Proposal full title	**Design Study for a Deep Sea Facility in the Mediterranean for Neutrino Astronomy and Associated Sciences**
Proposal acronym	**KM3NeT**

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Table 1 – List of participants of the Design Study, part 1/4

Participant number	Organisation	Short name	Short description (i.e. fields of excellence) and specific roles in the consortium
1	University of Erlangen, Germany	U-Erlangen	The physics institute of U-Erlangen has been participating in various high-energy physics experiments and is involved in the ANTARES pilot project since 2001. The University administration has managed several FP6 projects. U-Erlangen will contribute to simulation and reconstruction tasks as well as to the detector design and will coordinate the Design Study.
2	University of Kiel, Germany	U-Kiel	As a branch of U-Kiel, the *Forschungs- und Technologiezentrum Westküste (FTZ)* (Research and Technology Centre West Coast) at Büsum unites several disciplines of research on the Wadden Sea and the bordering coastline. The group working on applied physics and marine technology will contribute their expertise in marine technology to the Design Study.
3	University of Cyprus, Nikosia, Cyprus	U-Cyprus	The physics department of the U-Cyprus hosts all research activities in particle physics and astrophysics in the Republic of Cyprus. It has a large scientific computing centre. It will contribute to the simulation of astro-particle physics processes for the Design Study.
4	Institut Français de Recherche pour l'Exploitation de la Mer, France	IFREMER	IFREMER is the French Research Institute for the Exploitation of the Sea. It deals with most disciplines of sea reasearch in marine technology, oceanology (studies on climate, sea environment, bio-diversity, marine geology,. . .) and associated data management. IFREMER has designed the marine architecture for the ANTARES pilot project and performs all sea operations. It will contribute its expertise in the fields of marine technology, hydrodynamics and sea operations to the Design Study.
5	Centre National de la Recherche Scientifique/ Institut National de Physique Nucléaire et de Physique des Particules (CNRS/IN2P3), France	IN2P3	IN2P3 is a division of CNRS operating more than 20 laboratories around France charged with research in particle, astro-particle and nuclear physics. Of these, the Centre de Physique des Particules de Marseille (CPPM) and the Institut de Recherches Subatomiques (IReS) in Strasbourg are involved in the ANTARES pilot project, where CPPM has coordinated the design studies for the ANTARES pilot project and developed the deep sea acoustic positioning system. CPPM and IReS will contribute to the scientific and technical aspects of the Design Study and coordinate the *Astro-particle Physics* work package.
6	Département d'Astrophysique, de Physique des Particules, de Physique Nucléaire et de l'Instrumentation Associée, CEA/Saclay, France	Saclay	Saclay employs about 650 scientists, engineers and technicians and is specialised in astrophysics, particle physics and nuclear physics. Its fields of excellence include construction and operation of detectors for ground based and space experiments. Saclay is in charge of the coordination of physics studies in the ANTARES pilot project. It does the production of optical modules for ANTARES, coordinates the assembly of the detector units and contributes to the sea operations. It will coordinate the *System and Product Engineering* work package.
7	Hellenic Centre for Marine Research (Institute of Oceanography), Anavissos, Greece	HCMR	HCMR groups the majority of sea related research activities in Greece with about 450 researchers and technical staff. It owns and operates several surface and underwater research vessels and is engaged in several EU projects. Large scale facilities will be used in the project like the multi-beam bathymetry, sediment traps, a remotely operated submersible, etc.
8	Hellenic Open University, Patras, Greece	HOU	The Department of Natural Science of the HOU is member of the NESTOR pilot project. It has developed the main reconstruction algorithms for the analysis of the data. It will coordinate the *Physics Analysis* work package and will contribute to the data acquisition studies.

Table 1 – List of participants of the Design Study, part 2/4

Participant number	Organisation	Short name	Short description (i.e. fields of excellence) and specific roles in the consortium
9	National Centre for Scientific Research "Demokritos", Athens, Greece	NCSR "D"	NCSR "D" is the largest research centre in Greece covering most areas of natural science. It hosts "centres of excellence" in material science, nuclear physics, information technology, physical chemistry, nuclear safety and radiation biology. The institutes of nuclear physics and of nuclear technology will contribute to the Design Study. The governance, legal and funding aspects of the proposed infrastructure will be studied by a team led by the former director of NCSR "D" who has extensive experience of science policy, governance and funding issues in the EU context.
10	National Observatory of Athens/Nestor Institute of Astro-particle Physics, Athens, Greece	NOA/Nestor	NOA is the oldest science centre in Greece and hosts five institutes specialised in space physics, atmospheric physics, geo-dynamics, astronomy and astro-particle physics. The Nestor institute pioneered neutrino telescopy in Europe by initiating the NESTOR pilot project in 1991. It will contribute its experience with building, deploying and operating small-scale underwater structures to this Design Study. It will coordinate the *Sea Surface Infrastructure* work package.
11	University of Athens, Greece	U-Athens	Following a series of contributions to experiments in particle physics at CERN and Fermilab (USA), the physics department of the U-Athens was a founding member of the NESTOR pilot project in the early 90's. It will contribute to the reconstruction software and to the studies of a general-purpose sea surface infrastructure.
12	Istituto di Scienze Marine, La Spezia, Italy	CNR	The Istituto di Scienze Marine (ISMAR) is a multidisciplinary institute of the Consiglio Nazionale delle Ricerche (CNR), covering a large part of marine disciplines: from physics to geology, chemistry, biology and fishery. For the Design Study, the sections of La Spezia and Genova will contribute to the oceanographic characterisation of the deep sea, the measurements of fouling and corrosion and to the development of a model for long-term measurements of climate changes or trends.
13	Istituto Nazionale Fisica Nucleare, Rome, Italy	INFN	INFN supports all theoretical and experimental research activities in sub-nuclear, nuclear and astro-particle physics in Italy. It operates four national laboratories and participates in experiments at various international research centres. The INFN groups participating to this Design Study (Universities of Bari, Bologna, Catania, Genova, Messina, Pisa, Roma-1 and the laboratories LNS Catania and LNF Frascati) are members of the pilot projects NEMO and ANTARES. INFN will contribute to the physics studies and detector simulation of the Design Study and will coordinate the *Shore and Deep-Sea Infrastructure* and *Risk Assessment and Quality Assurance* work packages.
14	Istituto Nazionale di Geofisica e Vulcanologia, Rome, Italy	INGV	INGV is the most important research institute for seismic and volcanic hazard studies in Italy. Since 1995, INGV is involved through its RIDGE Marine Unit in geophysical and environmental monitoring at sea. It has been coordinator of the GEOSTAR and GEOSTAR 2 EU projects that developed the first European seafloor multidisciplinary observatory and is presently coordinator and partner of many other national and international projects. In the Design Study, INGV will perform marine geophysical and environmental studies, deep-sea monitoring, operation of benthic observatories and will study the opportunities offered by a deep sea platform for long-term multidisciplinary monitoring tasks.

Table 1 – List of participants of the Design Study, part 3/4

Participant number	Organisation	Short name	Short description (i.e. fields of excellence) and specific roles in the consortium
15	Tecnomare SpA, Venice, Italy	Tecnomare	Tecnomare S.p.A. (ENI group) is specialised in providing a complete range of off-shore design and engineering services for international oil and gas companies, supporting them in their core business developments. Since 30 years, Tecnomare has actively participated to a large number of research projects. It is presently involved in the development and demonstration of innovative technologies for long-term deep sea monitoring and observations (e.g. ABEL, GEOSTAR, GEOSTAR 2, ORION-GEOSTAR 3 and ESONET). Its tasks in the Design Study will be tooling for the deployment and recovery of deep-sea instruments.
16	Stichting voor Fundamenteel Onderzoek der Materie, Utrecht, The Netherlands	FOM	NIKHEF is the national institute for experimental and theoretical subatomic physics in The Netherlands, in which the funding agency FOM and the Universities of Amsterdam, Nijmegen and Utrecht participate. NIKHEF is principal partner in the DataGrid and EGEE projects and houses AMSIX, the Amsterdam Internet Exchange point. NIKHEF is the creator of the "All Data to Shore" solution for the readout system of the ANTARES pilot project. NIKHEF will coordinate the studies related to data acquisition, processing and distribution (*Information Technology* work package).
17	Consejo Superior de Investigaciones Científicas, Valencia, Spain	CSIC	CSIC and the University of Valencia (see participant 18) operate together the Institute of Particle Physics (*Instituto de Física Corpuscular, IFIC*). IFIC is member of the ANTARES pilot project. It contributes to the design and production of the timing calibration system and to the development of reconstruction algorithms and to physics analysis. It will contribute to the design and preliminary tests of spatial, time and amplitude calibration systems for the neutrino telescope.
18	Universitat de Valencia Estudi General, Spain	U-Valencia	U-Valencia is the second mother organisation of IFIC (see participant 17). IFIC is represented in the Design Study as one homogeneous scientific working group that appears as two participants for purely administrative reasons. The description of CSIC thus also applies to U-Valencia.
19	Universidad Politécnica de Valencia, Spain	UP-Valencia	The UP-Valencia group takes part in the Acoustic and Optic Devices and Systems R&D program (DISAO), investigating a.o. dynamic and piezoelectric transducers, ultrasounds, materials, acoustic positioning in the sea, etc. The competence of the group, combined with a particle physics background of several group members (DELPHI, ATLAS, HADES) will be contributed to this Design Study.

Table 1 – List of participants of the Design Study, part 4/4

Participant number	Organisation	Short name	Short description (i.e. fields of excellence) and specific roles in the consortium
20	University of Aberdeen, UK	UNIABDN	UNIABDN is an international university of which its sub-sea research is concentrated in the associated *Oceanlab* research centre. Oceanlab is coordinating member of the European Sea Floor Observatory Network (ESONET). It will coordinate the various marine biology, environmental, geology, geophysics and oceanography studies.
21	University of Leeds, UK	U-Leeds	With both Auger and VERITAS the School of Physics and Astronomy at U-Leeds participates in two major astro-particle physics projects. The group has expertise in photodetector development, electronics systems design and physics analysis. The contributions to KM3NeT will focus on detector simulation, and design optimisation w.r.t. the astrophysics potential and work on light collection, photodetectors and analogue signal transmission.
22	University of Liverpool, UK	U-Liverpool	U-Liverpool has one of the largest particle physics groups in the UK with expertise in detector development, simulation and data analysis using GRID and eScience technologies. U-Liverpool is involved in experiments at CERN, DESY, FNAL and SLAC. It will contribute to detector modelling and optimisation activities, to studies of the physics reach of KM3NeT and to prototyping of calibration devices.
23	John Moores University, Liverpool, UK	LJMU	John Moores University, through its wholly owned subsidiary Telescope Technologies Limited, has expertise in the field of design and production of high-precision automated systems and special interest in astronomical instrumentation. It will contribute its scientific requirements capture and system engineering expertise to this Design Study.
24	University of Sheffield, UK	U-Sheffield	The Particle Astrophysics group at U-Sheffield is specialised in matter searches via direct and indirect methods. The group has designed and commissioned the time calibration system for the ANTARES pilot project. U-Sheffield will contribute to simulating and optimising the KM3NeT detector and will also be involved in the design of new calibration sub-systems.

Table 2 – List of tasks for the Design Study

Task	Descriptive title	Leading participant	Short description and specific objectives of the task
WP1	Management of the Design Study	U-Erlangen	Management of the administrative, financial, legal, contractual and social aspects of the Design Study; audit and report activities; coordination of work packages and technical activities; knowledge and information management; development of KM3NeT cost models and definition of criteria on KM3NeT design and site decisions.
WP2	Astro-particle physics	IN2P3	Definition of benchmark neutrino fluxes; development of event simulation software; development of simulation software (including detector geometry, background sources, light propagation, modelling of online filter and detector response); software development for modelling and assessing accuracy of calibration procedures; optimisation of detector architecture.
WP3	Physics analysis	HOU	Development of algorithms and software for offline event selection and classification; development and optimisation of reconstruction algorithms for different event types; determination of the physics sensitivity as a function of the detector geometry, the environmental parameters and of the total cost of the KM3NeT infrastructure; development of data storage and distribution models.
WP4	System and product engineering	Saclay	Design of optical modules, calibration modules and mechanical support structures; optimisation of marine architecture, including evaluation of hydrodynamics and sea operation; implementation of readout system and calibration devices; development of assembly and transport procedures; design of detector production lines.
WP5	Information technology	FOM	Development of the readout and data handling technology, i.e. signal detection, transmission and digitisation as well as data processing and distribution. Definition of access protocols to scientific data.
WP6	Shore and deep-sea infrastructure	INFN	Site studies; design of installations and procedures for the deployment and recovery of telescope parts; specifications for cables and connections; construction drawings of the shore station; layout of the electrical power distribution; link to the European data network.
WP7	Sea surface infrastructure	NOA/Nestor	Technical preparatory work to develop and test techniques critical to the future use of autonomous, dynamically positioned, floating structures needed for deployment, recovery, maintenance and absolute angular calibration of the KM3NeT deep-sea infrastructure.
WP8	Risk assessment and quality assurance	INFN	Quality assurance of the telescope parts and the assembly procedures; risk analysis of design and operation of the telescope.
WP9	Resource exploration	NCSR "D"	Exploration of the governance, legal and funding aspects for the construction and operation of the telescope as a pan-European project.
WP10	Associated science	UNIABDN	Cooperation model between the neutrino telescope community and the deep-sea science communities; identification of the associated users and their data requirements in terms of temporal and spatial characteristics; definition of sensors, hardware and power requirements; definition of interfaces for common usage of the KM3NeT infrastructure; design concept of an associate science node; associated science input to the KM3NeT design.

