KM3NeT 2.0

Astroparticle & Oscillations Research

with Cosmics in the Abyss

Contents

Figure 1: The KM3NeT optical module.
The KM3NeT neutrino telescope comprises several thousand optical modules arranged in a three dimensional spatial array covering several cubic kilometres of sea water. Each optical module consists of a glass sphere with a diameter of 42 cm, housing 31 photo-sensors (yellowish disks). The small white dot in the middle is a piezo-sensor for acoustic position calibration. The glass sphere can withstand the pressure of the water and is transparent for the faint light that must be detected to see neutrinos from the cosmos.

PART A: PROJECT SUMMARY

PROPOSING ESFRI DELEGATION OR EIROforum MEMBER

The Netherlands, Leo le Duc and Hans Chang

TITLE of the RESEARCH INFRASTRUCTURE

FULL TITLE (maximum 200 characters with spacing)

KM^3 Neutrino Telescope 2.0:
Astroparticle & Oscillations Research with Cosmics in the Abyss

PROJECT'S ACRONYM (maximum 20 characters with spacing)

KM3NeT 2.0

PROJECT COORDINATOR AND PARTNERS

- Project Coordinator:
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- Partners:
  The following partners signed the KM3NeT Memorandum of Understanding of Phase-1 (see attachment):

  THE CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE, France;
  FRIEDRICH-ALEXANDER UNIVERSITÄT ERLANGEN-NÜRNBERG, Germany;
  JULIUS-MAXIMILIANS-UNIVERSITÄT WÜRZBURG, Germany;
  STICHTING VOOR FUNDAMENTEEL ONDERZOEK DER MATERIE, the Netherlands;
  L'ISTITUTO NAZIONALE DI FISICA NUCLEARE, Italy;
  INSTITUTO DE FÍSICA CORSPUSCULAR, Spain;
  UNIVERSITAT POLITÈCNICA DE VALÈNCIA, Spain;
  INSTITUTE OF NUCLEAR AND PARTICLE PHYSICS, Greece.

  Further partners from Cyprus, France, Germany, Greece, Ireland, Italy, the Netherlands, Poland, Romania and the United Kingdom as well as earth and sea scientists are members of the KM3NeT Collaboration as observers.

GENERAL DESCRIPTION

- ✓ Major Upgrade / Reorientation of existing Research Infrastructure

Please provide an abstract of your proposal. (maximum 2000 characters with spacing)

KM3NeT is a large research infrastructure, that will consist of a network of deep-sea neutrino telescopes in the Mediterranean Sea with user ports for earth and sea sciences. KM3NeT appeared on the first ESFRI road map (2006). During the EU-funded Design Study and Preparatory Phase, a cost-effective technology was developed and the Collaboration for the construction of the research infrastructure was formed. To match the funding profile, a phased implementation of the research infrastructure was adopted. Following the successful deployment and operation of a series of prototypes, the construction of the first phase of the KM3NeT research infrastructure has started at sites in Italy and France.

The recent proof that high-energy cosmic neutrinos exist and that the neutrino mixing angle θ_{13} is large greatly enhances the possible scientific program and strongly motivates a major upgrade of the research infrastructure: KM3NeT 2.0. With this upgrade, a research infrastructure will be realised ideally suited for the discovery and subsequent observation of the sources of high-energy neutrinos in the Universe and the determination of the mass hierarchy of neutrinos. The total budget to realise KM3NeT 2.0 is approximately 125 M€ of which 31 M€ has already been funded. The current collaboration is defined in a Memorandum of Understanding. The chosen legal structure for KM3NeT 2.0 is that of a distributed ERIC. Compared to the initial science objectives, KM3NeT 2.0 offers the breakthrough capability of doing all flavour neutrino astronomy and the first measurement of the neutrino mass hierarchy, thereby securing the future of neutrino astronomy and advancing fundamental neutrino physics.

With this proposal, we request that KM3NeT 2.0 will appear on the ESFRI roadmap of 2016. To acquire the additional funds to realise KM3NeT 2.0, a position on this road map is essential. It is expected that KM3NeT 2.0 will enter its implementation phase within three years thereafter.

ELIGIBILITY CRITERIA

KM3NeT 2.0 is a distributed research infrastructure.

Funding Commitment and Political Support:

Please identify the Member States and Associated Countries which have expressed **funding commitment** and **political support**:

a) Country codes:

FR, IT and NL.

b) identify expression of **funding commitment** (Please upload at least **1 Letter of Intent**[1], Memorandum of Understanding; in the case of EIROforum members, please upload a Council resolution expressing funding commitment)

The investment budget for the construction of the first phase of the KM3NeT research infrastructure (Phase-1) amounts to about 31 M€ which is already funded and matched by the participating institutions (see attached document: KM3NeT Phase-1 Memorandum of Understanding). The intended engagement and financial commitments for KM3NeT 2.0 are expressed in the three letters of intent attached.

c) Type and amount of funding commitment (feasibility study/preparatory study already financed or being agreed to be financed (cost covered, planned) construction and/or operation of the RI

The Design Study (9 M€) and Preparatory Phase (5 M€) were funded by the EU. These funds were matched by the corresponding funding authorities to cover personnel, facilities and (additional) travel costs.

The Phase-1 has a total investment budget of 31 M€ which is covered by national funds (NL 8.8 M€ and FR 3.5 M€) and ERDF (FR 3.5 M€ and IT 16 M€).

There are on-going funding requests for KM3NeT 2.0 in France (12.4 M€) and Italy (70 M€) and a proposal is being prepared for additional funding in the Netherlands (10 M€).

The operational costs of the KM3NeT research infrastructure are estimated at about 2% per year of the total investment which will be covered though in-kind contributions of the host countries and the annual fee of full members of the KM3NeT Collaboration.

d) potential siting/hosting of RI or Headquarters of Distributed RI (D-RI) or Node of D-RI (cost covered, planned)

The KM3NeT 2.0 research infrastructure comprises two deep-sea installations with shore stations, located off-shore Toulon, France and Capo Passero, Italy and a central computing centre in Lyon, France. It has been agreed to establish the headquarters of KM3NeT in the Netherlands with its place of residence in the Amsterdam Science Park.

