and
http://www.philnat.unibe.ch/
LHEP has also a long tradition in research and teaching. Elementary particle physics is one of the key specializations of the Institute of Physics at the University of Bern. It was introduced by H. Greinacher (lecturer 1924-1950) and F. Houtermans (lecturer 1952-1966), who was appointed to succeed H. Greinacher in 1952. F. Houtermans founded a working group in Bern which pursued experimental, fundamental research in the area of particle physics with a view to researching the fundamental building blocks of matter and their interactions. After the death of F. Houtermans (1966), J. Geiss was appointed as Head of the Institute of Physics. At the request of J. Geiss, the faculty and the government decided to set up an independent department of elementary particle physics at the Institute of Physics and to create a full professorship in this specialization. B. Hahn was appointed to this chair in 1968. K. Pretzl succeeded B. Hahn in 1988. He started a series of new projects in the field of particle physics. In particular he contributed to the search of strange-quark matter with the NA52 experiment in the heavy ion beam at the CERN Super Proton Synchrotron (SPS). Under his leadership the LHEP participated in the conceptual design of the ATLAS experiment for LHC. He also started a line of research on neutrino physics, joining the OPERA experiment for the search for neutrino oscillations. After retirement of K. Pretzl in 2006, A. Ereditato was appointed as his successor and is presently leading LHEP. The current activities of LHEP include the ATLAS, OPERA and T2K experiments in addition to an R&D study on novel particle detectors (as in particular LAr TPCs). As far as the latter subject is concerned we are realizing at LHEP,in collaboration with ETHZ and the University of Granada, a 5 m long LAr TPC detector (ARGONTUBE), in the framework of the GLACIER R&D program.

Profile of the staff members who will be undertaking the work:

- Prof. Dr. A. Ereditato, group leader, LAr detectors, management, physics. Experience in neutrino and astroparticle physics. Experience with large neutrino physics experiments at CERN and LNGS (CHARM II, CHORUS, OPERA, ICARUS) Experience with particle detectors: calorimeters, LAr TPC, emulsion detectors, imaging.
- Tit. Prof. Dr. U. Moser, Particle detectors, infrastructure, underground sites Experience with particle detectors and HEP experiments, also in neutrino physics (OPERA).Experience with organization of scientific activities.
- Dr. M. Messina, PostDoc senior researcher, Physics, LAr detectors, underground sites, outreach. Experience in particle physics and neutrino physics. Experience in LAr TPC detectors.
- Dr. I Kreslo, PostDoc researcher, Particle detectors, DAQ, experience with liquid scintillators, imaging. Experience in high space-resolution detectors (emulsions, capillaries, scintillator trackers, liquid scintillators, imaging).

[Jyväskylä] University of Jyväskylä

The University of Jyväskylä is one of the best and most popular Universities in Finland. It mainly attracts the students from the central part of the country. Natural sciences and mathematics, human-centred sciences, sport and health sciences as well as teacher education form the core fields of the research and education. The University has the third highest number of Centres of Excellence in Finland and has been named a University of Excellence in Adult Education by the Finnish Ministry of Education.

The Department of Physics performs research and offers education at highest international level on nuclear and accelerator-based physics, materials physics and high energy physics. In addition, it hosts a teacher education program. The accelerator laboratory is a Centre of Excellence under the national centre of excellence program. Part of the research is done at CERN. There is also a very strong theory group.

The main task of Jyväskylä is to work in close cooperation with CUPP on the design of the underground infrastructure for the new underground laboratory (WP2), address safety and environmental issues (WP3) and contribute to science impact and outreach (WP4).

Profile of the staff members who will be undertaking the work:

- Dr. Wladyslaw H. Trzaska. Scientific background in experimental nuclear and high energy physics, Project Leader of ALICE T0 detector, coordinator of the Nuclear Reaction Research at Jyväskylä, spokesman of the underground experiment EMMA. WP2, WP5.
- Prof. Jukka Maalampi, Head of the Department. Scientific background in theoretical physics, strong interest in sterile neutrinos. WP6.
- Prof. Jouni Suhonen. Scientific background in theoretical physics, strong interest in beta decay and matrix element calculations; author of a textbook for advanced students on nuclear concepts and microscopic theory. WP6.

[Oulu] University of Oulu

The University of Oulu is an active scientific learning and research community of 17 000 students and 3000 staff members. Its task is to promote well-being and education in Northern Finland by implementing high-quality international research. The University's six faculties and their departments form a multidisciplinary academic institution that enables diversified studies and multifaceted research.

The University aims to develop itself further as an internationally high-level scientific community by paying particular attention to the needs of science and society. The University's goal is to clarify and strengthen its competitiveness and know-how. Ability for renewal and multifaceted know-how form the recipe for success, and active participation in the international scientific community is the basis for such renewal and development. Strategic goals include the promotion of the University of Oulu as an attractive work place for international top-scientists, which means that teaching and research has to be of high quality. The University creates high-level research environments for international research groups.

The University of Oulu runs an underground laboratory in Pyhäsalmi mine, referred to as Centre for Underground Physics in Pyhäsalmi (CUPP). Oulu Southern Institute administers it, which is a regional organisation of the University of Oulu.

CUPP has been planning or running an underground laboratory since 1997. CUPP has hosted or realised some small-scale experiments in the lab, including neutron measurements. The current experimental activity focuses on a cosmic ray experiment EMMA (Experiment with MultiMuon Array) shallow underground, and the future plans concentrate on LAGUNA.

A prefeasibility study and preliminary plan for a new underground laboratory was made in 2002 with Rockplan. The University of Oulu has experience on participation on planning and developing of several major construction projects for its recent new premises.

The main task of Oulu in this Design Study is to work on WP2, the design of the underground infrastructure for the new underground laboratory that is the subject of this project. In more detail, Oulu is responsible for the scientific aspects for the Finnish candidate site and links with the participant Rockplan, which is the respective technical partner. Oulu also contributes to WP3 (safety and environmental issues), particularly studying the site specific aspects and WP4 (Science impact and outreach).

Profile of the staff members who will be undertaking the work:

- Dr. Juha Peltoniemi, project director of CUPP, adjoint professor: leads the local group in this Design Study. Scientific background in neutrino physics, with recent contributions to cosmic ray experiments. Managing EU-funded (ERDF) projects since 2001.
- Dr. Timo Enqvist, senior researcher, manager of the Pyhäsalmi laboratory. Scientific background: experimental nuclear physics and astroparticle physics.
- Dr. Pasi Kuusiniemi, PostDoc: experimental nuclear physics and astroparticle physics.
- Prof. Kari Rummukainen, Department of Physical Sciences, University of Oulu: professor of theoretical particle physics, with the responsibility for the research program and teaching of particle physics at the University of Oulu. Scientific background in Cosmology and Finite temperature field theory.

CNRS – CEA and IN2P3

Dapnia (CEA) and IN2P3 (CNRS) are the two national French institutes concerned with particle, nuclear physics. They also fund major programs in astroparticle physics in collaboration with the Institute of the Sciences of the Universe INSU/CNRS, other departments of CNRS and other national organisms (CNES for space, IFREMER for the sea, etc.) .
At CEA, the particle physics groups have merged, since 1991, with nuclear physics and astrophysics groups in the department called DAPNIA, Laboratory of research into the fundamental laws of the Universe. Dapnia works in coordination with IN2P3, in particle astroparticle and nuclear physics. In 2005 DAPNIA employed a total of 820 persons (420 engineers (including 200 researchers), 246 technicians and administrative staff, 19 CNRS or University staff and 135 non permanent staff (PHD, postdocs). DAPNIA is composed of 7 services.
IN2P3 has been created in 1971 as an institute of CNRS devoted to particle and nuclear physics, and more recently to astroparticle physics. It is tied by decree ties with the University research and has also strong connections with DAPNIA (CEA)(Dapnia) and CNES (Spatial program). IN2P3 is composed of 23 Laboratories most of which are contracting with universities and CNRS (so called UMR). One of these laboratories, the CCIN2P3, is a Computing Center supported and used by both DAPNIA (20%) and IN2P3 (80%).). In 2005 the total IN2P3 permanent staff was 2488 persons (491 CNRS researchers, 304 University professors, 1460 CNRS staff, 233 University staff). For both DAPNIA and IN2P3 there are about 180 graduate students. The IN2P3 & CEA run the Fréjus-Modane Underground Laboratory (LSM) since 25 years and are involved in a wide spectrum of neutrino and astroparticle experiments.