Table 3 – Summary table of the expected budget and of the requested Community contribution - Part 1/3

	Participant number																	
	1		2		3		4		5		6		7		8			
Task	**U-Erlangen**		**U-Kiel**		**U-Cyprus**		**IFREMER**		**IN2P3**		**Saclay**		**HCMR**		**HOU**		**sub-total**	
Amounts (k€)	exp. budget	req. contrib.	exp. budget	req. contrib.	exp. budget	req. contrib.	exp. budget	req. contrib.	exp. budget	req. contrib.	exp. budget	req. contrib.	exp. budget	req. contrib.	exp. budget	req. contrib.	exp. budget	req. contrib.
WP1	562	562															562	562
WP2	274	193			180	150			470	177	261	0					1185	520
WP3	355	175							427	177	720	240			500	400	2002	992
WP4	418	265	180	150			460	218	297	30	1433	240					2788	903
WP5	169	88							1022	250	1221	242			160	130	2572	710
WP6							270	128	145	50	283	0	560	280			1258	458
WP7			180	150					70	20	283	0					533	170
WP8											382	10					382	10
WP9									114	0							114	0
WP10							210	99	112	20			434	217			756	336
total expected budget (k€)	1778	—	360	—	180	—	940	—	2657	—	4583	—	994	—	660	—	12152	—
maximum Com. contrib. req. (k€)	—	1283	—	300	—	150	—	445	—	724	—	732	—	497	—	530	—	4661

Table 3 – Summary table of the expected budget and of the requested Community contribution - Part 2/3

			Participant number																	
			9		10		11		12		13		14		15		16			
Task	**carry-over**		**NCSR "D"**		**NOA/Nestor**		**U-Athens**		**CNR**		**INFN**		**INGV**		**Tecnomare**		**FOM**		**sub-total**	
Amounts (k€)	exp. budget	req. contrib.	exp. budget	req. contrib.	exp. budget	req. contrib.	exp. budget	req. contrib.	exp. budget	req. contrib.	exp. budget	req. contrib.	exp. budget	req. contrib.	exp. budget	req. contrib.	exp. budget	req. contrib.	exp. budget	req. contrib.
WP1	562	562																	562	562
WP2	1185	520									222	111					210	38	1617	669
WP3	2002	992									130	65					388	74	2520	1131
WP4	2788	903									398	199					588	151	3774	1253
WP5	2572	710									18	9					1710	433	4300	1152
WP6	1258	458					125	100	416	244	1786	893	718	423	90	45			4393	2163
WP7	533	170			1000	500	190	150											1723	820
WP8	382	10	330	165							424	212							1136	387
WP9	114	0	330	165															444	165
WP10	756	336							192	59			108	33					1056	428
total expected budget (k€)	12152	—	660	—	1000	—	315	—	608	—	2978	—	826	—	90	—	2896	—	21525	—
maximum Com. contrib. req. (k€)	—	4661	—	330	—	500	—	250	—	303	—	1489	—	456	—	45	—	696	—	8730

Table 3 – Summary table of the expected budget and of the requested Community contribution - Part 3/3

			Participant number																	
			17		18		19		20		21		22		23		24		total	max.
Task	**carry-over**		**CSIC**		**U-Valencia**		**UP-Valencia**		**UNIABDN**		**U-Leeds**		**LJMU**		**U-Liverpool**		**U-Sheffield**		**exp. budget**	**Com. contrib. req.**
Amounts (k€)	exp. budget	req. contrib.	exp. budget	req. contrib.	exp. budget	req. contrib.	exp. budget	req. contrib.	exp. budget	req. contrib.	exp. budget	req. contrib.	exp. budget	req. contrib.	exp. budget	req. contrib.	exp. budget	req. contrib.	**(k€)**	**(k€)**
WP1	562	562																	562	562
WP2	1617	669	286	83	111	83					116	46	37	30	122	62	176	62	2465	1035
WP3	2520	1131									117	46			152	62	162	62	2951	1301
WP4	3774	1253	102	30	40	30	205	94			187	93			151	61	162	61	4621	1622
WP5	4300	1152	20	6	8	6													4328	1164
WP6	4393	2163							320	210									4713	2373
WP7	1723	820																	1723	820
WP8	1136	387																	1136	387
WP9	444	165																	444	165
WP10	1056	428							180	119									1236	547
total expected budget (k€)	21525	—	408	—	159	—	205	—	500	—	420	—	37	—	425	—	500	—	24179	—
maximum Com. contrib. req. (k€)	—	8730	—	119	—	119	—	94	—	329	—	185	—	30	—	185	—	185	—	9976

1 European Added Value of the New Infrastructure

Philippe Busquin, EU Commisioner for Research:
We must converge and collaborate: no Member State on its own has the resources required to create the new large scale infrastructures that are required to compete with the US and Asia

Letizia Moratti, Minister of Research, Italy:
research infrastructures are a crucial tool for the growth of research in Europe . . . *while Member States have the right to develop individually, pan-European approaches can be more effective.*

Dimitris Deniozos, Secretary General for Research, Greece:
. . . a key issue is the transformation of existing national infrastructures into global facilities . . . this subject will have to be taken into account when designing the Seventh Framework Programme.

At a recent meeting[1] held at CERN to discuss the future of High Energy Physics, attended by seven Nobel Prize winners (S. Glashow, S. Ting and S. Weinberg from the USA and G. Charpak, S. van der Meer, C. Rubbia and M. Veltman from Europe) and a small number of other prominent physicists (amongst others P. Darriulat, L. Maiani, L. Okun and D. Perkins), the high level panel reached a remarkable consensus concerning the role and importance of astro-particle physics for future generations.

From a European perspective astro-particle physics – and underwater neutrino telescopy in particular – offers a unique opportunity for pioneering scientific infrastructure initiatives with a global appeal. At the moment the global effort in this field is focused around the IceCube[2] neutrino telescope in Antarctica, i.e. in the Southern hemisphere. The strong scientific case for a cubic kilometre deep-sea neutrino telescope in the Northern hemisphere has recently been documented in the report of the *High Energy Neutrino Astrophysics Panel (HENAP)* that was set up following the conclusions of the OECD MegaScience workshop of Taormina in May 1997.

At this time Europe is particularly well prepared to take up the technological challenge to build this frontier scientific facility in the Northern hemisphere as explained in the following: Over the past decade two major pilot initiatives in the Mediterranean have been exploring the technologies, building and deploying prototype telescopes designed to operate at depths ranging from 2500 to 4500 m. These two pilot projects, one off the coast of Toulon, France at a depth of 2500 m and one off the coast of Pylos, Greece at a depth of 4000 m have been essentially supported by national agencies and comprise pilot facilities that cover a few percent only of the desired infrastructure for a cubic kilometre neutrino telescope: KM3NeT. More recently a third national initiative in Italy has been exploring the properties of sites off the coast of Sicily and studying technological options for this cubic-kilometre infrastructure.

The total direct investment so far exceeds 50 M€ and several hundred years of human resources. Key components of a neutrino telescope have been built, deployed and successfully operated. Therefore, the scientific community involved feels confident to embark on a 3-year Design Study for a full KM3NeT facility. Given the scale of the facility, the budget required, if based on a simple extrapolation from the present pilot projects, would be of the order of 500 M€. We believe that, as a result of the proposed Design Study, this cost can be reduced by at least a factor of two, thus yielding an estimated investment of the order of 200 M€ for the planned infrastructure.

The new infrastructure will break new ground in deep-sea technology, in remote high-speed data acquisition and transmission to shore. Its realization thus poses challenging tasks at the forefront of current R&D by industry. Therefore, a synergetic cooperation is foreseen with enterprises specialised in these fields.

Scientifically, the KM3NeT infrastructure will have a world wide user community, to whom it will open a new window to the Universe by detecting cosmic neutrinos rather than electromagnetic radiation on which all observational astronomy and astrophysics is based so far. It will be a unique European facility that will complement and exceed the capabilities of the IceCube neutrino telescope in Antarctica.

Multidisciplinary research

The core discipline served by the new facility is astro-particle physics, a new scientific field with strong links to its two progenitors, astrophysics and accelerator-based particle physics. The new facility will attract significant interest from both these communities, and in this sense the planned facility is multidisciplinary *by construction*.

[1] see `http://agenda.cern.ch/fullAgenda.php?ida=a035290`
[2] See `http://icecube.wisc.edu/`

In addition, the possibility to monitor continuously over long periods and in real time the sea bottom at depths of the order of 4000 m is of utmost interest to a large number of sea-related disciplines like geophysics, biology, chemistry and environmental sciences.

The proposed Design Study includes participants from the associated science communities and establishes cooperation with the ESONET collaboration[3] that aims *to establish the basis for a marine component of GMES (Global Monitoring for Environment and Security) comprising a network of long-term, sea floor, multi-disciplinary observatories at key provinces around the European margin providing continuous vigilance in relation to geophysical, biogeochemical, oceanographic and biological phenomena. ESONET will be focused beyond the continental shelf edge in the ocean margin areas down to 4000 m depth which are less well known than the shelf itself and generally beyond the reach of existing ocean data systems.*

In this respect one should also note the USA/Canada-led Neptune[4] facility off the coast of British Columbia and the State of Washington that aims to provide an *"internet-linked platform for integrated Earth and ocean sciences at the scale of an entire tectonic plate using a network of submarine fibre optic/power cables to support multiple in situ sensor arrays and robotic laboratories for real time remote interactions with dynamic processes on, above or below the sea floor."*

Interest by EU organisations

- *EU member states*

  The three pilot projects in the Mediterranean Sea were initiated in the early 1990's: first off the coast of Pylos (NESTOR[5]), followed by the project off the coast of Toulon (ANTARES[6]) and more recently by the pilot project off the coast of Sicily (NEMO[7]). They have been essentially funded by national agencies through the appropriate agencies such as GSRT in Greece, CNRS and CEA in France and INFN in Italy. More recently, BMBF in Germany, PPARC in the UK, NWO/FOM in The Netherlands and CSIC in Spain have also made financial contributions. Underwater neutrino telescopy is thus on the agenda of seven EU funding agencies including all four Mediterranean EU countries. In addition to the total direct investment exceeding so far the 50 M€ mentioned earlier, the indirect investment in manpower and equipment adds up to about another 30 M€. The support for the pilot initiatives by the EU funding agencies mentioned above is expected to continue during the three-year KM3NeT Design Study period and, assuming that the outcome of the Design Study is technologically convincing and financially realistic, also in the construction phase of KM3NeT. In addition one new EU member (Cyprus) participates in the Design Study and several teams from new EU member states have expressed interest to join at a later stage (Czech Republic, Estonia, Hungary, Poland).

- *ApPEC*

  The Astro-particle Physics European Coordination (ApPEC), a body composed of leading scientists and representatives of several European research funding agencies, recommended in January 2003 that the three pilot neutrino telescopy projects in Europe join in a common effort towards a single cubic-kilometre telescope project. In November 2003 the proponents presented a draft version of the present proposal to the peer-review committee (PRC) of ApPEC. A final version was reviewed again by the PRC in January 2004. In February 2004 the ApPEC steering committee strongly recommended the submission of the present Design Study proposal to FP6 and certified it *a high degree of maturity*.

Interest by non-EU organisations

- *CERN*

  Both the ANTARES and NESTOR pilot projects have been granted the status of *Recognised Experiments* by CERN. This status was granted following a detailed presentation and review by the CERN Research Board and constitutes a peer testimonial to the scientific excellence and European interest of both projects. Although at present the top priority at CERN is the commissioning of the *Large Hadron Collider (LHC)* and its physics exploitation we believe that in the post-LHC period CERN is likely to expand its scope to non-accelerator astro-particle physics including neutrino telescopy. A corresponding personal statement was recently made by

[3] The European Sea Floor Observatory Network, see `http://www.abdn.ac.uk/ecosystem/esonet/`
[4] See `http://www.neptune.washington.edu/`
[5] See `http://www.nestor.org.gr/`
[6] See `http://antares.in2p3.fr/`
[7] See `http://nemoweb.lns.infn.it/`

the CERN Director General Prof. Luciano Maiani[8].

In the course of the proposed Design Study we will actively seek to draw upon CERN know-how, skills and experience in managing large international scientific projects. However, we must make clear that at this stage we do not envisage the organisational and physical structure of KM3NeT as a kind of mini-CERN dedicated to neutrino astro-particle physics. The balance between local, site-specific activities and global, distributed activities is more likely to draw from the experience of the large international observational astronomy facilities.

- *OECD*

  Following its meeting in Taormina in May 1997, the OECD MegaScience Forum asked the *International Union of Pure and Applied Physics (IUPAP)* to explore the scientific options for large scale research infrastructures in the emerging field of particle and nuclear astrophysics and gravitation. To this effect IUPAP created in 1998 the *Particle and Nuclear Astrophysics and Gravitation International Committee (PANAGIC)* which in turn set up the HENAP panel with the charge to investigate the scientific case for large-volume neutrino telescopes, to study the required detector specifications, to identify the needed steps to reach the required detector sensitivity and to address the socio-economic and cross-disciplinary aspects of these projects.

  The HENAP Report[9] was released in July 2002 and its nine recommendations provide the motivation and form the basis of the present proposal:

  1. The observation of cosmic neutrinos above 100 GeV is of great scientific importance. Such neutrinos open a new window to the most energetic phenomena in the Universe and represent an opportunity for scientific discovery that should be pursued.
  2. The detectors should be of km^3-scale, the construction of which is considered technically feasible.
  3. The driving motivation for km^3-scale neutrino detectors is the observation of cosmic point sources. For this purpose a complete coverage of the sky is an important goal, and thus a km^3-scale detector in the Northern hemisphere should be built to complement the IceCube detector being constructed at the South Pole.
  4. The existence of two detectors with different technologies is an important asset.
  5. The scientific objectives of km^3-scale detectors of cosmic neutrinos are strongly enhanced by contemporaneous observations of a broad spectrum of electromagnetic radiation, and thus it is important to set up coordination and communication between neutrino observatories and other major astronomy projects.
  6. The km^3-scale detector projects are unique facilities that should be open to all interested scientific teams who wish to contribute to their construction and exploitation.
  7. The km^3-scale detectors should be regularly monitored by international peer-review.
  8. Adequate planning to make the data collected by the detectors available to the scientific community is strongly encouraged.
  9. There is at this point no justification for more than one Northern hemisphere deep-water neutrino detector of km^3-scale.

- *USA*

  Many physicists from the USA have expressed interest in participating in the construction and utilisation of a cubic kilometre water Čerenkov detector. In 1976 they initiated the DUMAND project, an early precursor to KM3NeT. By 1989 a collaboration of 11 institutions in four countries had operated a prototype string at 4 km depth off Hawaii. Although a preproduction prototype was essentially ready to deploy in 1993, Department of Energy (DOE) funding for DUMAND (as well as for the Superconducting Super Collider) was cancelled due to the severe federal budget constraints in the USA at the time. All the equipment was transferred to NOA/Nestor, a collaborator of DUMAND, to assist the most advanced European project at the time.

  Last year the Antarctic Program of the US National Science Foundation (NSF) approved funding at the level of 100 M$ for a cubic kilometre detector deep in the ice at the South Pole. The substantial commitment of scientists funded by the NSF has engendered significant interest from the DOE in refunding a water detector in the northern hemisphere to follow up their earlier pioneering work.

- *Russia*

  Substantial contributions have also been made by the Academy of Sciences and the Institute for Theoretical and Instrumental Physics (ITEP) in Russia, who have provided manpower, knowhow, research vessels and materials, in particular to the NESTOR and ANTARES pilot projects.

[8] See `http://agenda.cern.ch/fullAgenda.php?ida=a035290`

[9] `http://www.lngs.infn.it/site/exppro/panagic/sections/particle/henap2002.pdf`

2 Scientific and Technological Excellence

The unique scientific value of measuring high-energy neutrinos of cosmogenic origin motivated searches for such signals in underground detectors originally dedicated to proton decay detection. Subsequently it has driven the development of various neutrino telescope pilot projects over the past 20 years. All these installations use naturally abundant material – water or ice – to detect the Čerenkov light emitted by secondary particles produced in neutrino reactions. Currently two such neutrino prototype telescopes, at Lake Baikal[10] in Siberia and AMANDA[11] at the South Pole are taking data. Two more small prototype telescopes in the Mediterranean are under construction in the framework of the pilot projects ANTARES and NESTOR. In the past years, it has become progressively clear that the exploitation of the full physics potential of neutrino astrophysics will require neutrino telescopes instrumenting at least one cubic kilometre of water or ice. Currently the only funded project that matches this requirement is IceCube, which will be installed until about 2010 at the South Pole using the experience of the AMANDA collaboration. The scientific community agrees that a second neutrino telescope of this size on the Northern hemisphere has to complement IceCube[12].

2.1 Quality of the New Infrastructure

The proposed KM3NeT infrastructure will accommodate a neutrino telescope with a volume of at least one cubic kilometre. The design, construction and operation of this neutrino telescope will be pursued by a collaboration formed around the institutes currently involved in the ANTARES, NESTOR and NEMO pilot projects. Based on the leading expertise of these research groups, the development of the KM3NeT telescope is envisaged to be achieved within a period of three years for preparatory R&D work plus five years for construction and deployment. The present proposal aims at performing the first of these phases in the framework of a Design Study of the European FP6 program.

The Mediterranean appears to be an ideal place for this future installation: it provides water of excellent optical properties at the right depth and excellent shore-based infrastructure for marine operations and on-shore data processing. Three possible sites in the Mediterranean Sea have been identified with good conditions (depth, accessibility and water properties). Several detector concepts have been proposed so far in the scientific community. The optimal combination of site and design will be found in the process of the Design Study.