The shore station and a part of the deep-sea infrastructure already exist at each installation site. Both shore stations are well equipped and connected via high-speed internet connections to the central computing centre (and beyond). The Italian and French installation sites are supported by a major laboratory of INFN (LNS) and CNRS (CPPM), respectively.

The Amsterdam Science Park is an internationally renowned centre for scientific research, education and knowledge related business activities. Amsterdam as the gateway to Europe is well connected internationally by plane and train. Many local people speak English, German and French making life convenient for foreigners. The Amsterdam Science Park offers a modern and well equipped location

[1] *Eligibility Criteria detailed in the 2016 ESFRI Short Guide*

for the KM3NeT headquarters. It boasts one of the fastest and most powerful internet nodes in the world.

The installation of the KM3NeT headquarters requires a budget of about 1 M€ for the first three years. This includes the costs for setting up the office space, the professional fees for administrative, legal and organisational assistance, and the salary of the chief administrative officer for three years. These costs will be covered by the proposal that is being prepared in the Netherlands (at the time of this writing, this proposal should be submitted in 2016). After the initial three years, the costs of 0.25 M€/year will be covered via the regular common fund contributions of the members of KM3NeT.

e) Identify expression of **political support** - Identify Country Codes (drop down list) and please upload at least **2 Letters of Intent**[2], Memorandum of Understanding or other collaboration/participation declaration of engagement)

The engangement of the current partners in KM3NeT is laid out in the Memorandum of Understanding (MoU) for Phase-1 (see attachment). This MoU includes the following articles: "*This Memorandum of Understanding defines the first phase of the KM3NeT research infrastructure. Its purpose is to define the parties and institutes and the programme of work to be carried out for this phase and the distribution of charges and responsibilities among the parties and institutes for the execution of this work. It sets out organizational, managerial and financial guidelines to be followed by the Collaboration and the external scientific and technical review processes... The first phase includes the preparation for the next phase of the KM3NeT neutrino detector with an instrumented volume of several cubic kilometres.".* The political support for KM3NeT 2.0 is expressed in the three letters of intent attached.

Please indicate which ESFRI Strategy Working Group do you believe to be the most suitable to analyse your Scientific Case:

Physical Sciences and Engineering

In case this project should, in your view, be also assessed by an additional ESFRI Strategy Working Group, please indicate which:

n.a.

[2] *Eligibility Criteria detailed in the 2016 ESFRI Short Guide*

PART B: SCIENTIFIC IMPACT, PAN EUROPEAN RELEVANCE, SOCIO-ECONOMIC IMPACT & E-NEEDS

Section1. SCIENTIFIC IMPACT OF THE RI

1.1. SCIENTIFIC FIELD (S)

Identify the RI Scientific field (1) Scientific field (2) and inter- or multidisciplinary scope of the RI (Maximum 500 characters)

The main scientific fields are neutrino astroparticle physics and earth and sea sciences. The former targets the study of astrophysical objects by detecting their high-energy neutrino emission and the investigation of neutrino properties by measuring neutrinos produced through cosmic-ray interactions in the atmosphere. The KM3NeT location in the deep sea offers interdisciplinary opportunities for continuous, real-time measurements, e.g. for marine biology, oceanography or environmental sciences.

Please summarise the Scientific Outline (Scope of Project) (maximum 5000 characters with spacing) Please Upload Scientific Case Document (limit 1 MB)

For neutrino astronomy, the main objective of KM3NeT 2.0 is the detection of high-energy neutrinos of cosmic origin. Even modest numbers of detected neutrinos will be of utmost scientific relevance since they carry unique information, such as indicating the astrophysical objects in which cosmic rays are accelerated or pointing to places where dark matter particles annihilate. These prospects have motivated the world-wide scientific community to construct, over several decades, a series of detectors with increasing sensitivity. Recently, the IceCube experiment at the South Pole has reported the discovery of high-energy cosmic neutrinos: A major breakthrough and the proof that neutrino astronomy is feasible. The high-energy neutrino telescope of KM3NeT 2.0 (*Astroparticle Research with Cosmics in the Abyss,* ARCA) will detect the neutrino flux reported by IceCube and will provide essential data concerning its origin, energy spectrum and flavour composition. Due to its location in the Northern hemisphere, the ARCA information will be complementary to the IceCube measurements: the same sources will be observed at different energies; sources that are not visible to IceCube can be observed; and, due to the smaller light scattering in water as compared to ice, the direction (and energy) of neutrinos will be measured with much better precision.

From neutrino oscillations measurements we know that neutrinos are massive, with three different mass eigenstates. So far, the measurements rather precisely constrain the mass differences, but two types of mass spectra are still possible: two light and one heavier neutrino (“normal hierarchy”), or one light and two heavier neutrinos (“inverted hierarchy”). The neutrino mass hierarchy is one of the most fundamental unknown parameters of particle physics and its knowledge is essential e.g. for the investigation of CP violation in the neutrino sector. In 2012, when the first measurement of the neutrino mixing angle θ_{13} was reported, it became clear that the neutrino mass hierarchy can be determined using neutrinos produced in the Earth’s atmosphere through interactions of cosmic rays. It has been shown that this measurement can be performed by a densely instrumented Cherenkov detector using the same technology developed for ARCA: *Oscillation Research with Cosmics in the Abyss,* ORCA. The measurement of the neutrino mass hierarchy with ORCA can be achieved earlier than with any other planned experiment and is the second major objective of KM3NeT 2.0.

It is interesting to note that the signal for ORCA is the background of ARCA (atmospheric neutrinos). By using the same technology and by operating both in parallel, the significance of the measurements performed with ARCA will be improved thanks to a better understanding of this background.

KM3NeT 2.0 is a cabled deep-sea infrastructure that provides continuous access to real-time measurements in situ. This is an important and unique opportunity for performing deep-sea research, e.g. by scientists from the fields of marine biology, oceanography, environmental sciences, geosciences or seismology. Corresponding cooperation has been established over the last decade in the ANTARES and NEMO projects and has already led to various publications. It is a declared objective of KM3NeT 2.0 to intensify and extend this cooperation. The KM3NeT sites are nodes of the *European Multidisciplinary Seafloor and water column Observatory* (EMSO).