The CEA & IN2P3 run the Fréjus-Modane Underground Laboratory (LSM) since 25 years and are involved in a wide spectrum of neutrino and astroparticle experiments. French laboratories have strong activities at CERN and all the other major particle physics facilities around the world (Fermilab, Stanford, Desy, Tsukuba, Jefferson laboratory, RHIC etc.). IN2P3 and DAPNIA have developed high competences in all technical fields related to particle physics.

Profile of staff members who will be undertaking the work:

- Dr. Luigi Mosca, former Director of LSM and at present Scientific Adviser for future projects at Fréjus site
- Dr. Marco Zito, PostDoc researcher at CEA/DAPNIA. Leader of the T2K team in Saclay.
- Dr. Christian Cavata, PostDoc researcher at CEA/DAPNIA. Scientific Deputy of the DAPNIA Chief of Department Scientific interest in neutrino physics and nucleon decay.
- Pr. Thomas Patzak, project director at APC/IN2P3: leads the IN2P3 group of this project. Scientific activity in neutrino physics and particle physics detector development.
- Dr Alain de Bellefon, senior researcher at APC/IN2P3, Scientific in charge with outreach at CNRS, scientific interest in dark matter and neutrino physics, and Borexino member.
- Dr Jean-Eric Campagne, PostDoc researcher at LAL/IN2P3. Scientific interest in neutrino physics and nucleon decay search, co-coordinator of the MEMPHYS project, chairman of the Modane Underground Laboratory Scientific Committee.
- Dr. Alessandra Tonazzo, researcher and lecturer at APC/IN2P3, has contributed to different high-energy collider experiments, both with detector development and with data analysis
- Dr. Jacques Dumarchez, senior researcher at LPNHE/IN2P3. Scientific interest in neutrino physics and nucleon decay.
- Dr. José Busto, PostDoc researcher at CPPM/IN2P3. Scientific interest in neutrino physics.
- Dr . Dario Autiero (IPNL/IN2P3), responsible of the neutrino group at IPN Lyon. Scientific background in neutrino physics with the NOMAD and OPERA experiments. Leads the local group of the LAGUNA project.
- Dr. Lionel Chaussard (UCBL/IPNL/IN2P3) responsible of the software working group in OPERA
- Dr. Yves Declais (IPNL/IN2P3), spokesman of the OPERA experiment and of the past CHOOZ experiment. Long standing scientific background in neutrino oscillation searches
- Dr. Jacques Marteau (UCBL/IPNL/IN2P3), project leader of the data acquisition system in OPERA

[MPG] Max-Planck-Gesellschaft zur Förderung der Wissenschaften e.V.

The Max-Planck-Institut für Kernphysik (MPIK) in Heidelberg and the May-Planck-Institut für Physik (MPP) in Munich are two well known institutions in particle and astroparticle physics. Both institutes are included via their head organisation, the Max-Planck-Gesellschaft (MPG). Coordination is done via the Max-Planck-Institute für Kernphysik in Heidelberg.

The experimental activities at MPIK are based on a strong research record in experimental neutrino physics and low-background techniques. The involved theoretical expertise at MPIK and MPP involves well known experts working on a broad set of topics which are directly and indirectly relevant for the LAGUNA proposal. The expertise includes on the formal side theoretical studies of neutrino mass models, extensions of the Standard Model which can accommodate neutrino properties and proton decay. The theoretical activities include various activities concerning the modelling of neutrino sources, including supernovae neutrinos, geo-neutrinos, neutrino beams, and reactor neutrinos. Another topics is the propagation of neutrinos in matter in the Earth and in supernovae and detection channels. Development and application of the GloBES software, a powerful simulation tool for long baseline and reactor neutrinos with three flavour oscillations in matter. There exists also a lot of expertise in the phenomenology of Dark Matter and axions and in theories beyond the Standard Model providing Dark Matter or axion candidates.

Profile of the staff members who will be undertaking the work:

- Prof. Dr. Manfred Lindner, director at MPI für Kernphysik, expertise in theoretical particle and astroparticle physics, phenomenological studies in neutrino physics.
- Dr. Stefan Schönert, MPI für Kernphysik, project leader, expertise in neutrino physics at low energies, underground and low background physics, detector technology.
- Prof. Dr. Georg Raffelt, MPI für Physik, senior research scientist at MPI für Physik, expertise in theoretical particle and astroparticle physics.
- Prof. Dr. Wolfgang Hampel, senior research scientist at MPIK, expertise in neutrino physics at low energies, underground and low background physics, detector technology.
- Prof. Evgeny Akhmedov, senior researcher at MPIK, expertise in theoretical particle physics
- Dr. Christian Buck, senior researcher at MPIK, expertise in neutrino physics and scintillator development.
- Dr. Hardy Simgen, senior researcher at MPIK, expertise in neutrino physics and low background techniques.
- Dr. Josefa Oehm, senior research scientists at MPIK, expertise in low background physics.
- Dr. Jochen Schreiner, senior research scientists at MPIK, expertise in low background physics.
- Dr. W. Rodejohann, senior researcher at MPIK, expertise in theoretical neutrino physics

[TUM] Technische Universität München, Physikdepartment E15

The institute E15 of the faculty of Physics at the Technische Universität München, Germany, is playing a leading role in Astroparticle Physics. Expertise has been achieved in the fields of solar neutrino measurements (GALLEX, GNO, and BOREXINO experiments), Dark Matter search (CRESST experiment), and experiments for investigating intrinsic neutrino properties (GÖSGEN, BUGEY, DOUBLE-CHOOZ). Technical expertise has been obtained in the development of scintillating detectors with extremely low levels in radioactivity. In addition large experience has been gained in cryogenic detector developments and in methods to characterise background levels with neutron activation and high sensitivity gamma spectroscopy. For this purpose a shallow site underground laboratory in Garching has been built. Experience in working in deep underground laboratories was obtained in the Italian Gran Sasso facility. Knowledge on electronics, data acquisition, single photon counting, data analysis, and Monte-Carlo calculations has been acquired. Connections to the High-Tech companies Fa. Vericold, Ketek, Infineon (Germany), Aquiris (CH) and ETL (UK) are fostered. The institute enforces public outreach with open doors days, information days for pupils, public seminars, by supporting the science-Lab of the Technical Museum in Munich. The group consists of 2 professors, 3 senior researchers and 7 PhD-students. A mechanical workshop including 2 engineers belongs to the institute. The group under Prof. F. von Feilitzsch is active in this field since 27 years.

Profile of the staff members who will be undertaking the work:

- Prof. Dr. Franz von Feilitzsch, chairman of the institute. Expertise in dark matter, neutrino and underground physics, and detector technology.
- Prof. Dr. Lothar Oberauer, Extraordinarius. Expertise in neutrino physics at low energies, rare event physics, detector technology and underground low background physics.
- Dr. Marianne Göger-Neff, senior researcher. Expertise in neutrino physics and scintillator development.
- Dr. Jean C. Lanfranchi, senior researcher. Expertise in low temperature detector developments, neutrino physics, and Dark Matter search.
- Dr. Walter Potzel, senior researcher. Expertise in Moessbauer-effect, low temperature detectors, neutrino physics, and Dark Matter.

IFJ PAN and its Polish partners

The H. Niewodniczanski Institute of Nuclear Physics of the Polish Academy of Sciences (IFJ PAN) in Cracow is one of the leading and of the largest Polish research institutes. The Institute carries out basic and applied research in physics. At present the Institute is involved, as a contructer, in 18 projects of the Sixth Framework Programme.

The basic research, both theoretical and experimental, concerns particle physics and astrophysics, nuclear and strong interactions physics and condensed matter physics. The experimental teams from IFJ PAN participate in the large international collaborations: ATLAS, LHCb and ALICE at LHC (CERN), ZEUS and H1 at HERA (DESY), Belle at KEKB (KEK), PHOBOS at RHIC (BNL), Auger in Argentina, ICARUS at Gran Sasso, T2K at J-PARC and ILC. Physicists in these teams are suplemented by an excellent technical staff whose mandate comprises the design and construction of detector mechanical structures, cooling systems, readout electronics, DAQ and trigger systems for experiments. This staff has also provided a significant contribution to the LHC Computing Grid and to the construction of the LHC accelerator.