The targeted operational parameters of the KM3NeT detector are: an angular resolution for muon events of better than 0.1° for neutrino energies exceeding 10 TeV; an energy threshold of a few 100 GeV (which can be lowered to around 100 GeV for specific directions by adapting the online filters accordingly); sensitivity to neutrinos of all flavours and to neutral-current reactions; maximal angular acceptance for all detectable signals (i.e. approaching 4π at high energies). Due to the reduced light scattering in water as compared to ice, the angular resolution and therefore the sensitivity to point sources will substantially exceed that of IceCube. The KM3NeT detector will thus be unique in the world in its physics sensitivity and will provide access to scientific data that will propel research in different fields, including astronomy, dark matter searches, cosmic ray and high energy physics. It is foreseen to make the data available to the scientific community, also beyond the KM3NeT collaboration. Furthermore, requests will be accepted after peer review by an independent panel to adjust the online data filters such that observations of particular sky regions can be performed with increased sensitivity (i.e. lower energy thresholds). This will be the first time that a neutrino telescope will be used as a scientific instrument available to a wide spectrum of users, as commonly practised in the astronomy community for observations with optical and radio telescopes.

Scientific motivation

Mankind has observed sources of light in the night sky for thousands of years. In recent decades, the observation of the sky has been dramatically extended from visible to "non visible" electromagnetic radiation with the detection of radio, X-rays and gamma-rays, leading to *multi-wavelength astronomy*. Recently, satellite experiments have shown the existence of galactic and extra-galactic sources of gamma rays up to several tens of GeV. Ground-based large-area detectors have shown that some of these sources produce electromagnetic radiation with an energy spectrum that extends up to several tens of TeV. The majority of the observed sources however become faint at these

[10] See `http://baikal1.jinr.ru/main.html`
[11] See `http://amanda.uci.edu/`
[12] See HENAP report, `http://www.lngs.infn.it/site/exppro/panagic/sections/particle/henap2002.pdf`

energies. This can be explained by the absorption of high-energy photons through interactions with the infrared (IR) or cosmic microwave background radiation (CMB). The detectable extragalactic sources with energies above a TeV should reside in the closest galaxies, as the CMB prevents us observing high-energy photons emitted by sources at larger distances. Apart from the energy spectra, the observed sources show different time behaviour: constant (e.g. the Sun); periodic (e.g. pulsars, Cepheids, binary stars); impulsive (e.g. gamma ray bursts (GRB), novae and supernovae) or erratic (e.g. active galactic nuclei (AGN)).

At the beginning of 20th century, the observation of increasing ionisation of the Earth's atmosphere at higher altitudes has led to the idea that charged particles from outer space impinge on Earth. Since the 1940's, larger and larger detectors have been built to detect cosmic rays (CR) at higher and higher energies. However, at energies above 5×10^{19} eV CRs are expected to have a limited range due to interactions with the CMB. This implies that the highest energy CRs observed so far, up to 3×10^{20} eV (50 Joules), should originate in the vicinity of our galaxy. The present knowledge of physics does not describe any acceleration model capable explaining these observations. At lower energies CRs are deflected by the galactic and extra-galactic magnetic fields; their origin cannot be traced back. At extreme high energies, where the origin of CRs could possibly be traced back, only huge detectors presently under construction (e.g. AUGER[13], EUSO[14]) will be able to detect CRs from extragalactic sources. In any case, detection of CRs, regardless of their energy, will not allow us to study their time behaviour, since the time of flight varies too much due to the intergalactic magnetic fields.

The observations mentioned above motivate a survey of the Universe at large distance and energy scales using different cosmic messengers to better understand the physics of the relevant phenomena.

An alternative solution for the observation of sources at large distances is the detection of neutrinos. Neutrinos have the characteristics required to complement the photon and CRs as cosmic messengers. Indeed, the neutrino has no charge and is therefore not deflected by magnetic fields. It is stable and interacts only weakly. Thus it can travel from the most remote places in the Universe to the Earth. Neutrinos with energies between 10^{12} eV and 10^{20} eV represent unique messengers to sound the deep Universe. High energy cosmic neutrinos have not been observed so far; their flux can only be evaluated using models. Generally these models assume that neutrinos originate predominantly as decay products of hadrons produced by interactions of high energy protons with photons or nuclei. The cross sections of these interactions are well known. Therefore, the relevant parameters entering the calculations of high-energy neutrino fluxes are the proton flux itself and the photon and nuclei densities. Several calculations based on different models have been made. Most calculations yield neutrino fluxes that require a neutrino telescope with a volume of at least a cubic kilometre: for AGNs and micro-quasars several hundred neutrinos could be detected per year while for GRBs the figure is several tens. The signature of GRB events should be very clean due to space and time correlation with optical observations; the background will be so small that a few events will be sufficient for the discovery of such a neutrino source. The correlated detection of photons and neutrinos will then constrain the GRB models.

Recently the NAOS-CONICA[15] device has measured the path of the S2 star through its pericentre. The results are consistent with the presence of a black hole in the centre of the Galaxy with the mass of $(2.6 \pm 0.2) \times 10^6$ times that of the Sun. The measurement of the light spectrum in the infrared region reveals signs of the presence of an accretion disk and of jets. It is therefore assumed that the Galactic Centre contains an AGN. Furthermore, the Cangaroo collaboration has recently reported the observation of a statistically significant multi-TeV photon signal from the Galactic Centre. This signal – which may be confirmed by HESS[16] in the near future – hints at the existence of an intense source of high-energy neutrinos in the Galactic Centre.

Another subject of interest is the search for non baryonic dark matter (DM). The direct search for DM is the subject of several present underground experiments. An indirect search for DM can be made with a neutrino telescope able to detect neutrinos generated by the annihilation of neutralinos accumulated – since the origin of the Universe – in the centres of massive celestial bodies such as the Earth, the Sun and the Galactic Centre. Calculations suggest that the sensitivity of this detection method makes it complementary to direct search methods.

A neutrino telescope in the Mediterranean Sea will complement the IceCube telescope being built at the South Pole. The superior optical properties of sea water – compared to Antarctic ice – will yield a better angular resolution

[13] See `http://www.auger.org/`

[14] See `http://www.euso-mission.org/`

[15] See `http://www.eso.org/instruments/naos/`

[16] See `http://www.mpi-hd.mpg.de/hfm/HESS/`

and hence a better background rejection. A neutrino telescope located in the Mediterranean Sea will survey the larger part of the Galactic disc, including the Galactic Centre. It is generally assumed that the spatial distribution of galactic sources is the same as that of the stars. Moreover, it is probable that an AGN is located in the Galactic Centre. However, the Galactic Centre is barely visible to a neutrino telescope at the South Pole.

Associated sciences:
The underwater world has not yet been extensively explored. Current technology allows autonomous vehicles or remotely operated vehicles (ROVs) to carry out scientific experiments at great depths only for relatively short periods and with accompanying support ships. The envisaged large deep-sea infrastructure providing mechanical structures, power supply from shore, data transfer to shore, deployment technology and maintenance possibilities is therefore highly attractive for long-term measurements of interest to a wide field of sciences including biology, environmental sciences, geology, geophysics and oceanography. Contacts with these communities have been established, and institutes playing leading roles in the respective fields of science participate in the Design Study to ensure that their needs are understood and suitable interfaces are defined and realized to connect their instruments to the KM3NeT infrastructure. Also the scientific and technological experience in deep-sea monitoring in the framework of EU-funded projects[17] will be included; the design, construction and operation of the KM3NeT neutrino telescope will profit strongly from the knowledge transfer from these projects.

All over the world, different scientific communities have repeatedly stressed in the last two decades the importance to perform long-term real-time measurements in extreme environments like the deep sea[18]. Such measurements of oceanographic (current velocity and direction) and environmental (temperature, conductibility, salinity, pressure, natural optical noise from sea organisms) parameters will be possible using a network of sensors installed as a part of the neutrino telescope. The installation of specialised instrumentation for seismology, gravimetry, radioactivity, geomagnetism, oceanography and geochemistry will make the KM3NeT infrastructure an abyssal multidisciplinary observatory for deep sea science that will offer a unique opportunity to explore the properties of a deep Mediterranean Sea site over a period of many years.

2.2 Quality of the Proposed Design Study

2.2.1 Objectives of the Design Study

The primary objectives of this Design Study are the development of a cost-effective design for a large neutrino telescope, the evaluation of procedures for the assembly and construction of the telescope and the preparation of models for the operation and maintenance of the infrastructure.

The combination of the relatively low flux of high energy cosmic neutrinos and their weak interaction with matter implies the need for a very massive detector (10^{12} kg). One solution is to instrument a large volume of deep sea water with a three-dimensional array of optical modules, i.e. photomultiplier tubes (PMTs) housed in transparent pressure vessels. The neutrinos can then be detected indirectly through detection of Čerenkov light produced by charged particles (muons) emerging from neutrino interactions in the sea water or sea bed. The angular resolution of the telescope is determined by the lever arm between the PMTs and the measurement precision of the PMT positions and the arrival times of the Čerenkov light. A position resolution of 0.2 m and a time resolution of 1 ns will allow the direction of (high-energy) muon neutrinos to be determined with an angular accuracy of about 0.1°.

Photomultipliers can safely be operated below the maximum penetration depth of daylight (around 1000 m). Even at these depths the detector can be swamped by Čerenkov light from muons produced in cosmic ray interactions in the Earth's atmosphere (10^{10} per km^2 per year). The greater the depth, the smaller the muon background. Therefore our design will be for a telescope capable of operation at depths of several kilometres. In seawater, an irreducible background of Čerenkov light is emitted by electrons from the decay of ^{40}K nuclei (typically 50 kHz for each PMT). Additional background is produced by bio-activity (which can reach rates of several hundred kHz for each PMT). We are challenged to design a readout and data processing system to efficiently extract the rare neutrino signals from these backgrounds. Bio-fouling of the optical modules should be minimal to assure the telescope an operational lifetime of least 10 years without a significant reduction in sensitivity.

[17] E.g. feasibility studies like ABEL and DESIBEL, and R&D projects, like GEOSTAR, GEOSTAR2, ORION-GEOSTAR3 and ASSEM
[18] See e.g. National Research Council: *The Future of Seafloor Observatory Science*, National Academy Press (2000).

Our technical design will target an overall cost below 200 M€ per cubic kilometre; a figure which represents an improvement of cost per unit volume of more than two from the present generation of underwater neutrino detectors. Cost can be reduced by optimising the quantum-efficiency and surface area of the PMTs, minimising the number of connectors in the array and by enlarging the average distance between the PMTs. Here, the sea water must have very high transparency, with low concentration of dissolved organic and inorganic particles which would otherwise degrade its optical properties. The distance between the telescope and the coast is a parameter in the design of the data transmission and off-shore data processing.

Three possible sites have been identified in the Mediterranean Sea. The optimal combination of site and detector design will be identified during the Design Study period. We will develop designs and technical drawings for the local infrastructure for the construction and operation of the facility.

We will evaluate production and assembly models to allow the construction of the neutrino telescope to be completed within five years after approval of funding. This will allow us to build a large neutrino telescope in Europe to take data concurrently with the IceCube neutrino telescope in the Southern Hemisphere.

Since the recovery, repair and redeployment of telescope components will be very costly, a quality assessment of the telescope parts and a risk analysis of the technical design and the operation model of the facility will be made to assure stable operation with minimal maintenance.

We will develop data distribution and analysis models not only to allow easy access to reconstructed data but also to allow appropriate and swift reaction to rare events triggered by observations at other facilities, including satellites and terrestrial telescopes.

We will also study how the KM3NeT infrastructure can be used by associated sciences as detailed in Sect. 2.1. This includes the development of cooperation models and the definition of suitable interfaces for the corresponding sensors as well as for data transfer. A major goal is to provide the associated science communities with well-defined access to the infrastructure from day one of operation.

The first 18 months of the Design Study will be devoted to the study of different detector concepts and their performance under the assumption of a site with optimal environmental properties. The results of these studies will be reported in a Conceptual Design Report (CDR). The final results of the Design Study will be collected in a Technical Design Report (TDR), which will contain the necessary information both for the construction and the operation of the neutrino telescope.

Several of the objectives of this Design Study are detailed further in Sect. 4.2 in the context of the justification of the financing requested per work package.

2.2.2 Multi-Annual Implementation Plan

Detector design and technological development:

The world expertise in the development and construction of deep-sea neutrino detectors is presently concentrated within the ANTARES, NEMO and NESTOR collaborations. From within these collaborations, the KM3NeT study group has formed. At the end of the Design Study period, we aim to have a TDR for a cubic kilometre-scale underwater neutrino telescope which would bear scrutiny from national funding agencies and will allow us to immediately commence the construction and operation of such an international facility.

Figures 1–4 show the multi-annual implementation plan in the form of a Gantt chart. Tasks and sub-tasks are based on the work packages WP1–WP10 outlined in Table 2. The relevant milestones (points at which the progress of the work can be assessed) and deliverables are specified (see also Table 4).

The ANTARES, NEMO and NESTOR collaborations have measured optical and oceanographic characteristics at their marine sites near Toulon (France), Capo Passero (Sicily) and Pylos (Greece), which are natural candidates for the construction of the Mediterranean km^3 neutrino telescope[19]. Simulation studies will begin early in the Design Study period and will run concurrently with continued long-term measurement campaigns. Although the site parameters are not yet known in all cases, they may be entered as free parameters into the simulation, allowing the quality of different design options to be evaluated in terms of their physics sensitivity as functions of these parameters. This simulation work will be a major task of the KM3NeT collaboration.

[19] See e.g. `http://www.vlvnt.nl`

ID	Task Name
1	**WP1: Management**
2	***Management of the Design Study***
3	Establish the project office
4	Manage DS (administrative, financial, legal, contractual, social)
5	Audit and report activities
6	Coordinate technical activities and knowledge management
7	Coordinate Work Packages
8	Develop cost model for KM3NeT configurations at different sites
9	Define selection criteria for the detector support structure
10	Define selection criteria for the KM3NeT site
11	**WP2: Astro-particle physics**
12	***Develop event simulation software***
13	Assess existing event simulation software
14	Define benchmark neutrino fluxes
15	Develop designated event simulation software
16	Describe benchmark neutrino fluxes in CDR
17	Describe benchmark neutrino fluxes in TDR
18	***Develop detector simulation software***
19	Assess existing detector simulation software
20	Adapt existing simulation software to detector geometries
21	Simulate light propagation in seawater
22	Simulate background light
23	Implementation of online filter
24	Quantify detector sensitivity in CDR
25	Quantify detector sensitivity in TDR
26	***Develop calibration models and determine calibration accuracies***
27	Model signal time and amplitude calibration
28	Model optical module relative position calibration
29	Describe calibration model and quantify calibration accuracies in CDR
30	Describe calibration model and quantify calibration accuracies in TDR
31	**WP3: Physics analysis**
32	***Develop event selection and reconstruction software***
33	Assess existing reconstruction software
34	Develop software for event selection and classification
35	Develop software for muon and shower reconstruction
36	Quantify detection efficiencies and resolutions in CDR
37	Quantify detection efficiencies and resolutions in TDR
38	***Determine physics sensitivity of detector configurations and sites***
39	Determine efficiency and effective volumes of detector configurations
40	Determine detector performance vs water quality, bioluminescence rate
41	Assess physics sensitivity per PM for different detector designs at different sites
42	Quantify physics sensitivity per PM in CDR
43	Assess physics sensitivity per Euro for different detector designs at different sites
44	Conclude physics sensitivity for preferred site(s) in TDR
45	***Define data formats and data distribution model***
46	Implement model for off-line data formats, storage and distribution
47	Interface online and offline data
48	Develop KM3Net Network model for access to data
49	Summarise data formats and distribution models in TDR