Neutrinos are detected by measuring the Cherenkov light induced by charged secondary particles emerging from a neutrino reaction. KM3NeT 2.0 will consist of arrays of light detectors constructed in the deep, clear water of the Mediterranean Sea that serves both as target material and Cherenkov radiator. The light detectors are photo-multiplier tubes (PMTs) arranged in glass spheres that resist the water pressure (optical modules). In KM3NeT, the optical modules will, for the first time in neutrino astronomy, house multiple small PMTs instead of one large one, thus optimising the photo-cathode area per optical module, while reducing the price per photo-cathode area to a minimum.

The optical modules are arranged along flexible strings kept vertical by a submerged buoy. ARCA, to be constructed near Sicily, consists of two building blocks of 115 strings each, with 18 optical modules per string; ORCA (near Toulon, France) is one block of 115 strings, but with much smaller horizontal and vertical spacing. Both installations will provide user ports for earth and sea sciences.

Currently, the installation of 31 strings in the KM3NeT Phase-1 is under way to demonstrate the viability of the technical design, the operational stability and the performance, and to establish best-practice cooperation models with the earth and sea science communities. The strings at the French site will be ORCA prototypes while the strings at the Italian site will already form the by far most sensitive neutrino telescope in the Northern hemisphere.

Does the project correspond to a long term science programme (20-40 years) by a well-established scientific community? Does the project address a multidisciplinary scientific frontier opening novel possibility in several research fields? Which ones and how? (maximum 2000 characters with spacing)

The first neutrino astronomy projects were initiated in the 1970s. Since then, a strong global science community has formed that currently pursues the installation of next-generation devices which are expected to become fully operational around 2020 and will have lifetimes of 10-20 years, at least. KM3NeT is already planning a next step in its staged implementation, that will extend into the 2040s. The sub-communities pursuing neutrino astronomy in the deep ice of the South Pole (IceCube) and in the deep water of the Mediterranean Sea (ANTARES, NEMO, NESTOR, KM3NeT) cooperate in scientific, technological, software and strategic questions. In 2014, an umbrella organisation, the Global Neutrino Network (GNN) was founded, which also includes the Russian GVD collaboration. GNN strengthens cooperation between the research groups and serves as a platform to coordinate the scientific and strategic program of the science community.

KM3NeT addresses questions at the forefront of astro- and particle physics. Its science perspectives are unique in both fields (see above). In addition to the specific questions to be addressed (cosmic accelerators, dark matter, neutrino mass hierarchy), neutrino astronomy also opens a new observation window to the Universe; past experience shows that this almost always entails completely new insights and paradigm changes.

The interdisciplinary earth and sea science aspect of KM3NeT offers new opportunities for a range of science fields. So far, measurements in the deep sea are typically performed by deploying and recovering autonomous devices that record data over a period of months to years. This method is severely constrained by bandwidth limitations, by the absence of real-time interaction with the measurement devices and by the delayed access to the data. A cabled observatory like KM3NeT 2.0 remedies these disadvantages. Devices connected with cables of up to several 100 km length allow for covering a significant seafloor area.

1.2. USER ANALYSIS AND INVOLVEMENT STRATEGY

1.2.1. What is the targeted user' community?

- ○ macro-regional[3]
- ○ pan-European
- ✓ global

1.2.2. What are the fields of research and size of the potential users community/communities? Please indicate estimates of the numbers of academic/publicly funded researchers, innovation/industrial technology developers, multidisciplinary/general public users. (maximum 4000 characters with spacing) (% per type of users)

A detailed analysis of user communities, their needs and requests has been documented in the framework of the Preparatory Phase. The following groups, described by their roles, will use the KM3NeT research infrastructure (note that these groups can have overlaps):

1. Owners and primary users of the neutrino telescope: The neutrino astronomy and neutrino physics community, including members of the KM3NeT Collaboration and beyond. In 2014, a global network of neutrino astronomers –the Global Neutrino Network (GNN)– has been established, which will provide a forum for this community and an organisational framework for the access to neutrino astronomy data world-wide. The main sub-communities, operating experiments in the Mediterranean Sea, at the South Pole and in Lake Baikal, currently comprise about 240, 300 and 50 authors (publicly funded researchers and engineers), respectively.
2. Users with impact on the neutrino telescope operation mode: The wider community of astroparticle, astro- and particle physicists will have the opportunity to propose observation priorities implemented by online filters providing enhanced sensitivity for particular celestial directions or other signals that can be enhanced by implementing special event filters. Also, the KM3NeT operation will actively contribute to global multi-messenger alert systems, thereby increasing the sensitivity for potential astrophysical transient neutrino emission phenomena.

[3] This concerns four macro-regions identified by the EU Macro-regional Strategies. For reference please see: http://ec.europa.eu/regional_policy/cooperate/macro_region_strategy/index_en.cfm

This community includes several thousand scientists, who are potential users. At least several hundred of them will directly or indirectly use the alert data. The number of scientists submitting observation proposals is difficult to estimate; corresponding expressions of interest have been made by numerous individuals.

3. Users shaping the earth and sea science program: The earth and sea sciences communities (environmental sciences, geosciences, marine biology, oceanography etc.) will connect their own, specialised instrumentation to the KM3NeT research infrastructure. The earth and sea sciences communities may also be interested to use the neutrino telescope data (e.g. for monitoring sea currents, temperature, bioluminescence and bioacoustics in the neutrino telescope volume), separately or in conjunction with their own data or to devise additional data filters. Cooperation with the multidisciplinary earth and sea sciences community has been established in the ANTARES, NEMO and NESTOR projects and consolidated in the KM3NeT design phase, in which about 20 earth and sea scientists participated, representing several major earth and sea science institutions with hundreds of scientists. Included in this category are developers of marine technology.
4. Users accessing the offline data: The general scientific community and the general public will have open access to all data from the infrastructure. This access will be provided with a certain latency required to perform appropriate data reconstruction and calibration and to secure priority scientific data access to the KM3NeT Collaboration and the proponents of observational campaigns (see point 2). The number of users in this group cannot be assessed before the data will be available; experience from satellite experiments is, however, that this number is substantial.