The Institute, originally established as a nuclear physics research laboratory over 50 years ago, has by now expanded its research over a broad range of interdisciplinary applications of physics. It has for several years served as a leading regional centre in radiation and environmental biology, environmental physics, medical physics, dosimetry, nuclear geophysics, radiochemistry and material engineering.

In the LAGUNA project the group from IFJ PAN will closely collaborate with three other groups of Polish physicists from the A.Soltan Institute for Nuclear Studies (IPJ) in Warsaw, University of Silesia (US) in Katowice and University of Wroclaw (Uwr). In a ranking of the Ministry of Science and Higher Education in Poland all four institutions are classified as belonging to the (top) first category in physics research. IPJ, similarly to IFJ, carries a variety of research in physics and in particular has very strong experimental groups in particle and nuclear physics participating in many international projects. US and UWr have strong theory groups specialising in different aspects of neutrino physics. The Laboratory of Low Activities, in the Institute of Physics of US, carries environmental studies with use of α, β and γ spectrometry systems. At present, the group, within the ILIAS/TARI project in the 6th FP, is involved in measurements of natural radioactivity in several European Underground Physics Laboratories.

The wide range of the basic and applied research carried out by the highly qualified staff of IFJ PAN and of its scientific partners in Poland will be fully exploited in WP4, coordinated by IFJ PAN. The list of the Polish higher level personnel involved in the LAGUNA project includes: Prof. Agnieszka Zalewska (F), IFJ PAN – Head of Department of Studies of Neutrinos and Dark Matter, Prof. E. Rondio (F), IPJ – senior researcher, Prof. J.Kisiel (M), US – senior researcher, Assoc. Prof. J. Sobczyk (M), Uwr – senior researcher, Assoc. Prof. J.W. Mietelski (M), IFJ PAN – Head of Department of Nuclear Physical Chemistry

[UGR] University of Granada

The University of Granada is one of the largest universities in Spain from the point of view of the number of students assigned to it and from the amount of scientific production in international peer-reviewed journals. At European level, it has played a significant role both in innovation for education and research. In 1990, a theoretical group on Particle Physics was created. It is now a well-established research group that plays a relevant international role in the study of the phenomenology of the Standard Model and the Physics beyond it.
Recently, in 2002, this group was complemented by the creation of an experimental group on High Energy Physics. This is one of the youngest and more emergent groups for this field in Spain. In particular, it is the only one of these characteristics in the autonomous region of Andalucia (FEDER region type I). The group activities have been fully funded and supported since their onset by the Spanish Agency for Particle Physics. Nowadays the group is composed of three doctors, five Ph.D. students, an electronic engineer plus two technicians. It also operates a laboratory mainly devoted to R&D with cryogenic detectors. This infrastructure is key to carry out the tasks assigned to our group in this Design Study and having to do with the development and instrumentation of extremely massive Liquid Argon detectors (WP4). The group also has broad experience in software development both for detector simulations and data analysis (WP6).

Profile of the staff members who will be undertaking the work:
- Dr Antonio Bueno, Professor of Physics. Leads the local group of this project.
- Dr.Julio Lozano, senior PostDoc researcher.
- Dr Sergio Navas, senior PostDoc researcher.

All three members of the group have an ample scientific background in experimental neutrino physics with liquid Argon detectors. Since recently, they have made contributions as well to forefront Particle Physics research topics as cosmic ray (Pierre Auger Observatory) and dark matter (ArDM experiment).

University of Sheffield and Boulby

The University of Sheffield is a premier research University in the UK, participating here through the Department of Physics and Astronomy. Members of the department (led by Spooner) play a leading role in UK and European Astroparticle Physics through development of underground detector technology (for dark matter and neutrino physics) in Boulby Underground Laboratory at Boulby Mine, North Yorkshire. Our role at Boulby gives us unique experience to be a major contributor to LAGUNA - Boulby is the largest and longest running deep mine-based laboratory in Europe. Established in 1988 and expanded in 1999 with new facilities, is has been host to successful dark matter (NAIAD, ZEPLIN, DRIFT) and other experiments and has a strong record of R&D in connection with the ILIAS FP6 programme. The group (currently three academics and 10 students, technicians and PDRAs) has extensive experience gained over 15 years directly relevant to the workpackages in LAGUNA including: excavation and mine operations; development of large underground infrastructures and laboratories in mine environments; underground background and environment research; scintillator, liquid Argon, photon detection, electronics and data acquisition technology for underground detectors; engineering of unusual pressure vessels for underground use; interaction with non-physics applications, industrial cooperation and public outreach.

Profile of the staff members who will be undertaking the work:

- Prof. Neil Spooner, Director Boulby Laboratory, group leader. Expertise in dark matter, neutrino and underground physics, and detector technology
- Dr. Vitaly Kudryavtsev, senior academic researcher. Expertise in dark matter and rare event physics, detector technology and underground background simulations
- Dr. Sean Paling, senior researcher. Expertise in underground operations and engineering, rare event physics, analysis and detector development
- Dr. Phil Lightfoot, senior researcher. Expertise in cryogenic liquid, scintillator and gas technology underground, mine operations and engineering, rare event physics, novel readout techniques.
- Dr Matt Robinson, senior researcher. Expertise in data reduction, data analysis, simulations and data acquisition systems.

[UDUR] Durham University

Durham University is a world-class university in the city of Durham and at the Queen's Campus in Stockton, in the United Kingdom. It is engaged in high-quality teaching and learning and advanced research and partnership with business. Its academic teaching and research programmes are delivered through departments contained within three faculties: Arts and Humanities, Science, and Social Sciences and Health. The Department of Physics is part of the Science Faculty.

The Institute for Particle Physics Phenomenology (IPPP) was founded in 2000 as a joint venture of Durham University and the UK Particle Physics and Astronomy Research Council (PPARC). The IPPP is part of the Centre for Particle Theory (CPT) in Durham, based jointly in the Departments of Mathematical Sciences and Physics, with a number of academic staff having joint appointments in the two Departments. Its aim is to foster world-class research in particle physics phenomenology, and to provide a forum for interaction between experimentalists and theorists, coordinating common interests and future research through a series of discussion meetings, workshops and conferences. Within a short space of time, the IPPP has achieved international recognition and the recent Second International Review of UK Research in Physics and Astronomy stated ``The IPPP has had major successes: creating a critical mass of particle theorists in Durham. There have been very healthy interactions reviving particle phenomenology throughout the UK." The IPPP currently comprises 14 permanent staff (Professors Glover (Director), Khoze, Pennington, Stirling and Drs Abel, Ball, Dedes, Krauss, Maxwell, Moortgat-Pick, Pascoli, Richardson, Signer and Weiglein) as well as 15 fixed term research staff and 22 postgraduate students. An extensive visitor programme brings world-class researchers to the IPPP for periods ranging from a few days to a year. Training for the next generation of particle physicists is provided through guidance in research, and dedicated graduate lecture programmes and summer schools.

Research activities cover all aspects of particle phenomenology and, in particular, topics directly related to the LAGUNA proposal, namely physics Beyond the Standard Model of Particle Physics, and neutrino physics. Known experts work on i) neutrino phenomenology, concerning the study of neutrino properties in present and future experiments, ii) theoretical aspects of neutrino physics with particular focus on the origin of neutrino masses, iii) the role of neutrinos in the Early Universe and in the evolution of astrophysical objects as supernovae. Expertise on extensions of the Standard Model, which predict proton decay, and on dark matter is also present.

The main task of Durham concerns the science impact and outreach (WP4), providing theoretical support to the experimental investigations and contributing to the detector simulations, in order to fully explore and optimise the physics potential of the LAGUNA research infrastructures.

Profile of the members who will be undertaking the work:

- Dr. S. Pascoli, faculty member. Research in neutrino physics, extensions of the Standard Model and cosmology.
- Dr. S. Palomares-Ruiz, postdoctoral researcher. Expertise in neutrino phenomenology, high energy cosmic rays, cosmology.

[U-Aarhus] University of Aarhus

A high level of quality in both research and education is the aim of the University of Aarhus. Since its early beginnings in 1928, the university has provided both the Danish and international communities with more than 42,000 graduates, and has left its own special mark on the city of Aarhus, the Danish society and the international research community. The University of Aarhus has a reputation for education and training – a brand that extends well beyond Denmark's borders. It is a lively, modern university, which collaborates with the business community, cultural centers and other universities throughout the world.