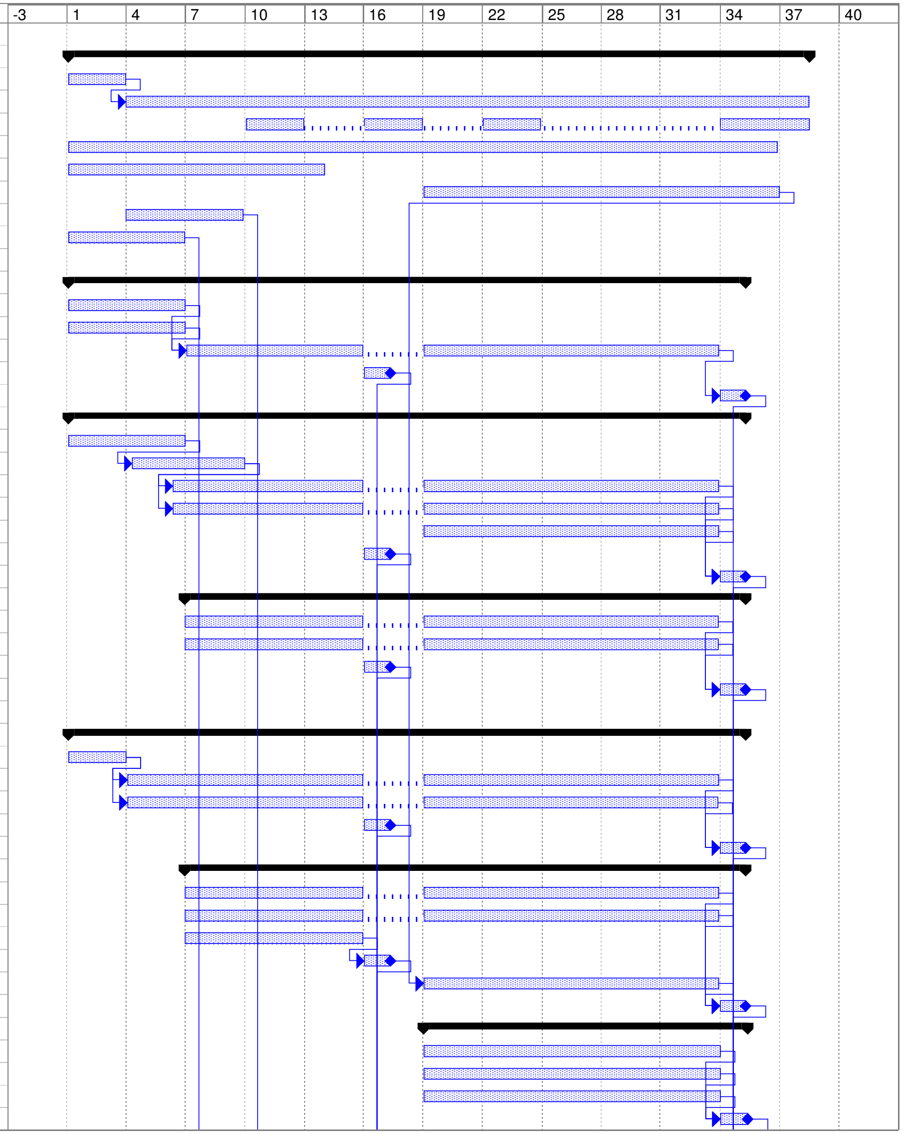

Figure 1: *Gantt chart of the multi-year implementation plan for work packages 1–3. The time lines are shown in units of months with 3-month intervals.*

ID	Task Name
50	**WP4: System and product engineering**
51	***Design specifications of optical module***
52	Evaluate and conclude on PMTs and PMT containers
53	Design PMT bases and F/E electronics
54	Build prototype PMT bases
55	Design optical module
56	Assess power budget of optical module
57	Implement PMT readout system
58	Describe design of optical module in CDR
59	Describe design of optical module in TDR
60	***Design specifications of calibration units***
61	Design signal time and amplitude calibration units
62	Design positioning system (transponders, hydrophones, tilt-meters, compass)
63	Describe design of calibration units in CDR
64	Describe design of calibration units in TDR
65	***Design specifications of mechanical structures***
66	Design support structures for optical modules
67	Design support structures for calibration units
68	Study cost-effective pressure housings
69	Dedicated material studies
70	Evaluate design for flexible line support structure
71	Evaluate design for rigid tower support structure
72	Evaluate design for flexible tower support structure
73	Conclude on preferred support structure in CDR
74	Develop final detector support-structure design
75	Describe design of preferred detector support structure in TDR
76	***Develop procedures and design tooling for detector assembly and transport***
77	Design and test assembly procedures and tooling for optical modules and calibration units
78	Design and test assembly and transport procedures and tooling for detector units
79	Describe design of assembly and transport of optical modules and calibration units in TDR
80	**WP5: Information technology**
81	***Design readout and data acquisition system***
82	Design system for data digitisation, processing and transport from PMT to shore
83	Design timing system and acquisition system for calibration data
84	Design slow-control system
85	Describe readout and data acquisition concept in CDR
86	Conclude readout and data acquisition technology in TDR
87	***Design on-shore data processing system***
88	Design online data filter model and data structures
89	Design system for data distribution to users and mass storage
90	Describe on-shore data processing concept in CDR
91	Describe on-shore data processing in TDR

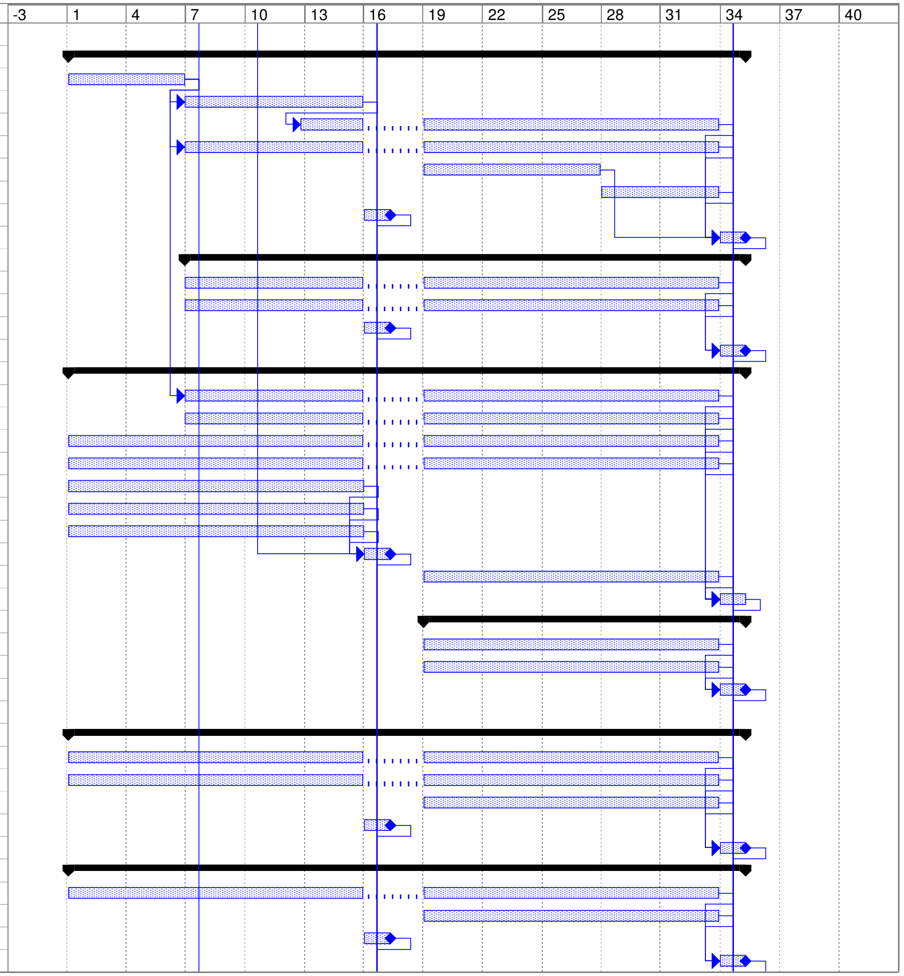

Figure 2: *Gantt chart of the multi-year implementation plan for work packages 4 and 5. The time lines are shown in units of months with 3-month intervals.*

ID	Task Name
92	**WP6: Shore and deep-sea infrastructure**
93	***Evaluate sites***
94	Assess and evaluate existing data on water, oceanographic, biol., geol. properties at 3 sites
95	Measure water, geological, biological, oceanographic properties of candidate sites
96	Analyse and compare measured properties of candidate sites
97	Conclude on preferred site(s) in CDR
98	***Perform long-term measurements at preferred site(s)***
99	Design multi-sensor probe
100	Construction and test of multisensor probe
101	Describe multisensor probe in CDR
102	Characterize geo-hazards
103	Measure optical, oceanographic and environmental parameters of seawater
104	Make high resolution image of sea bottom
105	Analyse sea bottom image data
106	Describe characteristics of preferred site(s) in TDR
107	***Design procedures and tooling for detector unit deployment and recovery***
108	Define procedures and design tooling for deployment and recovery of detector units
109	Design marine infrastructures and select equipment (ships, ROVs/AUVs, platforms)
110	Define procedures for on-site assembly, testing and storage of detector units
111	Design tooling for on-site assembly, testing and storage of detector units
112	Develop recovery procedure for KM3NeT decommissioning
113	Describe procedures and tooling for detector deployment and recovery in TDR
114	***Design specifications for deep-sea power and data network***
115	Specify and evaluate cables (interconnection and detector to shore)
116	Assess power consumption and develop power distribution model
117	Assess data transmission needs and design a model for data network architecture
118	Design junction box functionality, including power converters and data transfer
119	Evaluate connectors (wet and dry mateable types)
120	Describe deep-sea power and data network in CDR
121	Describe deep-sea power and data network in TDR
122	***Design shore infrastructure***
123	Define requirements for general computing facilities at the shore station
124	Define requirements for access to European data network
125	Prepare construction plans for shore station
126	Design on-shore electrical power distribution
127	Design model for transmission of associated science data to the European data network
128	Describe specifications for shore infrastructure in TDR

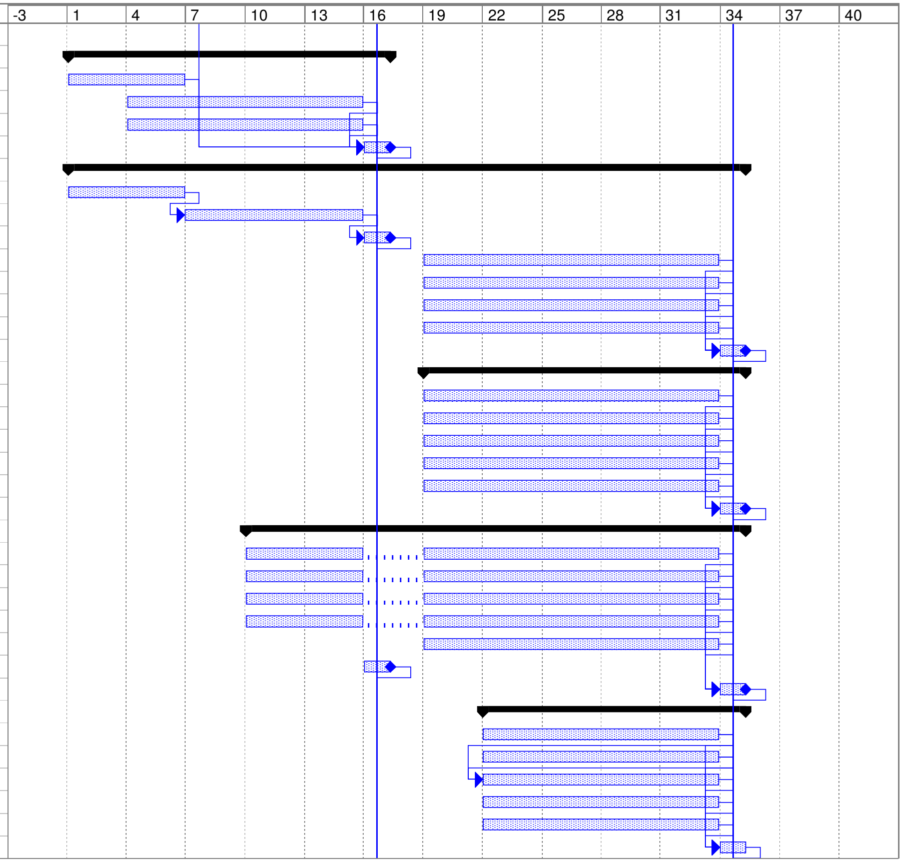

Figure 3: *Gantt chart of the multi-year implementation plan for work package 6. The time lines are shown in units of months with 3-month intervals.*

ID	Task Name
129	**WP7:Sea surface infrastructure**
130	***Design sea surface infrastructure***
131	Develop specifications for surface detector
132	Design floating platform
133	Describe floating platform in CDR
134	Prototype floating platform and surface detector
135	Implement dynamic positioning and absolute timing systems
136	Describe design of sea surface pointing detector in CDR
137	Describe design of sea surface pointing detector in TDR
138	**WP8: Risk assessment and quality assurance**
139	***Assess quality and risks of detector design, transport, deployment and recovery***
140	Perform FMECA assessment of design and operation of KM3NeT
141	Setup quality-assurance methods for KM3NeT parts and procedures
142	Prepare FMECA and quality-assurance report as annexe to TDR
143	**WP9: Resource exploration**
144	***Explore resources***
145	Explore funding sources
146	Establish governance model
147	Investigate legal aspects related to KM3NeT
148	Prepare documentation for TDR
149	**WP10: Associated sciences**
150	***Establish cooperation between neutrino telescope and deep-sea communities***
151	Establish cooperation model between neutrino telescope and deep-sea communities
152	Design specifications for data transmission for deep-sea science research
153	Environmental assessment of KM3NeT components
154	Prototype design
155	Prepare documentation for CDR
156	Prepare documentation for TDR
157	**Workshop to prepare Conceptual Design Report (CDR)**
158	**Write Conceptual Design Report**
159	**Workshop to prepare Technical Design Report (TDR)**
160	**Write Technical Design Report**

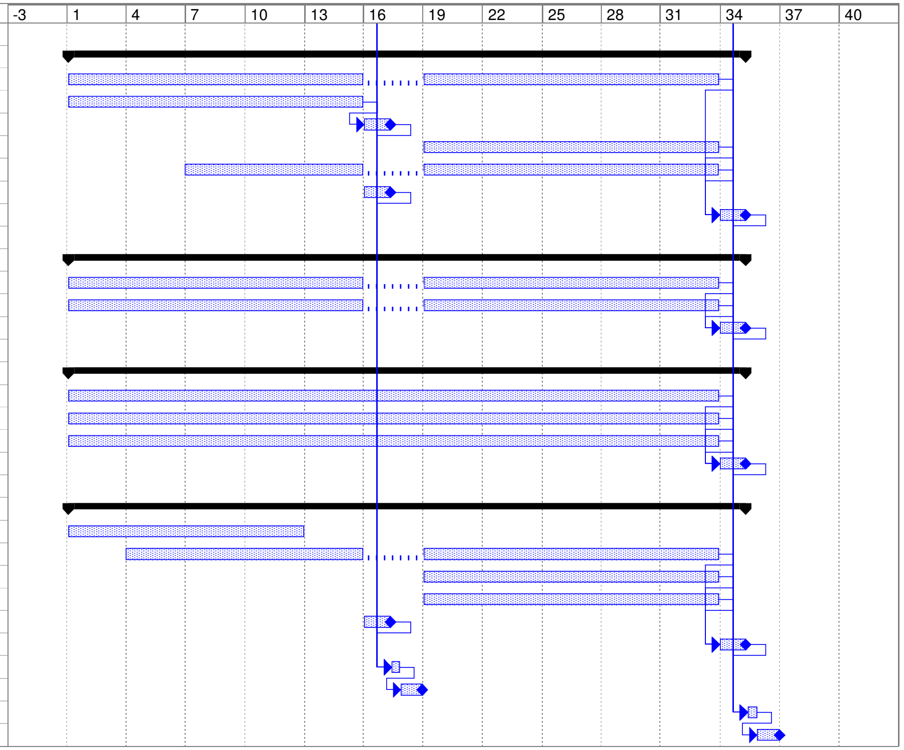

Figure 4: *Gantt chart of the multi-year implementation plan for work packages 7–10. The time lines are shown in units of months with 3-month intervals.*

Since nanosecond accuracy is needed in the measurement of the arrival of Čerenkov light at optical detection elements which may move on the order of meters in deep-sea currents, procedures and equipment for the *in-situ* calibration in position and time of the optical detectors of the underwater telescope will be developed. Possible approaches include acoustic and optical triangulation using pulses emitted at known times relative to the master clock of the detector.