It is conceivable that the infrastructure will also be used for public security purposes, such as tsunami warnings. This would imply the involvement of the responsible national authorities. No commitments or concrete plans to this end have been established to date.

The quoted user communities pursue cognition-oriented, curiosity-driven basic research. The corresponding users are typically affiliated at universities and research institutions. A commercial use of the infrastructure is currently not envisaged but would not be excluded if desired by commercial entities. If so, they will be subjected to the same rules and regulations as academia and publicly funded research institutes.

1.2.3. How has the potential user community been involved in the support and development of the project?

- ✓ In the definition of the science case
- ✓ in the definition of the technical design specifications
- ✓ in analysing Costs vs. Benefits
- ✓ in planning and financing parts of the infrastructure (experimental suites, collections, data-bases)
- ✓ Others

If Others, please describe: (maximum 1000 characters with spacing)

In the technical design work; in the site choice and the assessment of the site properties; in establishing the relevant contacts to industry; in environmental impact studies; in exploring governance models and establishing the current governance scheme.

1.3. ACCESS POLICY

1.3.1. What will be the access policy of the RI? Please define the access, e.g. by means of access unit like beam time or GB, and explain type of access, e.g. physical access to site, assisted-access from remote, remote submission of samples for analysis, virtual remote mode, access to data etc. Please also describe the conditions for access, e.g. restrictions of access via quota`s due to e.g. financial, programmatic or feasibility considerations. Please also elaborate on the processes to grant access and describe eventual support measures facilitating access. (maximum 4000 characters with spacing)

The KM3NeT research infrastructure is a distributed network of deep-sea installations, comprising the neutrino telescope, user ports for earth and sea sciences measurements and shore stations. Physical access will neither be possible nor desirable for the users. Instead, access to the research infrastructure can be summarised as follows.

1. Data access: This is the by far most demanding access type. The amount of persistent data collected by using the research infrastructure is several 100 TB/year. Massive data processing is required to make these data meaningful for the users. Access is therefore either through the central computing centre (CCIN2P3-Lyon), from where the users retrieve reduced data sets for local analyses using WAN (GRID) tools, or through the internet to pre-processed high-level data sets such as reconstructed neutrino event records. This data access will be exclusive for a certain embargo period of typically two years, during which the KM3NeT Collaboration reserves the right to scrutinise the data, optimise the calibration and event reconstruction methods, produce the high-level data sets for open access, apply blinding procedures to data analysis and draw scientific conclusions from the data. An indispensable prerequisite for the analysis of neutrino telescope data are Monte Carlo simulations, producing data sets of similar or even larger size than the real data. The access to the resulting data sets is the same as for the real data.
2. Access to user ports: Earth and sea scientists (and others) will have the opportunity to connect their devices to the user ports provided by KM3NeT. Corresponding applications will be screened for operational safety, bandwidth and electrical power compliance and scientific potential by a committee established under the auspices of KM3NeT and an entity representing the earth and sea sciences communities. It is foreseen to provide 5-10 connection interfaces per site, which can host multiple devices each. The earth and sea sciences groups will be responsible to finance their equipment and deployment operations. Services provided by KM3NeT could be financially compensated by an appropriate contribution of the earth and sea sciences community to KM3NeT construction and/or a user fee per instrument connected to KM3NeT. The earth and sea sciences data are collected by individual user groups and differ in data volume, processing needs and access path. Details will be regulated in bilateral agreements between the KM3NeT Collaboration and the earth and sea sciences user groups. Adherence to the principle of open data access will be a condition for access to the user ports.
3. Observation time: It has been shown that a significantly increased efficiency for neutrino signals from sources at known celestial positions can be achieved in the online filtering process if the direction of the incoming neutrino is used. More generally, new or additional filter algorithms (“observation filters”) can be implemented to search e.g. for hypothesised exotic particles. A variety of observation filters can be simultaneously operated, of which roughly 50% will be used by the KM3NeT Collaboration and the other 50% will be assigned according to observation proposals from the wider scientific community. These proposals will be evaluated and ranked by an

independent scientific committee. Selected proposals will be implemented without requesting financial compensation.

4. Alert networks: Online processing of the neutrino telescope data will allow for identifying signals that as such are not highly significant but could become so in combination with coincident observations by other instruments, e.g. optical, gamma-ray or gravitational wave telescopes or other neutrino telescopes. To exploit this potential, a global alert network system has been established and will continuously be extended. KM3NeT will provide alerts for other nodes of this system and will receive and follow up alerts by these nodes.

1.3.2. What are the plans for training users and managers of the facility? Are there plans for advanced training of professional scientists/engineers/data managers? (maximum 2000 characters with spacing)

Training of owners and primary users is mainly required in the data/software regime. In addition to collaborative training in the research groups, workshops and documentation will provide fast introduction of new users to the relevant tools. Detailed documentation, template analysis scripts as well as questions and answers will available for external users. Further support, such as a help desk, training courses or scrutinising of analysis methods and results can only be provided if additional funding is acquired, e.g. through an EU project along the line of the HEAP-MM proposal (INFRA-2011-1.1.23).

The neutrino telescope will be operated by shift crews. Training of the shift crews follows a cascading scheme, where experts are paired with “apprentices” and transfer their knowledge during a series of shift periods. The initial experts are trained during the construction phase. The remote operation of the research infrastructure allows for optimal use of experts. Earth and sea scientists will have to attend training courses on the technical, operational, data and legal aspects relevant for their projects. This training will be provided by the laboratories associated to the installation sites.

The data centres provide expert personnel for data and computing management. Experts in the Collaboration manage the application-specific online and offline software; training is a collaborative effort in the responsibility of the individual institutions.

Operation, maintenance and safeguard of the shore installations will require small local teams with computing experts, technicians and security personnel. Selection, training and supervision of these teams is managed by the host laboratories. Past operation of the ANTARES and NEMO sites over many years provides ample experience in this respect.