The main task of U-Aarhus in this Design Study is to work on WP2, the design of the underground infrastructure for the new underground laboratory in collaboration with the CUPP center at Oulu, and to WP4 (Science impact and outreach).

Profile of the staff members who will be undertaking the work:

- Dr. Steen Hannestad, scientific background: Theoretical astroparticle and neutrino physics. Current or past board member of several European networks in these fields. Member of the governing council for ILIAS.
- Dr. Hans Fynbo, scientific background: experimental nuclear physics and nuclear-astrophysics. Spokesperson and project leader for numerous experiments at CERN-ISOLDE and other radioactive beam facilities in Europe.

[Rockplan] KALLIOSUUNNITTELU OY ROCKPLAN LTD

is a consulting company founded in 1986 and has over 20 years experience in every kind of underground facilities. For the most part acting as main designer, the company has gained experience through various projects in the field of rock engineering. The staff is mainly made up of architects, civil and rock engineers and geologists. The staff of 30 persons is mainly made up of architects, civil and rock engineers and geologists. The company is SME. The company has specialized in managing the design, general design, rock engineering design and structural design. Additional plans and designs are produced in co-operation with experienced subcontractors.

- Kalliosuunnittelu Oy Rockplan Ltd, (Rockplan), is able to act as **Design Manager**, coordinating and controlling the work or as a main designer.
- **General design** by Rockplan embraces both layout design and architectural design. In carrying out general design the company aims to create a suitable, safe, technically high quality underground facility meeting the client's requirements.
- The aim of Rockplan in **rock engineering design** is to use properties of the rock to the best advantage, and to prepare high quality plans excavation, reinforcing the rock surface, sealing and waterproofing. A fundamental consideration of the design is safety during construction.
- Rockplan aims to produce **structural designs** that take account of the special requirements of underground construction in cost effective manner. Structural design is required for among other things: entrance ramps and shafts, internal floors and structures and blast-resistant barriers.

Additional plans and designs are produced in co-operation with experienced subcontractors.
The **main task** of Rockplan in this Design Study is to make the preliminary design and technical feasibility study of the underground construction in the Finnish site, within WP2, working in close collaboration with Oulu. Rockplan is involved also in WP3 (tanks) and WP5 (safety).

Rockplan has been actively taken part in innovate new technology underground projects. One of the first steps was Hirvihaara deep storage of natural gas in Southern Finland. Rock lined cavers of total volume of 1.6 M m^3 were located in 850 meters depth. The detailed design of hoisting and service systems was carried out in years 1990-92 for Neste Oy Natural Gas. To the same client Rockplan designed also a concept of steel lined natural gas storage. The client discontinued these projects.
Rockplan has completed design of a 150.000 m^3 steel lined petroleum storage in Finland. The storage consists of 5 tanks with diameter of 35 meters. This storage has been operated for 16 years. Client and details are confidential information.
Kamppi Centre (Kampin keskus), the largest single construction project that has been carried out in Finland, was the best construction site of the year 2003. The jury grounded the election on Kamppi's visionary rock engineering in difficult circumstances and innovative technical solutions. The blasting work has been remote sensored in realtime and the effects has been analysed for security purpose before the next coming blast.
Salmisaari, underground coal storage. The overall project involves 3,5 km of tunnel with 40 different cross sections. Total excavation of 550.000 m^3 of granite/gneiss has being undertaken, all of which was crushed and screened for reuse by the local construction industry. The underground silos are each 65 m-high x 40 m-diameter with circular plan cross-section. The volumetric capacity of each silo is 81.000 m^3. The Salmisaari coal transport tunnel will be re-equipped to charge the silos and a newly mined conveyor retrieval tunnel will be used to discharge the coal.

The staff members undertaking the work will include:

- Jarmo Roinisto, Chairman of the Board, Managing Director, M.Sc. (Civ.Eng.): Project management, design and supervision of rock engineering, tunnelling and underground spaces
- Juha Salmelainen, Development Director, M.Sc. (Eng.Geol.): management of rock engineering projects, site investigations and rock mechanical modelling
- Raimo Matikainen, emeritus professor of rock engineering, former Director General of the Finnish Geological Survey, Board member and vice chairman of The Finnish Academy of Technology: wide experience of engineering in mining industry and geological research
- Matti Hakala, Special Designer: rock modelling in 2D and 3D using the most advanced calculation programs

KGHM CUPRUM

The KGHM CUPRUM Ltd. Research and Development Centre (KGHM CUPRUM), which is a part of the KGHM Polska Miedź SA capital group, has existed for over 35 years. During the first few years of its activity the company developed the research and design studies for the Polish copper basin and then for many other home and foreign mine projects, which gave it a stable position in the non-ferrous metals, salt mining and mine construction industries. At present it widens its activity range participating in geological and mining projects of the European Union.

Being aware of the XXI-st century challenges the company widens its activity undertaking problems of environmental protection and companies restructuring. It is at the same time consultant, expert and authority in geology, extractive industry, minerals processing and environmental protection.

KGHM CUPRUM has a highly qualified and experienced team of specialists (over 140) who create the most modern technical solutions and guarantee services on a high quality level. It also has the ISO 9001 and 14001 certificates.

The company has its own, fully accredited laboratory of rock mechanics with excellent equipment for investigating rock behaviour under any kind of load. It has a special purpose software and unique test instruments like chromatographs for gas mixtures and volatile liquids analyses, an X-ray diffractometer, a spectrometer of infrared radiation, a modern noise level gauge, a portable system for gas emission measurements, a kit for measuring and analysing vibrations, thermovision equipment, instruments for non-destructive laboratory and field tests, and a set for water analyses.

The research activity of KGHM CUPRUM Ltd. RDC is presently focused on: geology, hydrogeology and mining projects feasibility studies, mining, including rock mechanics, mines electrification, automation, mechanisation and ventilation, minerals processing, environmental protection with its monitoring and wastes management, companies restructuring, economical studies, technical expertise and engineering concepts evaluation used mainly for copper mines (among them also the Sieroszowice mine) exploited by KGHM Polska Miedź S.A.

KGHM CUPRUM participated in geological and hydro geological, mining and environmental projects of the European Union within 5th and 6th FP including:

- Life Cycle Assessment of Mining Projects for Waste Minimization and Long Term Control of Rehabilitated Sites (LICYMIN) - G1RD - CT - 2000 – 00162
- Chemically Stabilized Layers (CLOTADAM) – G1RD-CT-2001-00480
- Lifetime Engineering of Buildings and Civil Infrastructures - (LIFETIME) - GTC1-2001-43046
- Network on European Extractive Mining Industries (NESMI) - G1RT-CT-2002-05078
- Search for a sustainable way of exploiting black ores using biotechnologies (BIOSHALE) – NMP2-CT-2004-50571

For many years CUPRUM has been organising domestic and international scientific conferences and seminars on roof bolting, minerals processing, metallurgy, environmental protection and mining in difficult rock-mass conditions. The company has an authorisation granted by the Minister of Environmental Protection, Natural Resources and Forestry to deal with: atmosphere protection, land surface protection, environmental impact assessments of investments and building structures.

The KGHM Cuprum contribution to the Laguna project will cover feasibility studies for large caverns, problems concerning the site accessibility, evaluating the geomechanical limitations excavation technology, ventilation requirements, costs evaluation (WP2), local geomechanical hazards assessment due to mine activity and environment protection analyses (WP3).

The staff members undertaking the work will include:

- Dr. hab. Witold Pytel – project leader, M.Sc. (Civ. Eng.), MBA: background in soil and rock mechanics, numerical modeling and rock mass stability analyses, risk assessment and management,
- Dr. Andrzej Grotowski, : expertise in environmental protection and mineral processing,
- Dr. Andrzej Markiewicz, Geologist: expertise in geological survey and tectonic structure research,
- Miroslaw Raczynski, M.Sc. (Electr. Eng.): expertise in electric power supply and automation in mines,
- Zbigniew Sadecki, M.Sc. (Min. Eng.): expertise in mine planning and equipment selection,
- Dr. Slawomir Gajosinski, M.Sc. (Min. Eng.): expertise in mine ventilation and air-conditioning

IGSMiE PAN

The Mineral and Energy Economy Research Institute is part of the Polish Academy of Sciences (IGSMiE PAN), which has been leading research work on mining, geology, engineering geology, geotechnics, raw materials management and environment protection.