The architecture of the underwater telescope will be addressed in terms of data flow paths, seafloor layout and powering, and the interconnection schemes of junction boxes and connecting cables to the shore station. A detailed risk/stability analysis will be made according to *Failure Modes, Effects and Criticality Analysis (FMECA)* principles to understand and minimise the loss/incapacity in the detector following individual component failure in the power delivery and data flow pathways.

Interaction with industry through market survey and/or sub-contracts is foreseen in the areas of production of optical modules and their support structures, data multiplexing technology, and in the domain of connectivity; particularly of underwater-mateable connectors (under development primarily for the off-shore oil industry) compatible for use with ROVs.

Readout system studies will include comparisons of off-shore laser signal multiplexing using the DWDM (Dense Wavelength Division Multiplexing) technique and alternative schemes including on-shore lasers and off-shore modulators. Risk/benefit analyses will be used to determine the balance between electronic fault probability and high data transfer rate to shore of placing data reduction electronics in undersea containers. The cost benefits of subdividing the readout pathways between fibre-optic and copper Ethernet links will also be addressed.

The various mechanical aspects of the telescope array will be addressed. Alternative support schemes for optical modules containing PMTs and readout electronics will be studied. The cost benefits of separating the corrosion resistance and pressure resistance of underwater electro-optical junction boxes with the use of external oil jackets around central steel pressure vessels will be studied; significant savings might be made relative to the approaches used in the present generation underwater detectors where titanium is used to combine both functions.

Procedures for assembly, transport, deployment and recovery of the detector will be developed. Conceptual designs for tooling for these operations will be developed.

The dissemination of data from the telescope through the European Data Grid network for distributed processing at remote institutes will be studied. We will establish connections with astronomy data networks to allow the rapid exchange of sky coordinates and time stamp information of events of astronomical interest between the neutrino telescope and other astronomy facilities. Data formats adapted to transmission through the data networks of the associated sciences communities (marine biology, seismology etc) will be developed.

Site selection:

The installation of Čerenkov detectors in natural radiators such as seawater requires a deep knowledge of the medium properties in the deployment site. These data are also mandatory to provide the right input parameters for Monte Carlo simulation programs and event reconstruction codes.

The future Mediterranean neutrino telescope must be installed in a site, not too far from the coast, having the following main characteristics: great depth, to minimise the atmospheric muon flux background; low geo-seismic and sea-current activities to avoid catastrophic damage to the detector (the characterisation of the sites in terms of geo-hazard will be obtained through long-term time series measurements); low presence of dissolved organic and inorganic particles, which worsen light transmission properties of seawater and increase the fouling on optical surfaces; low concentration of bioluminescent organisms, that yield a main component of the optical background.

The ANTARES, NEMO and NESTOR collaborations have measured optical and oceanographic characteristics at their marine sites, natural candidates for the construction of the Mediterranean km^3 neutrino telescope[19].

Due to possible changes of sea properties as a function of time, careful long-term measurements are needed in order to select and study the KM3NeT installation site. The ANTARES and NEMO collaborations have, over several years, performed short-term deep-sea parameter measurements at the Toulon and Capo Passero sites, that have provided important knowledge on the site parameters. For 3 years the two groups have conducted joint experimental campaigns of measurements that have allowed a direct comparison between the two sites.

The decision on where to locate the Mediterranean neutrino telescope has to be taken in due time to allow the preparation of the final detector design. For sites where we can exclude the possibility of catastrophic events, like avalanches, turbidity currents, strong and variable sea-currents, we will evaluate the impact of environment and water optical properties on the physics detector performance. This will be done by Monte Carlo simulations, to determine for different sites and given detector geometries, the cost of a neutrino telescope providing the required effective area, angular and energy resolutions. This simulation and physics analysis work will be a major task of the KM3NeT collaboration and will require knowledge of long-term water transparency (attenuation, absorption, scattering coefficients), optical noise, sedimentation and deep-sea currents. It will provide a quantitative evaluation tool to compare the candidate sites.

3 Relevance to the Objectives of the Scheme

3.1 Justification of the Proposed Design Study

The proposed Design Study will establish the feasibility of technologies and procedures for the construction of the KM3NeT deep-sea infrastructure including a neutrino telescope with the desired size and resolution. Since a straightforward enlargement from smaller, present-generation pilot telescopes would not be cost-effective and technically difficult if not impossible, technical preparatory work is required to accomplish this objective.

The harsh environment of the deep sea, the large size of the telescope and the high data rates are the three major challenges of this project. When all the difficulties involved are mastered, the reward will be a new window on the Universe; a window that will allow us to look further back than ever before: The new field of neutrino astronomy will be within reach.

Scientific and technological need of the Design Study

For scientific and technological and also for management-related reasons, the tasks of the Design Study have been grouped in the work packages listed in Table 2. Particular fields of expertise and experience are related to these packages. In the following, the tasks of all work packages (except WP1: Management of the Design Study) are summarised, demonstrating the scientific and technological need of the proposed Design Study:

WP2: *Astro-particle physics*

This work package covers the development of software for simulation of neutrino production, light transmission through the water and the detector response. Furthermore, calibration models will be developed and implemented in the simulation. A main objective is to contribute to the optimisation of the KM3NeT neutrino telescope in terms of its physics sensitivity. The work in WP2 will start from existing software and models. However, both the adaptation to a software environment that is flexible enough to accommodate different detector geometries and environmental parameters and the inclusion of all relevant physics processes in a consistent way establish major tasks that have to be successfully terminated in due time to make the resulting software available for KM3NeT design studies.

WP3: *Physics analysis*

This work package addresses the development of software to select and identify neutrino events in the raw data, to reconstruct the neutrino trajectory and to quantify the detection efficiencies. Also, suitable data formats and a data distribution model for dissemination of the data to scientific communities will be defined. Essentially, the goal of this work package is to prepare a complete data analysis environment for the future KM3NeT neutrino telescope. Together with WP2, the results of this package are needed for optimising the KM3NeT design and for assisting in the site characterisation. Therefore, a large fraction of the work has to be performed in the period of the Design Study before the CDR, requiring systematic software design from the very beginning.

WP4: *System and product engineering*

This working package entails the following system and product engineering tasks:

- Optimisation of the design of the optical modules, including the implementation of the readout system (work package WP5, *Information Technology*), in terms of cost, effective photon detection area and production speed (a production rate of 10-20 optical modules per day, spread over several parallel production lines, has to be achieved in order to install KM3NeT within a few years).
- The envisaged angular resolution of the telescope relies on an accurate *in-situ* calibration system that has to be designed to match the precision requirements and to cover the detector volume without interfering with

the measurement processes. The final evaluation of the calibration system will be made in the work package *Astro-particle Physics*.

- The environmental conditions of the future telescope impose severe constraints on the materials used, entailing the need for material studies towards cost-effective, pressure-safe and corrosion-free solutions.
- The design of the mechanical support structures has to be optimised such that the telescope units can be rapidly assembled, tested, transported and deployed. This involves the determination of hydrodynamic coefficients, simulation of hydrodynamic behaviour during deployment and tests with instrumented prototypes.
- The connectivity of the telescope units to the underwater cable network has to be worked out in cooperation with work package WP6, *Shore and deep-sea infrastructure*.
- The production line for the telescope components and their assembly requires proto-typing of automated systems and the assessment of different photon sensors and glass containers with respect to an optimisation of the overall production speed.
- It is foreseen that the assembly of telescope parts will go on in parallel at various locations in Europe. Planning and logistics for the transport of telescope parts to the deployment site need careful preparation and may impose design conditions; they are therefore also part of this Design Study.
- The optimisation of the underwater section of the observatory, including the connectivity of the telescope units with the seafloor cable network, has to be worked out in cooperation with work package WP6, *Shore and deep-sea infrastructure* using the input of a hydrodynamics and sea operation evaluation study.

WP5: *Information technology*

This work package concerns the development of the readout and data handling technology. A conclusion from the pilot projects driving the developments in this package is that the underwater electronics have to be greatly simplified. One possibility to achieve this goal is the so-called "all-data-to-shore" concept pioneered in one of the present neutrino telescope projects. In this scheme, the original signal from each PMT is transmitted to shore; the objective being a reduction in complexity of the under-water electronics. This would in turn reduce the overall power consumption, increase reliability and facilitate fast and cost effective production of optical modules. In order to realise this or similar concepts, a new application of the existing technology for signal transmission based on wavelength multiplexing will be explored. Furthermore, a detailed study of the fibre network has to be made to ensure a reliable link between deep-sea and shore. An on-shore system to convert the signals to digital time and amplitude information combined with a software data filter using a large farm of commodity PCs will be designed and procedures developed to distribute processed data across Europe using the European Data Grid.

WP6: *Shore and deep-sea infrastructure*

Knowledge of the properties of the sea water (absorption and scattering as well as optical noise and bioluminescence) and the environmental conditions (currents, temperature, salinity, bio-fouling, sedimentation, etc.) are crucial for the quantification and optimisation of the performance of the telescope. Corresponding measurements will be performed at different sites (Capo Passero, Toulon and Pylos). Using a free-fall instrument, the abundance, size, identity and light emission characteristics of luminescent organisms will be investigated. Diel, seasonal and inter-annual variation of the bioluminescence will be determined for the (final) qualification of the various sites and the long term operation of the neutrino telescope. Once the preferred site(s) have been identified, we plan to study their properties with long-term measurements targeting: characterisation of geo-hazards (seismicity, landslides, seafloor degradation) using an already developed benthic observatory; long-term time series data on the evolution of environmental parameters; space and time variability of deep-sea current, salinity and turbidity in the installation site(s); high-resolution imaging of sea-bottom and analysis of samples.

We will study and define the submarine layout of the underwater electro-optical cable network, taking into account the requirements for power distribution from the on-shore system to the individual submarine electronic components and involving the choice/design of suitable cables and connectors which then will have to be tested under conditions corresponding to realistic deployment, installation and running operations.

We will study technologies needed for deployment and recovery of the underwater detector subsystems and to optimise the efficiency and minimise cost and risk of these operations. Once the CDR is available, we will verify the capability of the developed technologies by simulating, building, testing and operating prototypes of the most critical parts of the system.

Additional aims of this task will be the definition of procedures needed for the integration of the various subsystems in the deep-sea infrastructure and the definition of the on-shore logistic structures needed for equipment storage, workshops and testing as well as for detector control and data acquisition, collection and distribution. Construction plans of the shore station will be produced. We will define the characteristics of the data transmission network needed to distribute data from the on-shore station to the external research laboratories and to the user community, together with the required technologies for data sharing and high-speed processing of huge data volumes (GRID[20]).

WP7: *Sea surface infrastructure*

This work package addresses sea surface operations needed for deployment, recovery and maintenance. Dynamically-positioned sea surface structures can provide floating support for surface array detectors for determination of the absolute pointing calibration of the telescope using down-going high-energy muons. A prototype, $1000\,\mathrm{m}^2$ self-propelled triangular floating platform based on a novel design has already been built at a cost of about 1.5 M€. Technical preparatory work will be undertaken to develop and test techniques critical to the future operation of such autonomous floating platforms in conjunction with the proposed infrastructure:

- Dedicated software for the dynamic positioning of the platform based on differential GPS under varying sea state conditions will be developed or acquired and adapted. The target accuracy is better than 10 m in absolute positioning.
- The performance of the platform will be studied and optimised for operation under varying static and dynamic loads and sea states to assess the stability and evaluate the performance of the existing propulsion and heave compensation systems.
- Surface array detectors on the platform itself and on floating satellite structures will be deployed and operated in coincidence with an existing pilot small-scale sea-bottom telescope to demonstrate the capability of such a system to provide adequate calibration of the absolute pointing resolution of the KM3NeT telescope.

WP8: *Risk analysis and quality assurance*

The objective of this work package is to apply risk analysis techniques (including FMECA) to the technical design of the KM3NeT infrastructure and its sub-systems and to set up detailed quality assurance procedures for the component production, module assembly, storage and deployment and for the KM3NeT operation. In the first phase of the Design Study we will define the standards and the quality evaluation method for all the Design Study procedures: conceptual design, study, document writing, data base implementation, etc.

WP9: *Resource exploration*

It is obvious to the Design Study proponents that the KM3NeT infrastructure is unlikely to be realised as an unilateral or even bilateral national initiative. In addition to the collaborating institutes a new legal entity will have to be set up to execute contracts for the construction and subsequent operation. It will also be necessary to establish independent supervisory mechanisms to assure proper management of funds. A separate structure, in which the funding agencies are represented, is also necessary in order to set financial policies and develop sustainable funding plans for construction, operation, exploitation and development of the infrastructure. Furthermore, a legal title will have to be assigned to the site and its enforcement established; this addresses questions like protection against damages by cable-laying or trawling, responsibilities in cases of damages by ship wreckages etc. In WP9 these requirements will be analysed and experience from similar public or private international structures will be collected with a view to produce reports on funding options, legal issues and governance options and recommendations.

WP10: *Associated sciences*

It is proposed that the KM3NeT infrastructure will form the basis for an important sub sea node of the ESONET or similar programme. We envisage that one or more seafloor junction boxes will be installed adjacent to the KM3NeT array providing power and data links which can be accessed by other users deploying observatories in the Mediterranean Sea. The objective of this work package is to define the interface between KM3NeT and the wider science community under particular consideration of: data from KM3NeT that are of interest to associated sciences; associated science data of use to KM3NeT design or operations; associated science data using the KM3NeT for infrastructure only. The work will address:

- the assessment of the associated science users and their data requirements in terms of temporal and spatial characteristics (e.g. real-time to long-term archive, water column, local and regional aspects);
- the definition of sensors, hardware and power requirements resulting in a proposal of standard interfaces;

[20] See `http://eu-datagrid.web.cern.ch/eu-datagrid/`

Milestones		
Number	**Date (months)**	**Description**
1	16	2-week workshop in preparation of CDR
2	16	detailed report on site characteristics
3	18	CDR completed
4	33	completion of all prototypes
5	34	2-week workshop in preparation of TDR
6	36	TDR completed
Deliverables		
Number	**associated to WP(s)**	**Description**
1–8	WP2–WP8,WP10	Work package reports for CDR
9	WP2–WP8,WP10	Conceptual Design Report (CDR)
10	WP2+WP3	complete set of software for data analysis (event and detector simulation; calibration; event selection and classification; event reconstruction; data storage and distribution)
11	WP4	prototypes of detector units (PMT bases; optical module; readout system; amplitude, time and position calibration, support structure)
12	WP4	tools for assembly and transportation
13	WP6	tools for deployment and recovery of detector units
14	WP10	prototype design for communication model with deep-sea community
15–24	WP2–WP10	Concluding work package reports for TDR
25	WP2–WP10	Technical Design Report (TDR)

Table 4: *List of milestones and deliverables of the KM3NeT Design Study. The date for the milestones is given in months after the start of the project.*

- the design concept of an associate science node, of its deployment and its operation, resulting in an proposal towards the decision makers of the scientific institutions interested in cooperation with the KM3NeT neutrino observatory;
- experimental studies for associated science data of use for KM3NeT operation;
- input to the KM3NeT TDR.