The project management will be supported by a project office with designated personnel for managerial, administrative, legal, organisational, communication and outreach tasks.

1.3.3. Which mode(s) of access is/are to be adopted? (maximum 1000 characters with spacing)

For access to the neutrino telescope data, two modes are planned: 1) remote log-in to the central computing centre on personalised accounts provided to authorised users; 2) free internet access to the high-level data through designated internet protocols. The second access mode will also be available for data taken that are relevant for the earth and sea sciences community (bioluminescence, sea currents, water properties etc.).

Access to data from earth and sea sciences instruments will be provided and designed by the corresponding earth and sea sciences groups, under the regulations of the bilateral agreements with KM3NeT.

Permission to connect earth and sea sciences devices as well as implementation of observation filters are by application with independent expert review. Corresponding calls will be published as appropriate.

Access to alert data is restricted to internationally recognised networks and is subject to the conditions in the corresponding multilateral agreements.

1.3.4. What is the estimated % of different mode(s) of access? How is this division linked to the financing? (maximum 1000 characters with spacing)

The different access modes are provided in parallel and are not mutually limitative; a partition in percentages is therefore meaningless. Limiting factors for data access are the bandwidth of the connection to Lyon or via internet, respectively, and the server and CPU capacities. It is expected that these limitations do not entail access bottlenecks.

The only access mode related to financial aspects is that of earth and sea sciences users (see above). The impact of this aspect on the overall funding of the KM3NeT research infrastructure is expected to be moderate, at most.

1.3.5. What is the expected amount of access to be provided in proper units (like instrument-time per year, gigabits of data per year, CPU time, etc…) specific to the different access modes offered? What is the typical quota of access that will be granted to a given (average) successful proposal? How much of expected demand will be satisfied by the new/upgraded RI?

Typical data volumes accessed by owners and priority users can go up to TB/day/user, while data volumes transferred from/to the central computing centre (CCIN2P3-Lyon) by other users are significantly smaller. Depending on the work load, data access at other computer centres (ReCaS and CNAF) may become similar.

Earth and sea sciences proposals will be endorsed subject to restrictions in data bandwidth, electrical power consumption and light and sound production in the deep sea; a connection time appropriate for the scientific purpose will be granted.

Observation proposals will be endorsed for limited periods, typically for several years due to the long-term nature of neutrino astronomy measurements.

For the owners and priority users, KM3NeT 2.0 is a major milestone that satisfies the needs and demands by the neutrino astronomy community within the given funding constraints (see section 1.1). On the long run, an extension to 6 building blocks of ARCA is envisaged to fully exploit the scientific potential of neutrino astronomy.

Since KM3NeT will be the first research infrastructure of its kind operated with the access policy described above, no solid estimate of the demand by external users can be made. Due to its global uniqueness, the KM3NeT research infrastructure will strive to cover the justified demand to the largest possible extent. This may require moderate additional investments over its lifetime, e.g. for computing upgrades or additional user ports.

Section 2. PAN- EUROPEAN RELEVANCE

2.1. PAN-EUROPEAN ADDED VALUE

2.1.1. Does the RI project address a gap in the current RI panorama in Europe and respond to unaddressed needs of the user communities? Is the project "unique" in the landscape of RIs? What is the RI project adding to European research capacity in one or more fields of research and innovation? (maximum 2000 characters with spacing)

The KM3NeT research infrastructure provides a very broad and unique scientific program ranging from neutrino astronomy to fundamental neutrino properties, as well as providing synergetic opportunities for the earth and sea sciences community.

The infrastructure will be the sole neutrino telescope operating in Europe. It will provide the European neutrino astronomy community with a flagship instrument which surpasses largely the performance of the USA led IceCube telescope at the South Pole. Together their complementary fields of view ensure a complete coverage of the neutrino sky. The low energy threshold of KM3NeT gives rapid access to leading measurements of fundamental neutrino properties which will be instrumental in defining the worldwide roadmap for future major neutrino facilities.

For the astroparticle community in Europe and worldwide, KM3NeT is a pillar in the arsenal of instruments needed to reveal and understand the high-energy Universe. It will complement with unique information the multi-messenger vision of the sky soon to be opened by a number of other ESFRI research infrastructures (ELT, CTA, SKA, Einstein Telescope, etc.).

With a timely measurement of the neutrino mass hierarchy, KM3NeT will put Europe back at the forefront neutrino physics. An early determination of the neutrino mass hierarchy by KM3NeT will also help to interpret results of ongoing experiments on the Majorana nature of the neutrino and to define the optimal configuration of future experiments dedicated to the measurement of the CP-violating phase.

The challenges inherent in constructing very large, complex infrastructures in the deep sea are pushing the boundaries of what is technologically possible. The R&D for KM3NeT (cables, connectors, fibre optic data transmission, time synchronisation, photo-sensors etc.), largely undertaken in partnership with European industry, is a driving force for innovation in Europe, examples of which are given in section 3.

2.1.2. Indicate current options (infrastructures or services that are operational and accessible) for the relevant science communities, if any, and explain why they are not adequate. (maximum 3000 characters with spacing)

For the last twenty years the European neutrino astroparticle community has focussed its efforts around the ANTARES, NEMO and NESTOR projects. ANTARES started data taking in 2006 and it is the first and only operating neutrino telescope in the deep sea. Intended as a proof of principle of the deep sea approach and as a discovery instrument to explore the then completely unknown southern neutrino sky, ANTARES has been very successful. With the recent discovery of a cosmic neutrino diffuse flux by IceCube, backed up by the ANTARES observations, it is now clear that the next steps in neutrino astronomy require a telescope with a sensitivity about a factor fifty times better than ANTARES; thus setting the ambition of the KM3NeT telescope. The design lifetime of ANTARES is ten years and it starts to show its age. As its maintenance is relatively expensive, it is preferred rather to invest efforts in the next generation KM3NeT infrastructure; ANTARES decommissioning will therefore start early 2017 once KM3NeT Phase-1 surpasses it in sensitivity. On completion, Phase-1 will exceed the sensitivity of ANTARES by a factor of three.