One of the main activities of the Institute is research on the physical and chemical properties, especially geological, geothermal, mineralogical, and hydrogeological of salt massifs. The results created a base for mathematical and physical models of rock salt formation which have been used for designing natural gas and liquid hydrocarbons storage caverns in rock salt deposits.

The Institute has been coordinating research work on the site selection and formation for the Polish deep radioactive waste storage project. The Institute is also participating in two European Union research framework FP6 projects related to geothermal energy and to carbon dioxide sequestration.

Staff members of the Institute have broad experience in design and in assessment of large-scale excavation long-term stability, including natural hazards (water, gas outburst) in Polish rock salt deposits. They have been participating in most of research projects, related with Polish salt mining in the last years.

In the case of the underground infrastructure for the SUNLAB project, the Institute is competent in the following tasks:

- Determining the optimum localization criteria for the laboratory,
- Study of the physical and chemical (including geological) properties of rock salt from the site of the potential localization,
- Formulating the constitutive law and effort criteria for rock salt formation,
- Cavern stability evaluation.

The staff members undertaking the work will include:

- Kazimierz Ślizowski – Head of the Underground Storage Department.
- Wiesław Bujakowski – Head of the Renewable Energy Department
- Zenon Pilecki – Head of the Department of Geodynamics and Environmental Engineering
- Kazimierz Urbańczyk – Specialist in the mathematical modelling of physical processes
- Jarosław Ślizowski – Specialist in the geomechanics of rheological media

[IFIN-HH] "Horia Hulubei" National Institute of R&D for Physics and Nuclear Engineering

The origins of the National Institute of R&D for Physics and Nuclear Engineering - Horia Hulubei, IFIN-HH go back to as early as 1949 when a small Institute of Physics of the Romanian Academy was founded. It was reshaped in 1956 and renamed as the Institute of Atomic Physics (IFA), http://www.nipne.ro.
In 1977 the Central Institute of Physics (ICEFIZ) was set up to co-ordinate the entire physics research in Romania. The main institute of this system was the Institute of Physics and Nuclear Engineering (IFIN). In late 1996, IFIN was elevated to national institute and was named after Horia Hulubei, its original founder, becoming the Horia Hulubei National Institute of R&D for Physics and Nuclear Engineering (IFIN-HH).
IFIN-HH is a National Institute of Research & Development mainly funded by the Ministry of Education and Research
Facilities: U120 Cyclotron, 1959, MP Tandem Accelerator, 1974, Radioisotope Production Center, 1974, Nuclear Waste Processing and Storage Centres, 1974, Multipurpose High Dose Gamma-Ray Irradiator, 2000, cosmic ray muon detector WILLI (1995), Underground Laboratory – Slanic Prahova (2006)
The main research and development areas: theoretical physics and high energy, particle and astroparticle physics, atomic physics and nuclear structure, interdisciplinary researches with accelerated particle beams, nuclear technologies and radiation metrology, radiation biophysics and biochemistry, radioecology, instrumentation for nuclear research and technologies, information systems, data bases and computer networks

Profile of the staff members who will be undertaking the work:
- Romul Mircea Margineanu: senior scientist, founder and head of the Romanian Underground Laboratoy – Slanic Prahova
- Apolodor Aristotel Raduta: Prof. senior scientist, work on theoretical particle and astroparticle physics, theoretical studies of neutrino physics
- Iliana Brancus: senior scientist, head of the Romanian group of astroparticle physics, work on cosmic ray muons, Extensive Air Showers, etc
- Corina Anca Simion: senior engineer, radio chemistry, Tritium, C14, Actinides, etc
- Ana Apostu: research assistant, work on high resolution gamma ray spectrometry, etc
- Alexandra Saftoiu: engineer, work on cosmic ray muons, Extensive Air Showers, etc
- Sabin Stoica: senior scientist, work on theoretical physics: neutrinos, double beta decay, etc
- Mirel Petcu: senior scientist, electronic specialist (DAQ)
- Octavian Duliu: Prof. Faculty of Physics Bucharest, Nuclear Physics Departement
- Octavian Sima: Prof. Faculty of Physics Bucharest, Nuclear Physics Departement
- Gheorghe Cata Danil: Prof. Poly-technical University Bucharest, head of physics cathedra
- Adrian Oprina: mine engineer, Slanic salt mine – director
- Florin Chipesiu: mine engineer, Slanic salt mine – technical director

Technodyne International Ltd

Technodyne International is a specialist Engineering Design consultancy, based in Eastleigh, on the UK South coast. Their main focus is on the design and engineering of Cryogenic Storage tanks but their broad scope of experience and flexible approach enables them to undertake a diverse range of projects, providing cost-effective and dependable solutions for their worldwide client base. Their in-house team of approximately 20 highly experienced and qualified engineers has accumulated over 300 man-years of valuable experience in the engineering industry, including Aviation, Automotive, Energy Supply, Marine, Nuclear, Oil & Gas, and Petrochemicals. During the last 10 years, they have worked on designs for over 40 large cryogenic storage tanks, including the current world's largest tanks for LNG storage, and they have been retained as engineering consultants on many others. No other company can combine this capability with their ability to harness the knowledge and experience gained from executing many very large and sophisticated projects for industrial applications, and defence projects: these are invariably "one-offs" (there are never any prototypes, or "trial runs", they must work first time). Their projects range from small consultancy roles, to involvement in those projects with a capital value in the hundreds of millions of Euros. As an ISO 9001 accredited company, their work is carried out to the highest quality standards, while their Health & Safety training complies with best industry practices.

The staff members undertaking the work will include:

- M. Haworth, director responsible for engineering, member of the institute of mechanical engineers, member of royal aeronautical society. Experience: 10 years as founder director, 4 years corporate management British Gas, 15 years in cryogenic tank and vessel engineering, and construction in the Petrochemical industry, 6 years experience in Defence and Aerospace special projects, total 35 years of experience in engieneering design, engineering, project management and construction of multi-discipline teams in small and large companies. Consultant of Owner's Team for tanks specs 3 new LNG tanks for Isle of Grain (UK), Owner Engieneer Team member for new LNG terminal in Europe, consultant on refurbishment Design of LNG tank for Isle of Grain, fitness for purpose assessment of LNG tank, India, Review seismic capability of existing LNG tank (UK), assessment of ability to meet current codes, calculations, establish failure rates, meeting with HSE. LNG piping stress analysis. Design of 4 LPG tanks for Agip (Italy). Design of LNG tank (China). Design of Propane tank (Spain). Design of 80'000 m3 LPG tanks (full design package of calc, detail drawings, MTO). Modifications to LNG tank Dynevor.
- D. Gurney, engineering manager, team leader. Professional and competent computer systems engineer. Experienced in leading teams of software and hardware engineers and in the use of a variety of computers, operating systems and programming languages. Has an in-depth knowledge of software quality control systems, cost/time estimation and the use of structured methods to ensure successful project completion. Lead Engineer for the design of 7500m^3 Liquid Ethylene Tank for Vijay Tanks, India. Lead Engineer for the concept design of a 75000m^3 Liquid Argon Tank for basic element physics research. Lead Engineer for the design of a 10000m^3 LNG Tank for Chemtex, China. Design and specification of insulation systems for various Cryogenic Tanks including LNG, Liquid Ethylene, Propane, Butane and Argon.
- J. Thompson, administration, finance, electrical and C&I engineering. Experience: 40 years in electrical and project engineering; 10 years as Director of Technodyne International Limited, a company specialising in cryogenic storage facilities for LNG, LPG etc, and in the design and supply of aerospace and industrial test facilities; Extensive project management experience of major electrical equipment installations worldwide; Bid preparation, equipment marketing and sales of high value capital projects worldwide; Corporate Management of USA subsidiary company.
- R. Rogers, mechanical engineer. Engineering manager, over 35 years experience of mechanical engineering design and management on a wide range of capital plant and equipment. Work has included direct line management and direction of multi-disciplined engineering and design.
- B. Brockway, senior mechanical design-engineer. Design of Cryogenic Tank components, detail draughting. Responsible for design and supply contracts for 3x80'000 m^3 LPG tanks, 15'000 m^3 Ethylene tank (China), 25'000 m^3 LPG tanks.
- Pool of three analysts and up to 8 drafters for engineering analysis

AGT Ingegneria Srl

AGT Ingegneria Srl (ISO 9001 accredited company), together with its partner (sub-contractor) Geoingegneria Srl, are both companies that work and collaborate in the field of road and geotechnical engineering.