Deliverables and milestones:

The milestones and deliverables of the Design Study are summarised in Table 4.

The main deliverable of the Design Study will a Technical Design Report (TDR) which will be made public and subject to external review. The TDR will contain sufficient technical detail (procedures and technical drawings) to allow a detailed planning of the mass production and delivery and deployment of all parts of the telescope. It will be produced in the final phase of the Design Study after a 2-week workshop in which the results of all work packages are presented, discussed and prepared for inclusion in the TDR.

After 18 months of the project, we foresee to produce a Conceptual Design Report (CDR) which will select the preferred technical options and contain a site characterisation. This CDR will contain a detailed review of the achievements of the first half of the Design Study and will serve as a reference document for the second half.

For all hardware developments, prototypes of the designed objects have to be produced and tested. These prototypes must be available 2 months before the end of the Design Study to be duly considered in the TDR.

Users:

The future neutrino telescope project will attract people from the astronomy, dark matter, cosmic ray and high energy physics communities. In fact, the proposed design studies will be made by an international collaboration with people from various communities. The foreseen operational lifetime of the facility of at least 10 years will provide data for a broad physics program. The operational configuration of the neutrino telescope and the general facilities will be subject to requests from users in different scientific communities.

Intellectual property rights:

The generally-accepted philosophy will be that new technologies as presented in the TDR and scientific results will be made public. Details of key patentable and licenseable developments however will be confidential but shared amongst the partnership with intellectual property protected under the terms of the consortium agreement.

It is likely in this programme of design of a large scale underwater 3D-structure that we shall develop methods that will be of wider use in underwater technology. It is our aim to ensure that such new "spin-off" technology is protected, promoted and exploited by European Industry.

Dissemination of data and results:

It is planned that reconstructed neutrino telescope data are made available to the scientific community, also beyond the KM3NeT collaboration. This allows in particular for cross-experiment and multi-messenger data analysis, and for coordinated reaction to astrophysical events. We hope to contribute to a future world-wide pool of astro-particle data that are available to all scientists. Internet connection will allow for remote continuous operation of the facility and for connection with other global networks (e.g. GCN[21]), so that particular phenomena may be studied with the greatest sensitivity.

The scientific results will be presented at international conferences and published in related journals. Workshops will be organised to discuss progress and plan future activities[22].

Risk monitoring:

In order to minimise the risk that failure in one of the main objectives of this Design Study leads to delays jeopardising the possibility of complimentary and simultaneous data taking with the Southern Hemisphere IceCube project or even to a cost increase threatening the KM3NeT project as a whole, alternative technical solutions based on existing technology and designs will be pursued up to the point where the feasibility of new solutions has been established.

A continuous, detailed monitoring of the Design Study progress will be a major task of the PCC (see Sect. 4.1). Furthermore, the preparation and production of the CDR and the other milestones defined in Table 4 will help to keep track of the timely progress of this Design Study.

3.2 Exploring the Feasibility of the Infrastructure

Funding aspects

1. *Structural Funds*

   Financing so far has benefited from EU Structural Funds (France, Greece, Italy). This is likely to continue during the Design Study period. The possibility of using EU structural funds for the construction of KM3NeT depends on the eligibility of the region that hosts the selected site. In addition the construction phase will coincide with the next *Community Support Framework (CSF)* which at the moment is in the early planning phase. Every effort will be made in candidate host countries to plan structural fund support from the next CSF.

2. *Article 169*

   Article 169 of the Treaty of Amsterdam[23] enables the Community to participate in research programs undertaken jointly by several member states, including participation in the structures created for the execution of national programs. It is potentially a very powerful instrument in order to integrate national programs. It is adopted as a funding instrument by a co-decision process between the European Parliament and the Council. The originality of Article 169 is related to the fact that the proposal comes from the Member States. The political players from the Member States are the policy makers and the operational players are the program managers

[21] Gamma ray burst Coordinate Network, see `http://gcn.gsfc.nasa.gov/`

[22] The first related workshop took place in October 2003 at NIKHEF, Amsterdam.

[23] See `http://www.cordis.lu/fp6/instr_169.htm`,
`http://www.ircscotland.net/euro_funding/article_169.cfm`

of national programs. The Commission is responsible for transforming each initiative into a formal proposal of Article 169 to the Council and Parliament who then decide through the co-decision process.

The basic criteria for the selection of the proposals for co-funding through Article 169 are as follows:

- involvement of enough Member States to obtain a significant structuring effect and critical mass;
- a topic of great interest to the Community, fitting with the thematic priorities of the Framework Program;
- principles of co-funding by Member States and Community and of additionality are respected;
- a significant European added-value.
- that Article 169 is the only way the project could be implemented.

Through the Design Study we will explore the option of co-funding KM3NeT through the Article 169 instrument. The construction phase of KM3NeT will run in parallel with FP7 and, possibly, with a new European Treaty and new forms of governance in the European Research Area.

3. *European Investment Bank (Innovation 2000 Initiative)*

In the framework of the Innovation 2000 Initiative[24], the European Investment Bank (EIB) is to give a special focus on projects that support innovation in the European Union. A lending program of 12 to 15 billion € over the next three years will be dedicated to this purpose.

Under this initiative, the EIB Governors approved a set of operational principles designed to channel EIB financing into five areas including "...**research and development** by co-financing public or private-sector research programs, corporate investment in R&D, research infrastructure, centres of excellence and measures enabling SMEs to obtain access to research programs"

This mode of financing KM3NeT construction through EIB loan will be actively explored in the course of the Design Study. It might allow research funding agencies to spread the initial construction costs over a long period thus making the initial capital expenditure less disrupting to their ongoing programs.

Regional dimension: Mediterranean

Three Mediterranean EU countries are involved in major pilot projects:
- France (Toulon);
- Greece (Pylos/Peloponnese);
- Italy (Catania/Capo Passero).

Two additional Mediterranean EU countries are involved in the Design Study for KM3NeT:
- Cyprus;
- Spain.

Trans-regional dimension

Non-Mediterranean EU countries have joined in the pilot projects (Germany, The Netherlands, UK) and participate in the KM3NeT Design Study proposal.

Whichever of the three candidate sites is ultimately selected for KM3NeT, it is likely that during the construction phase the shore facilities in the other two sites will be exploited as major regional centres for industrial activities. Following the construction phase all three shore facilities will operate as science centres for the exploitation of the results and as technology centres for further developments. To this effect they will be linked with high bandwidth data highways.

Other regional considerations/siting aspects

The European research landscape will probably undergo important changes in the years 2005–2007, concurrently with the execution of this Design Study. Structuring of the ERA is already a priority in FP6, and it is likely that in FP7 new instruments will be adopted to take into account new forms of governance and funding for understanding-driven research. In the proposed Design Study we intend to closely monitor these developments and, where possible, to provide useful input to both national and EU research agencies. To this effect, the study of the governance, legal and funding aspects of the KM3NeT infrastructure form a separate work package.

The selection of the optimal site for the infrastructure presents a unique challenge to our scientific community due to the intricate interplay between scientific, technological, financial and socio-political/regional considerations. It is our intention to deliver a clear prioritisation of site qualities based on scientific, technological and financial aspects

[24] See `http://www.eib.org/i2i/en/`

only. However, depending on the strength of this prioritisation, the final site selection may well be determined by socio-political/regional considerations. Whether weak or strong, this Design Study prioritisation will provide a sound, rational basis for decision-makers.

4 Quality of the Management

4.1 Management and Competence of the Participants

Management structure

The KM3NeT Design Study project will be performed under the regulations of a consortium agreement laying down, amongst others, the following:
– the responsibilities of all participating legal entities (*parties*) and their obligations towards each other;
– the bodies responsible for decisions and project steering;
– the decision procedures related to the implementation of the project;
– the procedures for financial transactions and the corresponding rules;
– the implementation of the start-up phase of the project;
– the rules applying to intellectual property rights;
– the rules for confidentiality and liabilities.
The foreseen management structure is shown in Fig. 5.

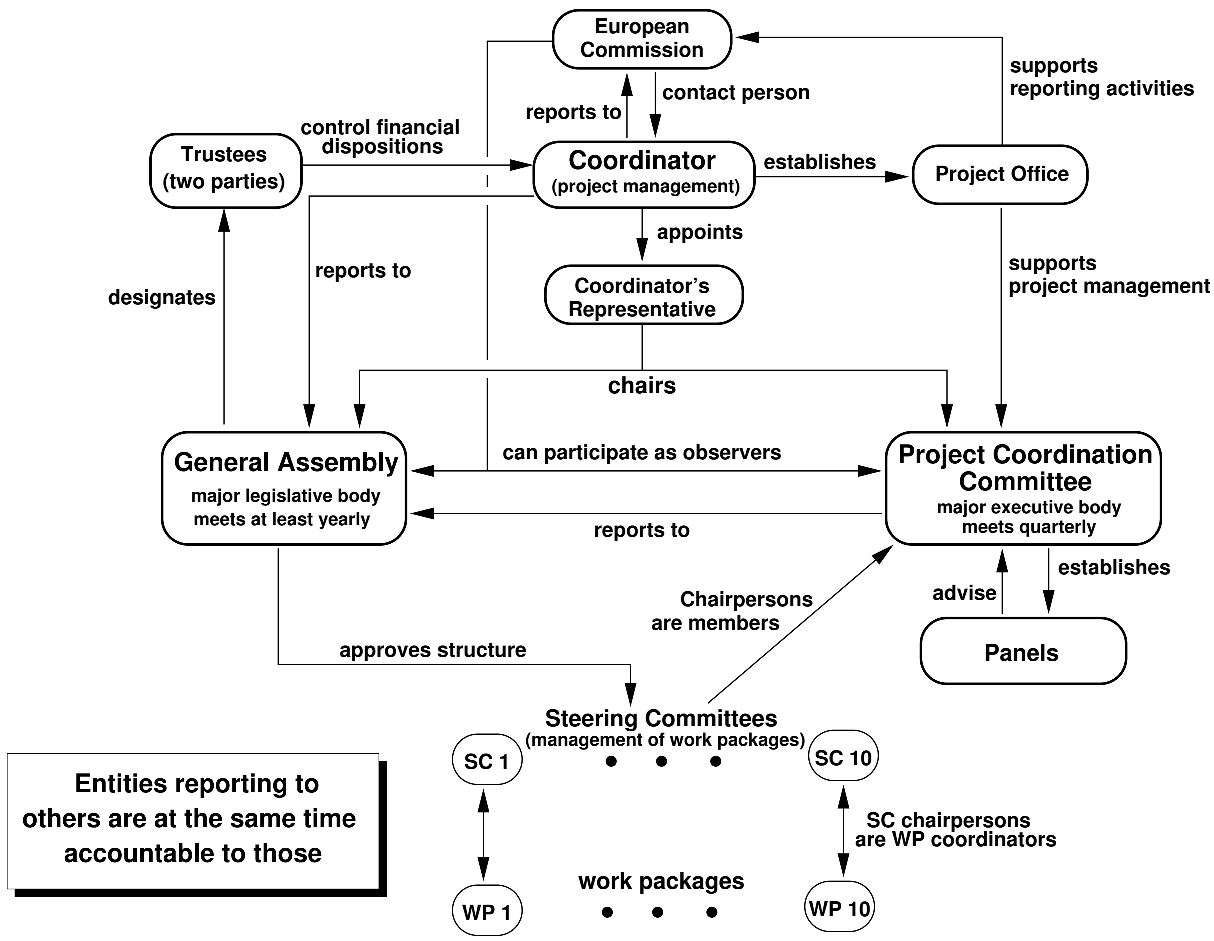

Figure 5: *Schematic representation of the foreseen management structure of the KM3NeT Design Study project.*

The *Coordinator* establishes the single point of contact between the *European Commission (EC)* and the consortium. The Coordinator is responsible for the overall management of the project. He/she will sign the contract after authorisation by the parties, will collect from the parties the statements and receipts for submission to the EC, is responsible for preparing the reports and project documents required by the EC and to deliver items requested by the EC for reviews and audits, including the financial audit reports prepared by independent auditors. He/she will be responsible for the maintenance of the consortium contract, the coordination of knowledge management and other innovation-related activities, the implementation of participants and of competitive calls, for overseeing the promotion of gender equality in the project and for overseeing social and, if applicable, ethical aspects. He/she will receive the project payment from the EC and distribute it to the parties according to the regulations in the *Implementation Plan*; in all financial transactions, he/she is supported by two parties who act as *Trustees* together with the Coordinator.

In these tasks, the Coordinator is supported by the *Project Office (PO)* that will be established for the duration of the project and led by two full-time employees specialised in EU administrative and legal affairs. They will provide support for the day-to-day project management tasks, for the reporting activities towards the EC, and for the maintenance of the project accounts and for obtaining the audit certificates. The PO also oversees the maintenance of the web site that serves as central instrument for communication inside the project and for dissemination of results (see below).

The major decision-taking body of the project is the *General Assembly (GA)*, consisting of one representative per party. The GA is convened and chaired by a representative of the Coordinator. It meets at least once per year, receives and considers the report of the *Project Coordination Committee (PCC)* and reaches legally binding decisions on the following points:
– approval of the yearly Implementation Plan prior to its submission to the EC;
– all budget-related matters, in particular approval of the accounts for the past financial year;
– acceptance of new parties and exclusion of parties;
– structure and restructuring of the *work packages*;
– alterations of the consortium agreement;
– designation of Trustees.

The voting rules are based on double majorities in the number of parties and in the amount of requested budget represented by the parties. In the initial GA meeting, the partition and coordination of the work packages is confirmed by the GA. Subsequently, the parties involved in each work package, forming its *Steering Committee (SC)*, elect its chairperson who shall represent the work package in the Project Coordination Committee.

The PCC, formed by the chairpersons of the work packages, is the supervisory body for the project execution which shall report and be accountable to the GA. It assumes overall responsibility towards the GA for liaison between the parties for analysing and approving the results generated under SCs and/or parties. It may set up advisory panels providing support in the coordination and management of the project. It will be chaired and convened by the Coordinator's representative and meets at least quarterly. Its tasks include preparing the Implementation Plan for approval by the GA, supporting the Coordinator in fulfilling his obligations towards the European Commission, monitoring and reporting the progress of the work packages, steering the work and budget sharing between parties, reviewing and proposing to the GA budget transfers and agreeing on press releases and joint publications.

To facilitate the organisation and management, the project is structured in work packages which together comprise the project. Each work package has its own SC, established as detailed above. The SCs shall be responsible for their own organisational arrangements, work procedures and time schedules, provided they are in accordance with the Implementation Plan and requests made by the Coordinator, the PCC or the EC.

The communication between partners and management bodies will be facilitated by installing a central computer server providing a web platform which is used both for the distribution of password-protected internal information (like invitations to and minutes of meetings, reports, preliminary results, repositories for software development, etc.) and for the dissemination of results to the public. The URL `http://www.km3net.org` has already been reserved for this purpose.

The tight time schedule of the proposed Design Study necessitates a continuous monitoring of the progress made in the different work packages and the setup of mechanisms that provide corrective action in case of delays or technical problems. The PCC has the main responsibility for this task and will, in each of its quarterly meetings, review the work status in sufficient detail to detect problematic developments in due time. If necessary, the PCC shall redistribute the work load between the partners or, in more serious cases, make strategic decisions up to suggesting modifications of the Implementation Plan that then need to be discussed and decided by an extraordinary GA meeting. As a major intermediate review of the project status, a 2-week workshop in preparation of the CDR is planned 16 months after project start.