Although ANTARES was able to make the first ever measurement of neutrino oscillations with a large volume neutrino telescope, its density of instrumentation is not sufficiently high to address the energy range relevant for the determination of the neutrino mass hierarchy. The KM3NeT-ORCA site will be optimised to match exactly the requirements for this measurement.

KM3NeT has been designed in close cooperation with the earth and sea scientists. For the earth and sea community**,** KM3NeT will be the only facility in Europe that offers multi-site, long term and non-stop access to the deep sea (2500–3500 m) with real-time, high-power and high-frequency sampling capabilities. The emerging opportunities for studies in oceanography, tsunami detection, climate change, seismology, bioacoustics, bioluminescence, etc. are unprecedented. KM3NeT also incorporates an innovative capability of acoustic data transfer from distant autonomous sensors to the cabled node. This expands significantly the volume of the sea that can be monitored and alleviates the need of an expensive submersible to make the underwater connections.

2.1.3. Is the development of a new Infrastructure the most appropriate solution to address this need? What, in your view, is the added value of performing the research activities foreseen within a RI instead of performing it as a research programme in consortia, cooperation networks etc.? (maximum 3000 characters with spacing)

The development of a new infrastructure is the only solution to fulfil the promise of the fledgling field of neutrino astronomy and explore the neutrino Universe with the necessary sensitivity and precision.

Instrumenting the required volume of seawater with previously existing technology would have been prohibitive in terms of cost and effort. After a long program of R&D, partially funded via the EU in the FP6 design study, the KM3NeT design is now cost effective and proven. It is based on innovative new ideas for string deployment, photo-sensor design, low power electronics, data transmission and computing. These in turn have given rise to dramatically improved performances in terms of the background reduction, angular resolution and energy resolution.

KM3NeT comprises multiple sites and multiple science objectives. A strong management and centralised coordination team is imperative in order to achieve a coherent implementation and efficient operation. Such a management structure is more appropriate within a research infrastructure than the more “loose” coordination usually associated with a consortium or cooperative network. In addition, the enhanced funding opportunities at the national and European level associated with being a research infrastructure are considered an important advantage when leveraging funding and manpower/technical resources within the collaborating countries and institutes.

The possibility provided by a research infrastructure to adopt the ERIC for the legal framework is also felt important to establish a well-defined legal entity with capability to hire centralised personnel, attract expertise, submit tenders, facilitate the interaction with industry and last but not least benefit from VAT exemption.

2.1.4. How does the RI project contribute to the enhancement of the European Research Area?[4] (maximum 3000 characters with spacing)

The KM3NeT research infrastructure contributes in numerous ways to the European Research Area. Firstly, it will undoubtedly provide world class science which will serve to attract and retain the best scientific talent to the ERA knowledge base. Such a pool of excellence will have a direct impact on the quality of training of students, researchers and engineers throughout the member states participating to the research infrastructure. The research infrastructure has also established close partnership to complementary research infrastructures in its field of interest outside of Europe (IceCube, LBNF, Neptune, etc.). Such links will foster knowledge exchange even beyond the borders of the ERA. Scientific excellence is also key for public outreach events and the inspiration of Europe's youth to pursue a science based career path.

Being a distributed research infrastructure with host sites located in areas identified in need of enhanced regional development, KM3NeT will serve to facilitate the transfer of knowledge and expertise between the highly performing and lagging member states. Furthermore, the research infrastructure commits to actively promote the exchange of highly qualified personnel and technology between its partner institutes.

KM3NeT is a multidisciplinary research infrastructure which catalyses the interaction of scientists from very different fields of research. In the past, this has led to interdisciplinary collaborations and completely unexpected discoveries, for example in bioluminescence (Prix special de la Recherche 2014) and in oceanography and bioacoustics (Nature communications). Such synergetic research is only possible at the interface of multiple disciplines and will undoubtedly present additional "surprises" within the KM3NeT context.

The KM3NeT research infrastructure already is and will continue to be a driving force of innovation within the ERA via its partnership with industry. This is further emphasised by the fact that the activities on the host sites are in phase with their declared smart specialisation strategies and their regional poles of expertise. An example spin-off is the development of low-cost, wet-mateable electrical and fibre optic connectors. This has led to a patent and the creation of a French start-up company (PowerMate). Of course, a large fraction of the investment cost of the research infrastructure is distributed to local, national and Europe wide industry with its consequent economic benefit, promotion of competiveness and growth. The open access philosophy, adopted by KM3NeT is in line with the policy of the ERA.

During its development, the KM3NeT research infrastructure and its researchers have been fully engaged in the ERA instruments designed to promote excellence and innovation (ERANETs such as ASPERA, Design Study, Preparatory Phase, etc.). This will continue with participation to many of the ongoing and future calls (Marie-Curie, ERC grants, RI specific calls, etc.).

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[4] Communication "A Reinforced European Research Area Partnership for Excellence and Growth" COM(2012) 392 expressed ERA Priorities: **More effective national research systems** – including increased competition within national borders and sustained or greater investment in research; **Optimal transnational co-operation and competition** - defining and implementing common research agendas on grand-challenges, raising quality through Europe-wide open competition, and constructing and running effectively key research infrastructures on a pan-European basis; **An open labour market for researchers** - to ensure the removal of barriers to researcher mobility, training and attractive careers; **Gender equality and gender mainstreaming in research** – to end the waste of talent which we cannot afford and to diversify views and approaches in research and foster excellence; **Optimal circulation, access to and transfer of scientific knowledge including via digital ERA** - to guarantee access to and uptake of knowledge by all.

2.2. EUROPEAN INVESTMENT ALIGNMENT

2.2.1. How will this RI help to focus national investment in this field at a European level? (maximum 3000 characters with spacing)

The KM3NeT Phase-1 comprises 41 institutes from 8 countries of Europe. In the MoU for Phase-1 funds amounting to 31 M€ are already committed to the cost of its construction. Much of this is sourced from regional and ERDF contributions from the host sites of France and Italy. For KM3NeT 2.0 additional funds amounting to 95 M€ are needed. As for Phase-1, a significant fraction of this is also anticipated to be sourced via regional and ERDF contributions from France (6 M€) and Italy (70 M€), the remainder must therefore be sourced from national programmes and elsewhere.