The staff members who would be undertaking the work:
The two Technical Directors, Ing. Marco Temussi (AGT Ingegneria) and Ing. Giuseppe Ristaino (Geoingegneria) have more that 20 year experience in the above fields; their jobs in design have been committed by some of the most important italian purchasers, in the public and in the private sectors (both building firms and engineering companies)
The most significant achievements in the recent years are:

- the preliminary design of all the road and railway connections in the General Contractor tender for the bridge over the "Stretto di Messina" (coordinator: Ing. M. Temussi), which includes several tunnels longer than 1 km;
- advise, as consultants, about geotechnical, geo mechanics and computing matters in many executive designs committed for the renovation of several parts of the Salerno-Reggio Calabria motorway, including natural tunnels with double pipe, for a total length of 5,744 Km, and all the needed connections;
- advise, as consultants, about geotechnical, geo mechanical and computing matters in the executive design and the construction of the closest part to Terni of the new highway Civitavecchia-Orte-Terni-Rieti, which includes three natural tunnels (the "Valnerina" Tunnel – about 4 Km long - the "Svincolo Valnerina" Tunnel and the intermediate access, called "Discenderia" Tunnel) for about a total length of 5,060 Km, together will all the artificial excavations needed to connect them;

The feasibility study proposed by AGTingegneria, in co-operation with Geoingegneria and other experienced subcontractors, will include:

- The determination of the optimal location for the underground laboratory, based on the geological, the geomorphological and the hydro geological characteristics of the site, and taking into account the scientific requirements as well;
- The geological, geotechnical and geo mechanical characterization of the formations found in the area under investigation and in the selected site; the prediction of the mechanical behaviour of the rocks and the preliminary design of the underground pits, including the assessment and the check of the stabilization work for the excavation, achieved through the use of specific computing programs based either on custom code, developed within the companies, or on standard technical codes (f.e.m.), internationally used, such as: PHASES (Plastic Hybrid Analysis of Stresses for Estimation of Support), developed by E. Hoek, J.L. Corvalho e B.T. Corkum at the Toronto University; FLAC (Fast Lagrangian Analysis of Continua), developed by M.J. Coetzee, R.D. Hart, P.M. Varona e P.A. Cundall for the Itasca Consulting Group, Inc. Minneapolis, Minnesota, USA;
- The preliminary design of the infrastructure equipments (ventilation, power supply, etc.);
- The analysis and the study of the safety requirements and infrastructures;
- The preliminary design of the road links within the site, at all phases of the project (building, assembling and installation of the scientific equipment, normal working of the laboratory);
- The study and the evaluation of the environmental impact of the project;
- The estimation of the costs for civil works (excavation, structures, external roads) and of the time for the execution of the excavation and of the subsequent works.

B.1.6. Consortium as a whole

The consortium includes very different participants from academic and industrial sectors. These combine the best European expertise in their technical and scientific fields. Due to the many stages involved in the transferral of concepts into functional technical plans, dissemination of knowledge is guaranteed between the scientific community and industry throughout the process. This guarantees the best possible potential for the exploitation of the results of this study and of the subsequent steps.

There is a clear complementarity of expertise among the scientific partners of the consortium. They are united by common physics goals and form a community speaking the same language. A list of most relevant scientific publications by members of the consortium can be found below. The study gathers some of the top specialists in the field, working at some of the leading institutes in European particle and astroparticle physics, as can be seen in the list of selected references below. This will assure that results will be delivered within the given time and cost framework. A long and well-structured preparation process has brought the members closer together and created a strong spirit of togetherness. A common scientific paper has already been published[9].

At the same time, a clear fraction of the consortium is composed of industries, selected uniquely because of their level of expertise. These companies represent the highest level of expertise that can be found in Europe to solve a particular problem. We are fortunate to have them as partners rather than subcontractors. In this way, they will be better integrated in the workflow and the exchange between scientists and engineers will be more efficient. In addition, the synergy between different companies in different countries working together, exchanging local expertise, to study multiple sites, with open access to information, will be an enriching experience. This is also one of the reasons why we proposed them as technical partners and not subcontractors.

Overall, we expect that all members from different communities will be integrated and united within the goal of the DS.

Additional scientific partners could be tempted to join the DS at later stages. We can mention the U-Helsinki who has already expressed an interest. Similarly, some other members from European universities and institutions have expressed desire to join the effort, possibly at a later stage.

Subcontracting: we intend to rely on subcontracting of part of the WP work in two specific cases:

- Feasibility study in Canfranc (LSC): The LSC does not have its own Geotechnic Department and therefore the Characterization-Feasibility Study will be subcontracted to one outside company. This will be chosen between at least three candidates after the mandatory tendering procedure within the Spanish Law. We have identified and contacted three geotechnic companies in Spain which apparently are able to do the job and have explicitly shown their interest on it. They are a) "STMR S.L." which has participated in some crucial phases of the construction of the current LSC, b) "GEOCONSULT-España, Ingenieros Consultores S.A." which accredits the design and construction-supervision of caverns with volumes of the same order of magnitude as required in LAGUNA (mainly for mining purposes), and c) "GEOCONTROL S.A." which accredits the design of large caverns for several hydraulic power plants both in Portugal and Spain.
- Feasibility in Fréjus (LSM): the region is very well known from a geophysics point of view thanks to the existing highway tunnel and in particular because of the recent investigations related to the construction of the new safety tunnel. Several companies exist in Europe, which could be ideal candidates to perform the subcontracted work. We intend to follow the tendering rules to adjudicate the contract. It is already foreseen that the firm, which will win the contract for the Fréjus safety gallery, will be in the best condition to perform the work for LAGUNA DS. We expect that the name of the firm will be known by the time of the start of the DS.

Additional beneficiaries / competitive calls: we do not a priori intend to attract additional beneficiaries following competitive calls. However, it is worth underlining that the participation of the Italian National Institute for Nuclear Research (INFN) would have been welcome: the INFN has traditionally played and continues to play an important role in particle physics and astrophysics in Europe and should have therefore been interesting in participating in the present design study. Unfortunately, it was not possible to convince INFN to sign the proposal or to enter negotiation once the proposal was accepted. In addition, we support the recommendation from the ESR to aim at a possible eventual participation of the INFN during the duration of the design study.

[9] J. Aysto et al., arXiv:0705.0116v1 [hep-ph].

B.1.7. Resources to be committed

The "added-value" of the DS revolves around the need for an integrated and coherent European effort towards next generation large-scale underground science. The site and tank engineering corresponds to two regions of focus (explicitly WP2, and WP5), where the FP7 funding is expected to make the largest impact. In addition, the DS includes coherent activities in phenomenological and theoretical activities (WP4). In these latter, the involved institutes will commit their experienced manpower as shown in Table 1.3d. This experienced staff will obviously bring along and make available their existing local infrastructure and available equipment to the DS project, in particular for what concern experimental activities. Below we list in more details resources from each participant:

- The ETH Zurich group will contribute with personnel and staff, available equipment, local and national funds and large infrastructure to the implementation of the project.
- The group of LHEP Bern will contribute with personnel, funds, and local infrastructure.
- The University of Oulu receives and expects to receive substantial additional funding from the European Regional Development Fund for projects whose goals integrate with this DS, but because of EU regulations they cannot be counted as the local funding. The level of this funding is currently about 300 k€/year, and both the total amount and the share devoted to support LAGUNA may be significantly increased when LAGUNA is accepted.
- The DAPNIA (CEA) Department will contribute with personnel and with relevant equipment from its infrastructure. There are 5 laboratories of IN2P3/CNRS participating in LAGUNA (APC, LAL, LPNHE, CPPM and UCBL). They have on average 150 researchers and engineers each, developed mechanics laboratories (very large testing rooms in APC, CPPM and LAL), large expertise in electronics development. High level electronics experts participate in the project (C. Girerd from Lyon, C. De la Taille from LAL and also indirectly J. Pouthas from IPNO). The infrastructure of the Laboratoire Souterrain de Modane LSM will be available for the Design Study with a reasonable percentage of use of resources (10%). The Tier-1 level computing platform of IN2P3 in Lyon (CC-IN2P3) will be available for computing. Finally the legal, valorisation and financial services of IN2P3 will be used for the development of the contractual and financial aspects. The overall local available budget will be of the order of half a million euros in personnel and a quarter of a million in investment.
- The MPG(MPIK) will make available its very highly qualified staff in experimental and theoretical physics.
- The Technische Universität München will contribute to the DS with the already existing infrastructure and personnel, local and national funding.
- The Polish groups will contribute with personnel and infrastructure.
- The Sheffield group will contribute experienced local academic staff and technical effort (Table 1.3d) supported by infrastructure built from past and current local and national grants.