Competence of the participants:

A summary of the infrastructural equipment, of the group structure and of selected relevant references for each participant is collected in Table 5. Below, the main fields of competence relevant for the Design Study are summarised:

U-Erlangen: The physics institute of the U-Erlangen has long-standing experience in designing, constructing, operating and maintaining detectors in international high-energy physics experiments and in physics data analysis. The U-Erlangen groups taking part in this Design Study are involved in the ANTARES pilot project, contributing to simulation and data analysis as well as to calibration tasks. The University administration manages the coordination of several international FP6 projects.

U-Kiel: As a branch of U-Kiel, the Research and Technology Centre Westcoast (FTZ) at Büsum unites several disciplines of coastal North Sea research. With about 40 employees the centre focuses on interdisciplinary, applied and regionally oriented research on the Wadden Sea and the bordering coastline and in particular on applied physics and marine technology.

U-Cyprus: The physics department of the U-Cyprus hosts all research activities in particle physics and astrophysics in the Republic of Cyprus as well as a major scientific computing centre. The U-Cyprus team has extensive experience in physics simulation studies for major experiments at LHC/CERN.

IFREMER: IFREMER is the French Research Institute for the Exploitation of the Sea. IFREMER deals with most disciplines of sea research (studies on climate, sea environment, sea technology R&D, bio-diversity, marine geology, deep sea observatories,. . .). IFREMER is involved in many projects of oceanology and associated data management in the Mediterranean Sea. IFREMER developed the marine architecture concept, performs the sea operations for the ANTARES pilot project (including provision of deep-sea submersibles) and provides hydrodynamic simulations and hydrodynamic and hyperbaric tests.

IN2P3: IN2P3 is a division of CNRS operating more than 20 laboratories around France charged with research in particle and nuclear physics. Of these, the Centre de Physique des Particules de Marseille (CPPM) and the Institut de Recherches Subatomiques (IReS) in Strasbourg will participate in KM3NeT. These institutes' expertise encompasses physics analysis and simulation, computing and networking (including GRID), electronics, microelectronics and the development and construction of large detectors. IN2P3 is involved in most aspects of the ANTARES pilot project. It has developed the deep-sea acoustic positioning system and provided the local infrastructure.

Saclay: Research laboratory with about 650 scientists, engineers and technicians, specialised in astrophysics, particle physics and nuclear physics. Its fields of excellence are construction and operation of detectors for ground based and space experiments. It does the mass production of optical modules for the ANTARES pilot project, coordinates the assembly of the detector units and contributes to the sea operations.

HCMR: HCMR groups the majority of sea related research activities in Greece. It owns and operates several surface and underwater research vessels and is engaged in several major EU projects.

HOU: The research group in the Department of Natural Science of the HOU is member of the NESTOR pilot project and has developed the main reconstruction algorithms for the analysis of the data.

NCSR "D": NCSR "D" is the largest research centre in Greece covering most areas of natural science. It hosts *centres of excellence* in material science, nuclear physics information technology, physical chemistry, nuclear safety and radiation biology. The institute of nuclear technology has performed several probabilistic risk assessment studies for complex industrial systems in Greece and abroad and has participated in and led several EU projects in the field of nuclear safety and risk assessment. The former director of NCSR "D", who has extensive experience of science policy, governance and funding issues in the EU context, will participate in thew Design Study.

NOA/Nestor: NOA is the oldest science centre in Greece and hosts five institutes engaged in space physics, atmospheric physics, geodynamics, astronomy and astro-particle physics. The Nestor institute pioneered neutrino telescopy in Europe by initiating the NESTOR pilot project in 1991. It has accumulated extensive experience in building, deploying and operating small scale underwater structures.

U-Athens: Following a long history of contributions to experiments in particle physics at CERN and Fermilab (USA), the physics department of the U-Athens was a founding member of the NESTOR pilot project in the early 90's.

CNR: The Istituto di Scienze Marine (ISMAR) is a multidisciplinary institute of Consiglio Nazionale delle Ricerche (CNR), covering large part of marine disciplines: from physics to geology, chemistry, biology, and fishery. ISMAR has a long experience on deep circulation studies and participated in several EU projects on marine studies of the Mediterranean basin.

INFN: The INFN supports all theoretical and experimental research activities in sub-nuclear, nuclear and astroparticle physics in Italy. INFN operates four national laboratories and participates in experiments in the major international research centres. INFN groups participating to this Design Study (Universities of Bari, Bologna, Catania, Genova, Messina, Pisa, Roma-1 and the laboratories LNS Catania and LNF Frascati) have experience in construction and operation of big detectors for experimental physics, neutrino physics, simulation studies, computing networking (GRID), mechanics, electronics and micro-electronics, sea operations, deep sea measurements. These groups participate in the pilot projects NEMO and ANTARES.

INGV: INGV is the most important Italian research institution on seismic and volcanic hazard studies. Since 1995, INGV through its RIDGE Marine Unit, headed by Paolo Favali, is involved in geophysical and environmental monitoring at sea. INGV has been coordinator of the GEOSTAR and GEOSTAR 2 projects that developed the first European seafloor multidisciplinary observatory. It is presently coordinator of the ORION-GEOSTAR 3 project for the development of an observatory network. It is partner/coordinator in many other international and Italian projects (e.g. ASSEM and ESONET; SN-1; MABEL).

Tecnomare: Tecnomare S.p.A. (ENI group), founded in 1971, specialises in providing a complete range of offshore design and engineering services for international oil and gas companies, supporting them in their core business developments. During 30 years of life, Tecnomare has actively participated to a large number of research projects. On this regard, it is presently involved in some of the most important initiatives related to the development and demonstration of innovative technologies for long-term deep-sea monitoring and observations (e.g. ABEL, GEOSTAR, GEOSTAR 2, ORION-GEOSTAR 3 and ESONET).

FOM: NIKHEF is the national institute for experimental[25] and theoretical[26] subatomic physics in The Netherlands, in which the funding agency FOM and the Universities of Amsterdam, Nijmegen and Utrecht participate. The staff consists of about 120 physicists including Ph.D. students and postdoctoral fellows and about 100 engineers and technicians in well-equipped mechanical, electronic and information technology departments. NIKHEF coordinates and supports all activities in experimental subatomic (high energy) physics in The Netherlands. NIKHEF participates in the preparation of experiments at the Large Hadron Collider at CERN and is actively involved in experiments in the USA (DØ at FNAL, BaBar at SLAC and STAR at RHIC) and in Germany at DESY (ZEUS and HERMES). Astro-particle physics is part of NIKHEF's scientific programme through participation in the ANTARES pilot project and collaboration with astronomers of the Anton Pannekoek Institute in Amsterdam. NIKHEF has a theory group with a research programme which also includes topics related to the experimental programme of the institute.

CSIC and U-Valencia: CSIC and U-Valencia operate together the Institute of Particle Physics (*Instituto de Física Corpuscular, IFIC*) with a long-standing experience in particle physics experiments both at CERN and FNAL. IFIC is a member of the ANTARES pilot project and has made important contributions in the selection of the photomultiplier tubes, in the design and construction of a timing calibration system and to reconstruction algorithms and physics analysis.

UP-Valencia: The UP-Valencia group takes part in the Acoustic and Optic Devices and Systems R&D program (DISAO), investigating a.o. dynamic and piezoelectric transducers, ultrasounds, materials, acoustic positioning in the sea, etc. A laboratory with acoustic equipment including an anechoic chamber and a reverberant chamber is available. The group has particular competence in applied acoustic methods and a particle physics background from participation in the DELPHI and ATLAS experiments at CERN and the HADES experiment at GSI in Germany.

UNIABDN: The University of Aberdeen is an internationally recognised centre of excellence in ocean sciences and technology with interdisciplinary facilities concentrated at Oceanlab. Oceanlab is the coordinating member of the European Sea Floor Observatory Network (ESONET).

U-Leeds: The astrophysics group at the University of Leeds have a long record of involvement in astro-particle

[25] The former NIKHEF director Prof. Dr. J.J. Engelen is currently scientific director of CERN.

[26] M. Veltman and G. 't Hooft shared the Nobel prize in physics in 1998.

physics experiments and are currently members of the Auger and VERITAS projects. Most relevant for KM3NeT is the expertise in high-energy astrophysics and in Čerenkov light detection techniques gained in ground based high gamma ray astronomy with the earlier Whipple telescope and now with VERITAS. A new astro-particle physics laboratory will support the development of prototypes for Čerenkov detectors. Upgraded computing facilities provide sufficient parallel processing capacity and data storage for Monte Carlo simulation, subsequent data reduction and physics analysis.

U-Liverpool: U-Liverpool has one of the largest particle physics groups in the UK. It has long-standing involvement in particle physics experiments at CERN, DESY, FNAL and SLAC. U-Liverpool has considerable expertise in detector development, simulation and data analysis using GRID and eScience technologies. It will contribute to detector modelling and optimisation activities, to studies of the physics reach of KM3NeT and to prototyping of calibration devices.

LJMU: John Moores University, through its wholly owned subsidiary Telescope Technologies Limited, has expertise in the field of design and production of high-precision automated systems and special interest in astronomical instrumentation.

U-Sheffield: The Particle Astrophysics group at U-Sheffield has world-class expertise in dark matter searches via direct and indirect methods. The group has designed and commissioned the time calibration system for the ANTARES pilot project. U-Sheffield will contribute to simulating and optimising the KM3NeT detector, paying specific attention to the sensitivity for dark matter searches and will also be involved in the design of new calibration sub-systems.

Potential future participants:

- From Russia, groups from the *Institute for Theoretical and Instrumental Physics (ITEP)* in Moscow and from the *Institute for Nuclear Research (INR)* in Moscow have expressed the wish to cooperate with the KM3NeT consortium. In view of the large experience of these groups in the pilot projects and the expected synergetic effects, these requests are welcome and strongly supported by the KM3NeT participants. After approval of the Design Study, a funding approach via INTAS will be made.
- The *Groupe de Recherche en Physique des Hautes Energies (GRPHE)* of the *Université de Haute Alsace (UHA)* is a member of the ANTARES pilot project and works closely together with the IReS group in Strasbourg. A collaboration between KM3NeT and UHA is foreseen.

Participant	References	Role in tasks and research effort
U-Erlangen	[1] [2] [3]	WP1: Design Study coordination WP2: Development of simulation software WP3: Development of reconstruction software, physics analysis WP4: Investigation of pressure-safe electronics housings WP5: Contributions to online filter FTEMs: $216 + 115 = 331$
U-Kiel	[4] [5] [6]	WP4: Contributions to marine architecture WP7: Engineering of mechanical structures FTEMs: $72 + 11 = 83$
U-Cyprus	[7] [8] [9]	WP2: development of calibration algorithms and simulation code FTEMs: $38 + 58 = 96$
IFREMER	[10] [11] [12] [13] [14] [15]	WP4: Optimisation and tests of evaluation for the marine architecture, studies of flexible line and OM support structures, studies of cost-effective pressure housings WP6: Studies of deployment and recovery procedures WP10: Develop standards for the associated science experiments, deployment methods for associated science equipments, study the electrochemical processes in the deep sea prototype devices for deep-sea studies of bacterial adhesion FTEMs: 64

Participant	References	Role in tasks and research effort
IN2P3	[13] [16] [17] [18]	WP2: Coordination of work package, contributions to event and detector simulation software, WP3: Contribute to event selection and reconstruction software, assess physics sensitivity of detector WP4: Design of optical module and its mechanical support structure WP5: Design readout and data acquisition system WP6: Contribute to site evaluation WP7: Contribute to design of surface detector WP9: Explore funding resources and legal aspects WP10: Contribute to design of specifications for data exchange FTEMs: 398
Saclay	[19] [20] [21]	WP2: Contribute to event simulation software WP3: Contribute to event selection and reconstruction software WP4: Coordination of work package, design FMT bases and F/E electronics, design optical module WP5: Design readout and data acquisition system, design on-shore data processing system WP6: Design deep-sea power and data network WP7: Contribute to development of surface detector WP8: Assess quality and risks of detector design and operations FTEMs: 361
HCMR	[22] [23] [24] [25] [15]	WP6: Survey of water properties and detailed sea bottom topography WP10: Definition of associated sea science requirements, prototype design FTEMs: 132
HOU	[26] [27] [28]	WP3: Coordination of work package offline event selection and reconstruction, study of physics sensitivity vs detector geometry, define data formats and data distribution model WP5: Design for data handling and transmission FTEMs: $168 + 104 = 272$
NCSR “D”	[29] [30] [31]	WP8: Probabilistic risk assessment at system level WP9: Coordination of work package, study governance, legal and funding issues FTEMs: 70
NOA/Nestor	[27] [32] [33]	WP7: Coordination of work package, technical design for modifications and tests of existing prototype surface infrastructure FTEMs: 220
U-Athens	[29] [34] [35]	WP6: Investigation of connectors and cables, WP7: Tests of existing prototype surface platform FTEMs: $84 + 63 = 147$
CNR	[36] [37] [38]	WP6: Oceanographic characterisation of deep-sea locations, evaluation of bio-fouling and corrosion effects at telescope structure WP10: Prototype devices for monitoring of deep oceanographic environment for climate studies, prototype devices for investigation of ecosystem of abyssal bio-fouling FTEMs: 82
INFN	[39] [40] [41] [42] [43]	WP2: Develop simulation programs WP3: Study detector physics sensitivity as function of water parameters and detector geometry WP4: Evaluation of commercial PMTs, development of electronics for PMT read-out, development of calibration system specifications of mechanical structures

Participant	References	Role in tasks and research effort
INFN (cont'd)		WP5: Contribute to design of system for data processing and for signal transport from PMT to shore WP6: Coordination of work package, site evaluation, long term measurement of selected site(s), design procedure and tooling for detector unit deployment and recovery, design specifications for deep-sea power and data network, design shore infrastructure WP8: Coordination of work package, assess quality and risk of detector design, transport and recovery FTEMs: $396 + 540 = 936$
INGV	[44] [45] [46] [47] [48] [15]	WP6: Geo-environmental characterisation of the sites through long-term time series monitoring WP10: Definition of opportunities offered by a deep sea platform for long-term multidisciplinary monitoring, prototype design FTEMs: $81 + 12 = 93$
Tecnomare	[49] [50] [51] [15]	WP6: Engineering work for the characterisation of sites, adaptation of an innovative nuclear spectrometer FTEMs: 8
FOM	[52] [53] [54] [55]	WP2: Develop calibration procedures for detector WP3: Contributions to offline event selection and classification define data formats and data distribution model WP4: Implementation of PMT readout system WP5: Coordination of work package design readout and data acquisition system, design on-shore data processing system FTEMs: 432
CSIC	[56] [57] [58]	WP2: Develop event simulation software WP4: Design optical modules WP5: Design on-shore data processing system FTEMs: 48
U-Valencia	[56] [57] [58]	WP2: Develop detector simulation software WP4: Design acoustic positioning system WP5: Design readout and data acquisition system FTEMs: $43 + 15 = 58$
UP-Valencia	[59] [60] [61]	WP4: Design of positioning systems FTEMs: 76
UNIABDN	[25] [62] [15]	WP6: Water column profiling of temporal and spatial variation in abundance of luminescent organisms at sites, studies on mobile deep-sea animals living in proposed observatory areas WP10: Coordination of work package, liaison with the associated sciences user community, design Concept of associated science node and data protocols, prototype design, environmental assessment of KM3NeT components FTEMs: $36 + 12 = 48$
U-Leeds	[63] [64] [65]	WP2: Detector simulation, detector design optimisation WP3: Astrophysics potential WP4: light collection, photo-detectors, analogue signal transmission FTEMs: $114 + 13 = 127$
LJMU	[66] [67] [68] [69]	WP2: Contribute to detector simulation software FTEMs: $14 + 8 = 22$
U-Liverpool	[70] [71] [72]	WP2: Software development WP3: Assessment of scientific potential of different detector layouts WP4: Calibrator prototyping FTEMs: $66 + 20 = 86$

Participant	References	Role in tasks and research effort
U-Sheffield	[13] [14] [73]	WP2: Assessment of calibration procedures WP3: Optimisation of detector for dark matter physics WP4: Calibrator prototyping FTEMs: $120 + 36 = 156$

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Table 5: *Selected relevant references of the participants and their involvement in the Design Study tasks. At the beginning of the table (page 32), the right column lists the specific roles in the work packages and the research effort in professional person-months, including contributions by staff of institutions following the Additional Cost model that are not indicated in Table 3 (right numbers in sums).*

4.2 Justification of Financing Requested

The requested funding for the proposed Design Study is to a large extent meant for personnel cost. This is motivated by two facts: (i) The existing pilot projects and their member institutes have substantial equipment, laboratory/workshop infrastructure and testing grounds that will be made available to this Design Study and reduces the investment needs significantly. (ii) The main objective – to produce a TDR containing the information necessary to commence the construction of the KM3NeT infrastructure 36 months after the begin of the Design Study – is ambitious and requires new efforts for various tasks.