To attain its funding goal, KM3NeT will not only have to amplify the contributions from its existing stakeholders but attract new stakeholders from within Europe and also worldwide. The management is working very actively in this direction. It is clear that having the KM3NeT research infrastructure included in the ESFRI roadmap has raised the visibility of the project and has proven to be a considerable advantage when leveraging funding at the regional and national levels. It is also inevitable that if KM3NeT was removed from the roadmap at this time, the negative impact would be very detrimental to this effort and act to thwart various ongoing discussions.

For astroparticle physics In Europe the national funding agencies coordinate amongst themselves through the Astroparticle Physics European Consortium (APPEC), which evolved from the EU funded ASPERA networking activity. APPEC has, and will continue to do so, strongly supported the KM3NeT research infrastructure through its roadmap, letters of support to evaluation committees, R&D calls, etc. Indeed, the KM3NeT vision of a multi-site/multi-physics approach has been formulated in close consultation with APPEC.

The participation in KM3NET is, to some extent, also linked to future funding decisions outside Europe. The existence of KM3NeT as a recognised research infrastructure, included on the ESFRI roadmap, will be invaluable to attract new scientists and possibly new funds.

2.2.2. How is the RI going to effectively orient resources from the relevant science communities and stimulate a substantial “joint programming”? (e.g. contributing complementary instrumentation, activating partnerships, training more young researchers in the relevant fields of science) (maximum 2000 characters with spacing)

The KM3NeT Collaboration is open to observers from any scientific field who may be interested in using the research infrastructure. This “open access” strategy has led some institutions from other scientific fields (e.g. earth and sea sciences) to join the Collaboration and become full member. Earth and sea scientists helped developing deployment methods and during (early) sea campaigns contributed various equipment, including temperature sensors, sea-current profilers and sound velocity meters. This proved very useful for evaluating the quality of the deep-sea sites. The availability of user ports provides the necessary means for a continued synergetic operation. The science case of KM3NeT has also attracted (traditional) astronomers (ARCA) and particle physicists (ORCA). Their contributions are particularly relevant in astrophysics and neutrino physics, respectively. The ORCA detector presents also sensitivity to low-mass dark matter (via annihilation in e.g. the Sun) and possibly also to the composition of the Earth interior (via neutrino tomography). This has attracted interest from yet again different scientific fields.

The scientific scope of the KM3NeT research infrastructure offers clear opportunities for synergy and joint programs which will surely materialize with KM3NeT 2.0.

2.2.3. What are the linkages with existing platforms, and networks and other ESFRI RI's? (maximum 3000 characters with spacing)

The KM3NeT research infrastructure has close ties with the operating ANTARES neutrino telescope and the NEMO and NESTOR R&D platforms. The KM3NeT Collaboration meetings (3 per year) are organised conjunctly with those of the ANTARES collaboration. The simulation and analysis software of KM3NeT inherits much from that of the ANTARES software and indeed developments are pursued in close collaboration and improvements are propagated between collaborations. In some cases key responsibilities are held by the same person in both collaborations.

The connections between KM3NeT and IceCube have strengthened over the years. The software analysis framework of KM3NeT (SeaTray) is based on the framework originally developed by IceCube (IceTray). More recently the worldwide (ANTARES, GVD, KM3NeT, IceCube) neutrino astronomy community have formed a Global Neutrino Network (GNN, http://www.globalneutrinonetwork.org/). GNN serves as a forum for strategy discussions and fosters the annual MANTS meetings and the biannual international workshop on *Very Large Volume Neutrino Telescope*s (VLVNT). Goals of GNN include the coordination of alert and multi-messenger policies, exchange and mutual checks of software, creation of a common software pool, establishing a common legacy of public documents, developing standards for data representation, cross-checks of results with different systematics, the organization of schools, and other forms of exchanging expertise, e.g. through mutual working visits of scientists and engineers.

Within the framework of H2020, KM3NeT participated in the ASTERICS (Astronomy ESFRI & Research Infrastructure Cluster) proposal which aims to address the cross-cutting synergies and common challenges shared by the various Astronomy ESFRI facilities (SKA, CTA, KM3NeT and E-ELT). With the recent approval of the ASTERICS proposal, the implementation of the ESFRI telescopes will be supported and accelerated, their performance enhanced beyond the current state-of-the-art, and their interoperation as a multi-wavelength and multi-messenger facility realized. An important focal point is the management, processing and scientific exploitation of the huge datasets the ESFRI facilities will generate. In addition, ASTERICS will enable astronomers from across the member states to have broad access to the reduced data products of the ESFRI telescopes via a seamless interface to the Virtual Observatory framework.

Once operational, KM3NeT will strive to establish MoUs with the plethora of telescopes (HESS, MAGIC, VERITAS, CTA, Auger, VIRGO/LIGO, SKA, ELT, LSST, ROTSE, TAROT, etc.) and satellites (FERMI, SWIFT, SVOM, Euclid, etc.) relevant to pursue its multi-messenger program of research.

For the earth and sea sciences, KM3NeT has established effective links with EMSO to ensure efficient coordination between the RIs. Indeed already the two research infrastructures share same the ethics board and a draft MoU was prepared during the preparatory phase of KM3NeT.

2.2.4. Is this project as such, or in preliminary form, already adopted in one or more National Roadmaps?

✓ YES   o NO / Not Yet

If YES explain and indicate Country-Codes, amount of funds already allocated to the project in the framework of National Roadmaps. (maximum 1000 characters with spacing)

KM3NeT is listed on the European roadmaps of APPEC/ASPERA and AstroNet and on various national roadmaps. The Phase-1 has a total budget of 31 M€ which is covered by national funds (NL 8.8 M€ and FR 3.5 M€), ERDF (FR 3.5 M€ and IT 16 M€). There are on-going funding requests in France (12.4 M€) and Italy (70 M€) and there are plans for funding requests in the Netherlands (10 M€). For the acquisition of these funds, the appearance of KM3NeT on the ESFRI road map of 2016 is essential.