Finally, one can expect specific local or global sources of funding, to be synergistically employed with the EU funds. In addition, some of the underground sites included in this DS already have substantial infrastructures that can be exploited for this DS. The hosts (mine, tunnel) will also provide their infrastructures like access to existing and planned laboratory sites, typically at true-cost basis, and they will be involved in and informed on relevant steps of this DS. Most of the numerical computation involved in the civil and mechanical engineering will rely on the available infrastructure at the technical participants' home base.

It is also to be expected that several scientists from universities or institutes other than those listed as beneficiaries, will directly or indirectly complement the EC contribution by giving their time to work on the topics pertaining to this DS. In particular, we expect the physics work package (WP4) to foster an environment for general discussions within the scientific community, in dedicated seminar, workshops or international conferences.

Last but not least, specific entities, like for example the University of Helsinki, will also contribute to the DS although there are not direct beneficiaries. Helsinki Institute of Physics is considering a major proposal to establish a neutrino physics group to study neutrino phenomenology related to LAGUNA and neutrino beams.

B2. Impact

B.2.1. Strategic impact

B.2.1.1. Direct impact of this DS on scientific performance of Europe

The Conceptual Design Report resulting from this DS will be delivered to the appropriate funding agencies and policy makers (ApPEC, ASPERA, national agencies) for their evaluation. After appropriate reviews and consultancy, the respective organisations are expected to make decisions to realise the considered infrastructures. This Design Report should contain all necessary technical information required for the decisions, to be combined with the scientific priorities of the decision time.

The physics studies related to or motivated by this Design Study may widen our understanding of the universe and the properties of elementary particles. Particularly these studies may have major impact on many other experiments using similar kind of infrastructures, techniques or equipment.

B.2.1.2. Direct impact of the planned experiments on particle and astroparticle physics

Astroparticle physics has evolved as a new interdisciplinary field at the intersection of particle physics, astronomy and cosmology. It combines the experimental techniques and theoretical methods from both astronomy and particle physics. Particle physics is devoted to the intimate structure of matter and the laws that govern it. Cosmology addresses the large-scale structure of the Universe and its evolution since the Big Bang. Astrophysics studies the physical processes at work in celestial objects. Most discoveries in particle physics have immediate consequences on the understanding of the Universe and, vice versa, discoveries in cosmology have fundamental impact on theories of the infinitely small.

In 2005 the CERN Council initiated a Strategy Group to produce a Draft Strategy Document (DSD) addressing the main lines of Particle Physics in Europe, including R&D for novel accelerator and detector technologies. The DSD[10] was delivered to Council in July 2006 and unanimously approved. This document formed the basis of Particle Physics input to the European Roadmap on future, large-scale research infrastructures produced by European Strategy Forum on Research Infrastructures.

In this document, Council recognised that "A range of very important non-accelerator experiments take place at the overlap between particle and astroparticle physics exploring otherwise inaccessible phenomena; Council will seek to work with ApPEC to develop a coordinated strategy in these areas of mutual interest."

This DS will explore different detector technologies and different underground laboratory sites in order to identify the best strategy for future large-scale instruments in the domain of low energy neutrino astronomy as well as direct investigation of Grand Unification of the known elementary forces. Such detectors are needed for experiments where a small counting rate or weak interaction cross sections play a key role, notably the search for proton decay and for numerous applications in the area of neutrino physics and neutrino astronomy.

One major objective of such detectors is the search for proton decay, a fundamental process that has eluded detection, yet is a natural consequence of virtually all unified particle-physics theories. They are strongly supported by indirect evidence besides their compelling theoretical appeal. The detection of proton decay and the identification of the decay channels would be a major discovery, providing us with new and deep insights into the structure of matter at extremely small scales.

The second major motivation obtains from the unique capabilities of the proposed large-scale detectors in the area of neutrino physics. These detectors allow for unprecedented measurements of fundamental neutrino properties, providing crucial input for the understanding of the elementary structure of matter. In addition, one can probe the properties of the neutrino sources, notably the Sun, core-collapse supernovae, and the Earth itself.

The solar neutrino flux would be measured with unprecedented accuracy, allowing for real-time observations of the Sun in the ``light of neutrinos.'' Such precision observations would both improve our understanding of the Sun as a typical main-sequence star and lead to a much improved measurement of the neutrino mixing parameters that are responsible for solar neutrino oscillations.

Atmospheric neutrinos will be observed with high statistics and superior angular resolution, allowing for improved measurements of atmospheric neutrino oscillation parameters. Turning the argument around,

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[10] The CERN Council, in a special meeting held the 14th of July 2006 in Lisbon, agreed on the European strategy for particle physics. The strategy is defined by the 17 statements approved by Council, and contained in the Strategy Statement (available at http://council-strategygroup.web.cern.ch/council-strategygroup/).

this would also lead to a better understanding of the primaries and the neutrino production in the atmosphere.

The large-scale detectors that we study would have outstanding capabilities to observe in detail the spectral and temporal features of the “neutrino light curve” from a core-collapse supernova in our galaxy. Such an observation would provide crucial tests of the core-collapse paradigm and the delayed explosion mechanism. In combination with electromagnetic and perhaps gravitational-wave observations, a true multi-messenger understanding of this spectacular phenomenon would be obtained. Moreover, the neutrino signal carries information about neutrino mixing parameters that conceivably can be extracted with a large-scale detector.

Galactic supernovae are rare, perhaps a few per century. Still, one can detect the cosmic diffuse supernova neutrino background (DSNB) that originates from all past core-collapse events in the universe. Observing this flux would push the frontiers of neutrino astronomy to the edge of the visible universe, providing information, for example, about the cosmic star formation history.

Recently the Earth itself has been added to the list of measured natural neutrino sources. Studying these ``geo neutrinos,'' i.e. anti-neutrinos from the decays of natural radioactive elements in the Earth's mantle and crust, may eventually lead to serious geological investigations with neutrinos. The large detectors studied here could play a pioneering role in this field.

Reactor anti-neutrinos are a background for many of the delicate measurements envisaged with the large-scale detectors so that locations far away from nuclear reactors are desirable. On the other hand, reactor anti-neutrinos allow for very interesting measurements so that we will study scenarios where a reactor would be visible only for some time because of a movable or switch-on situation.

In combination with a neutrino beam, large-scale detectors allow for very precise measurements of oscillation parameters. These measurements aim - amongst others - at determining leptonic CP violation, which likely is connected to the creation of the matter-antimatter asymmetry of the Universe.

The origin and evolution of earth's geomagnetic dynamo is tied to its energy sources, and this in turn depends on the composition of the core. Does earth’s core contain a natural “geo-reactor”? By observing the number of neutrinos emanating from the core large underground detectors will measure radioactive decays in the earth's core to determine whether a geo-reactor sustains the earth's magnetic field.

The physics behind some of these observable effects has also interesting consequences for up-coming experiments at the Large Hadron Collider (LHC) and in Lepton Flavour Violation experiments (LFV). The LHC, for example, will test if the Minimal Supersymmetric Standard Model or some other new physics is realized in the TeV energy range. This will be a direct test of the extension of the particle spectrum, which is required for the unification of the known couplings of the electromagnetic, weak and strong forces. The type of extension has a sizable effect on the scale where proton decay is mediated, significantly affecting the expected proton lifetime. In addition the expectations for the dominant proton decay modes depend on the physics results to be found by the LHC.

B.2.1.3. Impact to technological development capacity in Europe

In addition to a boost to all the physics and engineering technologies associated with the tank and detector aspects of the project, we highlight here the anticipated major impact on the technological expertise of Europe in all aspects of underground engineering, safety and environmental fields across a range of disciplines. There is an ever-increasing demand for underground space worldwide and Europe holds leading positions in the field. However, there remain major engineering challenges so solve. An underground laboratory would provide both the academic and industrial communities with low-cost, long-term access to underground research sites to address these issues. For instance, progressive and sustained underground research is needed to develop new technologies for accurate prediction of rock behaviour, to understand the stability of deep underground constructions, the consequences of engineering activity there, the strength dependencies and mechanical properties of rock and the wider environmental impacts.