Based on the experience in the participating institutes, it is expected that the project will attract a large number of young scientists and will promote multi-disciplinary scientific research. It will increase the number of young high-quality experts, selected and trained under consideration of equal gender opportunities.

In the following, the requested budget per work package is associated to the corresponding subtasks; for the cost of labour, travel and consumables, percentages of the corresponding budgets (including overheads where appropriate) assigned to the different work packages are given. An overview of the budget breakdown by work packages is summarised in Table 6; the corresponding breakdown by participants is given in Table 7.

WP1: *Management of the Design Study*

The management of the Design Study is centralised at the University of Erlangen. According to the management structure described in Sect. 4.1, a project office will be established, requiring 12 k€ investment in a web server, two desktop PCs and other equipment to be depreciated over 3 years. Two full-time administrative experts will be employed for the project duration; in addition, auxiliary personnel is needed for setting up and maintaining a web platform for inter-collaboration communication and outreach purposes. A budget of 86 k€ is forseen for travels of the coordinator, the GA/PCC chairperson and the administrative staff. The expenses by other partners for audits, management-related travel etc. will be refunded from the 152 k€ reserved for “other costs”.

WP2: *Astro-particle physics*

The requested budget of 903 k€ is to be used for the hiring of personnel, for travel and for consumables and will be allocated as follows: development of event simulation software (20%); development of detector simulation software (30%); development of calibration models and determination of calibration accuracies (30%); determination of signal sensitivity of different detector configurations at different sites (20%). In addition, Saclay, U-Leeds, U-Liverpool and U-Sheffield will purchase computer equipment without requesting an EU contribution for it (78 k€ total).

WP	FTEMs	personnel t/r (k€)	equipm. t/r (k€)	travel t/r (k€)	consum. t/r (k€)	subcont. t/r (k€)	other t/r (k€)	sum t/r (k€)
1	108	306/ 306	12/ 12	86/ 86	6/ 6		152/ 152	562/ 562
2	500	2173/ 903	78/ 0	161/120	53/ 12			2465/1035
3	559	2660/1182	104/ 10	141/ 99	46/ 10			2951/1301
4	687	3688/1193	309/117	204/140	277/102		143/ 70	4621/1622
5	576	3332/ 697	143/ 60	104/ 56	137/ 56	125/55	487/ 240	4328/1164
6	417	2329/1090	210/ 96	235/136	829/486		1110/ 565	4713/2373
7	334	1495/ 734	150/ 50	46/ 34	2/ 2		30/ 0	1723/ 820
8	133	810/ 250	20/ 10	102/ 50	204/ 77			1136/ 387
9	50	357/ 125		27/ 10			60/ 30	444/ 165
10	191	1094/ 463	6/ 6	77/ 46	17/ 11		42/ 21	1236/ 547
Sum	3555	18244/6943	1032/361	1183/777	1571/762	125/55	2024/1078	24179/9976

Table 6: *Breakdown of the budget by work packages and cost categories. The column "FTEMs" indicates the number of full-time equivalent person months corresponding to the total budget associated to the work package. The amounts denoted by "t" and "r" are the total and the requested sub-budgets, respectively. The budgets include overheads as applicable.*

participant	FTEMs	personnel t/r (k€)	equipm. t/r (k€)	travel t/r (k€)	consum. t/r (k€)	subcont. t/r (k€)	other t/r (k€)	sum t/r (k€)
U-Erlangen	432	1332/ 909	156/ 84	132/132	6/ 6		152/ 152	1778/1283
U-Kiel	72	326/ 266		30/ 30	4/ 4			360/ 300
U-Cyprus	38	170/ 140		10/ 10				180/ 150
IFREMER	64	827/ 391		23/ 11	40/ 19		50/ 24	940/ 445
IN2P3	398	2480/ 656		65/ 30	34/ 18		78/ 20	2657/ 724
Saclay	361	4248/ 662	140/ 70	55/ 0	140/ 0			4583/ 732
HCMR	132	654/ 327		70/ 35	70/ 35		200/ 100	994/ 497
HOU	168	630/ 500		30/ 30				660/ 530
NCSR "D"	70	570/ 285		30/ 15			60/ 30	660/ 330
NOA/Nestor	220	830/ 440	150/ 50	20/ 10				1000/ 500
U-Athens	84	300/ 235		15/ 15				315/ 250
CNR	82	518/ 258		30/ 15	60/ 30			608/ 303
INFN	396	1065/ 532	186/ 93	360/180	817/409		550/ 275	2978/1489
INGV	81	372/ 162		24/ 24	90/ 90		340/ 180	826/ 456
Tecnomare	8	88/ 44		2/ 1				90/ 45
FOM	432	1946/ 241	63/ 20	70/ 35	105/ 55	125/55	587/ 290	2896/ 696
CSIC	48	367/ 92		25/ 18	16/ 9			408/ 119
U-Valencia	43	150/ 112		4/ 3	5/ 4			159/ 119
UP-Valencia	76	151/ 40		33/ 33	14/ 14		7/ 7	205/ 94
U-Aberdeen	36	285/ 186	100/ 44	35/ 30	80/ 69			500/ 329
U-Leeds	114	254/ 150	107/ 0	35/ 35	24/ 0			420/ 185
LJMU	14	20/ 15		15/ 15	2/ 0			37/ 30
U-Liverpool	66	290/ 150	70/ 0	35/ 35	30/ 0			425/ 185
U-Sheffield	120	371/ 150	60/ 0	35/ 35	34/ 0			500/ 185
Sum	3555	18244/6943	1032 /361	1183/777	1571/762	125/55	2024/1078	24179/9976

Table 7: *Breakdown of the budget by participants and cost categories. The column "FTEMs" indicates the number of full-time equivalent person months corresponding to the total budget associated to the participant. The amounts denoted by "t" and "r" are the total and the requested sub-budgets, respectively. The budgets include overheads as applicable.*

WP3: *Physics analysis*

The requested budget of 1182 k€ is to be used for the hiring of personnel, for travel and for consumables and on travel and will be allocated as follows: development of event selection and reconstruction software (50%); physics analysis of reconstructed events (20%); definition of data formats and data distribution model (30%). Saclay, U-Leeds, U-Liverpool and U-Sheffield will invest in computer equipment (104 k€ total), of which Saclay requests (10 k€) from the EU budgets.

WP4: *System and product engineering*

About 30% of the requested personnel/travel/consumables budget of 1435 k€ will be allocated to the design and optimisation of the optical module. For the design of the *in-situ* calibration system, 10% of the requested budget will be allocated. U-Leeds, U-Liverpool and U-Sheffield will purchase equipment for calibration prototyping (no EU contribution requested).

The design and optimisation of the mechanical support structures, material studies, their hydrodynamic assessment, the prototyping and the design of the production line will require 50% of the requested budget. In this subtask, an investment of about 400 k€ will be made by the Erlangen group for a hyperbaric chamber for development and tests of pressure-safe components. This chamber will complement the corresponding installation at IFREMER in its specifications and turn-around. Since the chamber will be used to 50% for the KM3NeT project, a total of 144 k€ are eligible cost, of which 72 k€ are requested. Furthermore, tools for prototyping will be purchased by INFN (35 k€ requested, 70 k€ total), and Saclay allocates (20 k€ total/10 k€ requested) to prototypes of mechanical structures.

The remaining 10% of the budget are needed for proto-typing of automated systems for the production line for telescope components and for planning the transport of telescope parts. Prototype objects like different photon sensors and glass containers have to be purchased to optimise the overall production speed (70 k€ requested as "other" costs).

WP5: *Information technology*

Following the signal from the optical module to the end-user we will allocate the requested budget as follows: The new application of existing technology for signal transmission requires the purchase of specialised opto-electronic components to be used for prototypes (DWDM lasers [40 × 2 k€], avalanche photo diode [40 × 1 k€], fibres/electronics [145 k€], optical add/drop multiplexers [15 × 2 k€], DWDM filters [4 × 40 k€], EDFA-amplifiers [2 × 16 k€], all in "other cost") and equipment (tunable lasers [2 × 30 k€], optical spectrum analysers [2 × 32 k€], optical time domain refractometer [19 k€]). Altogether this corresponds to about 15% of the total budget. Another 5% will be used for consultancy with companies specialised in R&D in this field. Another 15% will be used for standard equipment (PCs, software licences etc.).

The very precise timing needed for the envisaged angular resolution of the telescope requires a high level of electronic engineering for the fibre network linking the detector to the shore. Therefore, about 10% of the budget will be used to further enhance the existing expertise amongst the participants of this Design Study. The design of the readout of the underwater calibration systems is expected to be based on existing designs. Therefore, no additional money is requested for this.

About 25% of the budget is allocated for the development of the software filter and the design of a designated farm of computers.

About 30% of the budget is used to complete this work package within the three years period of the KM3NeT Design Study.

WP6: *Shore and deep-sea infrastructure*

For the various measurements at the candidate sites, 30% of the personnel and travel budget of this work package are foreseen. Additional funding requests are due to ship rentals and transports (6 campaigns, 9 days each for 15 k€ per day, resulting in a contribution of 810 kEuro to the total budget in "other costs", of which 415 k€ are requested). The measurements will require a 1000 m long line equipped with 3 stations carrying instruments that have to be purchased as equipment: 3 profiling current meters (60 k€), 6 photomultiplier tubes including bases and front-end electronics (45 k€), 2 buoys (18 k€), 3 instruments for water parameter measurements (CTDs) (30 k€), cables and auxiliary equipment (40 k€); the total cost is 193 k€ of which 116 k€ are eligible and 58 k€ are requested. Furthermore, UNIABDN will purchase equipment for bioluminescence studies, for which 60 k€ are requested.

For the development and verification of deployment and recovery procedures of the telescope, 40% of the overall budget are allocated. This sub-task involves further 4 sea campaigns of 5 days each (300 k€ total, 150 k€ requested). The selection and testing of cables and connectors requires another 10% of the personnel budget and necessitates investments in prototype objects (consumables: 829 k€ total/486 k€ requested).

Finally, 20% of the budget are foreseen for the development of the on-shore infrastructure for data acquisition, collection and distribution, and the control of the off-shore detector.

WP7: *Sea surface infrastructure*

For this work package, the requested funding is mostly intended for the hiring of personnel, for travel and for consumables. The personnel will be allocated to about equal parts to the preparation of the platform for KM3NeT operations and to the development and tests of surface detector prototypes. In addition, the platform will be equipped with auxiliary tools (cranes, winches, generators) for the operations in the KM3NeT project. For this equipment an investment of around 250 k€ is required, of which 50 k€ is requested from the EU.

WP8: *Risk analysis and quality assurance*

The requested budget is foreseen for manpower costs, for strengthening the teams of specialised engineers at INFN, Saclay and NCSR "D", for travels of specialists to the participant laboratories and for consumables.

WP9: *Resource exploration*

The budget request for WP9 is mainly determined by manpower costs, travel expenses and administrative work. In addition, an amount of 60 k€ (30 k€ requested) is foreseen for organising symposia and workshops gathering the international experts an questions of funding, governance and legal aspects related to multi-national science projects.

WP10: *Associated sciences*

The main part of the requested budget (463 k€) will be for personnel at UNIABDN co-ordinating this package and at IFREMER, IN2P3, HCMR, CNR and INGV developing the design and implementation of associated science cable observatory systems. Equipment (6 k€) and other costs (21 k€) are to enable practical experimental studies (data management protocols) and using testing facilities. Travel (46 k€) will be for meetings and for visits between institutes for technical discussions. Consumables (21 k€) include the experimental studies and preparation of public media associated with outreach to the wider science community and general public.

5 Other Issues

Gender issues:

The representation of women in the KM3NeT collaboration itself and in the partner institutions is still fairly unequal and can be improved. Most of the partners in KM3NeT are scientific organisations with an established policy of equal gender opportunities. The KM3NeT management will strive to ensure equal opportunity, according to EU rules and guidelines, when hiring the new project staff. Furthermore, the following action plan is proposed:

- collect gender statistics and segregation indicators within the different institutions of the KM3NeT in order to better understand the positions women occupy;
- during the meetings of the GA, a seminar will be organised to share experience on gender policies and propose actions. Figures concerning gender distribution in the partner institutions will be gathered in light of the work of the Helsinki Group[27];
- a section of the web site (see Sect. 4.1) will provide information concerning gender distribution in the partner institutions and of the published gender actions taken at different places in the world.

There will be a concerted effort to support special actions and procedures to encourage equal access to the research teams for students, post doctoral fellow, researchers and technicians, as well as to senior management and decision-taking positions for men and women in the project. Mrs. Prof. G. Anton (U-Erlangen) and Mrs. Dr. Els de Wolf (FOM) will co-lead the tutorial for female young scientists.

[27] See `http://www.cordis.lu/improving/women/helsinki.htm`

In the context of data storage and distribution of a future KM3NeT project, the options offered by the GRID will be assessed in the course of this Design Study. The GRID provides remote access to data and thus helps to reduce the burden of child bearing and raising on scientifically active parents and the aggravating effects these burdens can have in practice on equal gender opportunities in scientific careers.

Several employers involved in the Design Study have taken measures which promote the participation of women in physics. For NIKHEF, e.g., the most prominent of these is the so-called FOm/v programme, open only to women researchers, allowing them to obtain a grant for a (three to five year) postdoc position. Research institutes can obtain from the programme additional funding for five years for tenure positions for female physicist. Furthermore in FOM's collective labour agreement a *care clause* is included in the procedure for job vacancies with an age criterion, which allows persons taking care of children to apply and be appointed[28].

Ethical issues:

The Design Study, the envisaged infrastructure and all participants conform to the respective national legislation, to the EU legislation, to the international conventions and declarations of human rights and to the Helsinki Declaration. Ethical issues related to the protection of animals or the genetic heritage of human beings are not involved.

Environmental protection:

The installation of a complex deep-sea infrastructure can potentially interfere with the deep-sea biosphere. However, the hazard is reduced to almost zero by the requirement that all materials used have to be extremely stable in salt water and must not disturb the environment monitored by the instruments of the associated science communities. All materials are therefore essentially inert by selection. In addition, the expertise of the sea science and technology institutes involved in the project will be exploited to guarantee that the KM3NeT design will be environmentally safe in accordance with international regulations. A corresponding assessment of each component to be deployed in the deep sea will be declared imperative by the regulations of the consortium.

After decommissioning of KM3NeT, its components will be recovered to the extent that is required to ensure the exclusion of long-term environmental risks. Recovery procedures will be outlined in the Design Study, based on evaluating the long-term behaviour of all KM3NeT materials in the deep-sea Mediterranean environment.

[28] More information is available at `http://www.fom.nl/`.