A deep massive volume underground laboratory as proposed provides a unique opportunity to address these challenges by making available a dedicated volume of rock directly accessible for long-term scientific and engineering research. A wide collection of rock engineering studies can then address fundamental questions in rock geophysics, expanding our technological capacity in areas such as fluid flow in rocks, excavation stability vs. rock fracture, and the relationship between high rock stress and increases in hazardous ground behaviours. A large, dedicated facility would also allow trials of new underground equipment to take place under controlled conditions free from constraints imposed by mining or tunnel operations.

All these aspects are core impacts available from the LAGUNA DS, which requires an engineering program to include rock characterization, design and construction, rock engineering, underground technology and safety. The engineering research envisaged will stimulate advances in underground construction techniques, improving cost-effectiveness and reducing risk. It will benefit European capacity and efficiency in the field by uniting expertise from different sub-fields, notably mining engineering with road tunnel engineering, and uniting activities across many countries. This process can build also on the demonstrated success of the FP6 ILIAS underground laboratory programme, which has, for instance, developed new approaches to the technology of safety underground.

A particular aspect anticipated will be technological impact on the development of better sensing techniques to characterise rock at depth - the development of emerging remote imaging technologies. This would be a core component of the underground engineering program providing an excellent opportunity for geoscientists and engineers to cooperate on new technologies. Studies of rock variables include hydrodynamics, plastic flow, gases, impact strength and fracture mechanisms. The ability to recognize and characterize rock complexity is important for design and construction of large underground caverns. Meanwhile, the combination of depth and large span plus the need for stability for over 50 years stretches current knowledge. The construction period itself provides a unique opportunity for development of excavation technologies and designs.

Of the highest importance, for what will be a civil facility possibly in a working mine or transport tunnel, is safety and environmental impact. These must be fully integrated throughout the planning, design and construction stages. The design study and subsequent laboratory thus provide an ideal route for developing advances in safety systems and technology. Particular attention would go to advances in areas such as underground communication, fire prevention, ventilation, access, emergency egress and refuge design. Advances in environmental science and engineering are also possible. For instance, rock temperatures increase typically at 1-3 ºC per 100 m of depth. This provides a means to undertake mechanical-systems research into environmental life support such as air conditioning and filtration at depth.

B.2.1.4. Impact on society

Environmental pressures, global warming, increasing population densities, increasing energy requirements, water shortages and protection of water supplies, growing transport systems, waste storage and disposal issues, increasing demand for scarce minerals and raw materials and concern for Earthquakes are all contributing to an accelerating demand worldwide for underground activity and the technology to support it. The LAGUNA programme, can provide clear impact on this demand from society.

For instance, new and deep underground laboratory space can provide vital access for research into geothermal energy and water flow behaviour in relation to fissures and rock mechanics. The latter can provide input to reservoir design and development to allow improved protection of drinking supplies. Bioengineering has a role to play here in understanding water purity aspects but also the possibility of improving waste disposal underground and carbon sequestration as a route to reduction of CO_2 in the atmosphere.

Radon emanation and fluid flow underground is now known to be related to rock seismic activity at depth. This opens the possibility of a route to prediction of Earthquakes. New underground laboratory space would offer the opportunity to measure directly the relationships and confirm the seismic properties of rock in this respect. In particular, this would allow researchers to understand the time-development of fault processes and hence produce improved computer simulations to allow predictions to be made of possible future earthquake activity that could have severe impact on local populations.

Life is now known to exist underground, in fact accounting for around 50% of the Earth’s biomass. It is even possible that life originated deep underground. A new discipline in biology, geomicrobiology, has emerged to study this deep subsurface microbe population (“dark life”). The studies could have extreme implications for society, including progress towards an understanding of the origins of life, the impact of the biomass on the environment and evolution of the Earth. Development of pristine underground areas is now vital to the research and would stimulate further merger of fields as diverse as geochemistry, geology and hydrology with biology and genetics. The interaction of this life with the environment past and present is not understood and there are likely new practical applications that will emerge. The future large underground facility will offer an exceptional opportunity to carry out the studies needed.

B.2.2. Plan for the use and dissemination of foreground

This DS has a clear “user chain” flow for dissemination and exploitation, as illustrated in Figure 6. As was mentioned in the ApPEC/ASPERA roadmap, this DS emerges from a need of the scientific community. During the DS, the many reports to be compiled (see deliverables list) will serve as database of open documents. Any publication will be opened to the public and be disseminated in various ways:

- The intermediate results and the status of the project will be reported to the scientific community by regular presentations in conferences, workshops and seminars.

- The final report will be transmitted to ApPEC/ASPERA with the plan that the results of the feasibility of a large underground deep science research infrastructure in Europe (but global in nature) be included in the ESFRI roadmap.
- A web page showing the goals, results and status of the project will be set up and maintained by the LAGUNA executive board and secretariat.
- Technical reports resulting from this DS will be made available for all interested parties by electronic distribution.
- Scientific results will be published according to good scientific traditions in journals, reports and conferences.
- The final technical report (CDR) will be announced on month 36 and distributed to the community, to the funding agencies, and where appropriate to the press.
- The "deep science" document will be printed and distributed to funding agencies, universities and schools worldwide.
- The LAGUNA web site will remain active even after month 36, although updates will be less likely to occur.

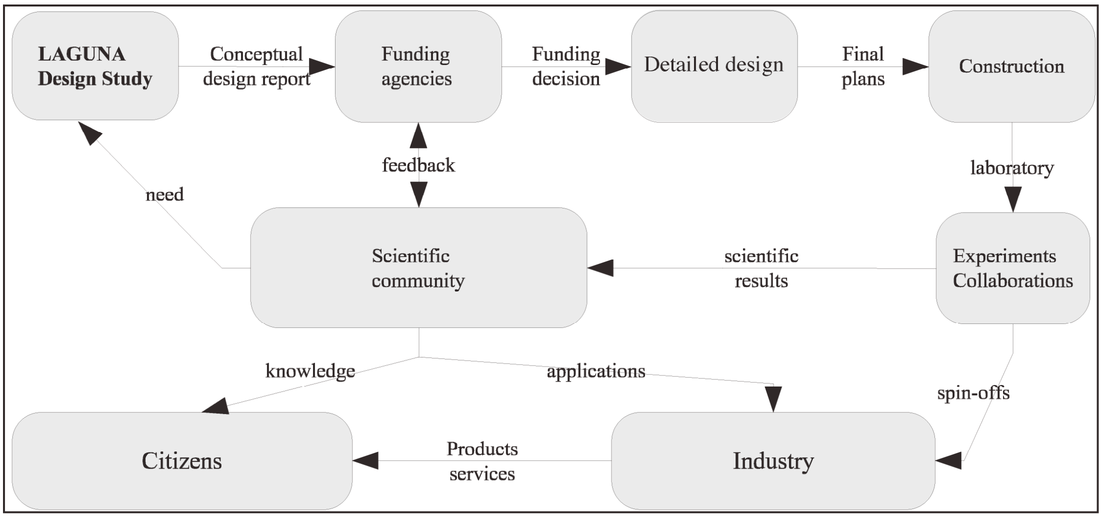

Figure 6 User chain flow.

The results of the studies will be published in a series a document, culminating with the final document. The final report will contain the objective and scientific information needed to reach the funding and construction phase. Assuming a positive feed-back from the funding agencies, the final report will be a starting point for a subsequent detailed design work. This would lead to final plans for construction and approval of the new research infrastructure. The experimental results to be obtained in the research infrastructure will provide top-class, forefront scientific results, which will feedback to the scientific community. Of course, citizens will be part of the process and will acquire knowledge from the scientific community. Similarly, direct spin-offs and applications will feed into the industrial component, which itself via products and services will provide improved quality of life to the citizens.

No serious issues related to intellectual properties management are expected, as the design study will produce information to the public, except otherwise governed by specific intellectual property rights or a confidentiality agreement, like e.g. in a few explicit internal items related to the exploitation of particular sites. In particular, some information about the mines will not be made public.