If NO / Not Yet, do you plan an application to National Roadmaps? In which countries?

n.a.

2.3. EUROPEAN GEOGRAPHICAL COVERAGE

2.3.1. What is the estimated capacity of the RI as compared to the Pan-European expected needs, and how is the Pan-European coverage addressed? (maximum 2000 characters with spacing)

The KM3NeT 2.0 research infrastructure will satisfy the expressed needs of European scientists in the fields of neutrino astronomy and cabled deep sea observatories for the next ten years. Further extension of the research infrastructure will extend its importance for the community beyond 2030.

KM3NeT has stakeholders in many countries of Europe (Cyprus, France, Germany, Greece, Ireland, Italy, Netherlands, Poland, Romania, Spain, United Kingdom). Efforts (seminar presentations, discussions with national funding agencies, APPEC) are ongoing to aggregate new partners from additional European countries.

Through well advertised open calls for dedicated observation time and open calls to incorporate new sensors to the infrastructure the user base will certainly be extended beyond that of the original stakeholders.

2.3.2. What is the estimated % of non-hosting country users in Europe?

About 50% (45%) of the members of the KM3NeT Collaboration are not based in the host countries (France or Italy (or Greece)). There are no estimates of the percentages of non-hosting country users including all other users (see section 1.2.2) but it may be expected that these follow the composition of the KM3NeT Collaboration.

2.4. INTERNATIONALISATION POTENTIAL

2.4.1. What is the estimated % of non-European users?

Until recently, the KM3NeT Collaboration was exclusively European. At the Collaboration meeting in February 2015, Oujda University (Morocco) joined the Collaboration.

Once the research infrastructure is constructed and the neutrino alert system active, the alerts will be used by a large non-European community of researchers (and vice versa).

Within the context of the GNN, once KM3NeT is of similar sensitivity to IceCube, the stated aim is to form a Global Neutrino Observatory in which GVD (Russia), KM3NeT (Europe) and IceCube (USA) will cooperate to mutualise their research infrastructures, their data and analysis methods. By this, the percentage of non-Europeans users will be increased to about 50%.

2.4.2. How will it help European scientific communities' mobility and internationalisation? (linkage with the access model which should include open access through international competition on the basis of excellence) (maximum 2000 characters with spacing)

The research infrastructure is committed to enhancing scientific mobility within the ERA. Given the distributed nature of the research infrastructure, during construction it will be necessary for scientists and engineers to pass extended periods of time at the integration and installation sites located at the various institutes of the Collaboration. Personal exchange between collaborating institutes is also encouraged.

As discussed in Section 1.3.1 the research infrastructure has an open access policy. Proposals will be invited for improved observation of specific locations in the sky. Due to the limited bandwidth this will necessarily be competitive and based on the scientific excellence of the proposal. Similarly for deep sea studies, international scientists will be invited to propose projects which either make use of the existing sensors or connect new sensors to the infrastructure.

2.4.3. How can this project leverage European competitiveness in the specific field/fields of research? (e.g. uniqueness of technical offer, advancement of technical standard, innovation in research process, effective impact to innovation of research products, setting reference standard in data management, etc.) (maximum 3000 characters with spacing)

The KM3NeT research infrastructure will be a world class instrument generating world class science. Its capabilities (view of sky, angular resolution, energy resolution, flavour separation) are far superior to that of competing facilities outside of Europe. The research infrastructure will therefore allow ERA scientists to once more play the leading role in the field of neutrino astronomy as it comes of age.

The research infrastructure will also be world leading in the competition to determine certain fundamental parameters of the neutrino. Its rapid implementation will guarantee major results 2-3 years in advance of the competition from the PINGU and JUNO experiments.

The infrastructure will open the deep sea to high-frequency, precise, long-term scrutiny. It will allow European scientists to catch-up with and surpass similar deep-sea observatories in Canada (Neptune) and Japan (DONUT).

2.4.4. Testing your proposal against the Pan-European ex-ante indicators[5] how would you rate the overall Pan-European relevance of the project: high, medium or low? Please explain (maximum 3000 characters with spacing)

The Pan-European relevance of the project is rated as high.

The project has successfully completed a design study and a preparatory phase, with corresponding completion of the associated deliverables, in particular a conceptual design report and a technical design report. The project addresses new scientific challenges with innovative solutions thus strengthening European leadership. The project is physically located in Europe and has resolved all issues connected with siting and management. The project has agreed to adopt the ERIC as it preferred legal entity.

The membership indicator is high: With Phase-1 the research infrastructure has unified and federated the previously dispersed neutrino astroparticle community within Europe. Significant funds for the construction of the research infrastructure have been secured and efforts to attract the required additional funds are progressing well. The project has established a strong centralised management and introduced effective oversight mechanisms through a Scientific and Technical Advisory Committee (STAC) and a Resources Review Board (RRB) comprising eminent researchers and science managers.

The user strategy indicator is high: the project is at the forefront of many scientific fields (neutrino astronomy, fundamental neutrino properties, earth and sea sciences) and has a strong potential for interdisciplinary studies. The project has a tremendous potential for future expansion and to address other major questions in particle and astroparticle physics.

The networking indicator is high: the project comprises around 240 collaborators directly involved in the construction and analysis. Once operational the project will receive and generate transient alerts to a large network of space and ground based telescopes for multi-wavelength and multi-messenger studies. The project is involved in networking activities of other ESFRI research infrastructures. The project intends to link with IceCube and GVD to establish the Global Neutrino Observatory.

The excellence indicator is high: the project has attracted renowned and highly qualified personnel. The project has been formally labelled by regional poles of excellence. The project is supported by national funding agencies and included in the various national and European roadmaps. The anticipated scientific output will be of the highest calibre and prize winning.

The knowledge transfer indicator is high: The project is distributed over many centres (integration, installation, data treatment, headquarters) facilitating exchange of knowledge and personnel through the ERA. The project has very close connections to some of the major universities and research centres in Europe and will foster the training of PhD students and postdocs. Industry has helped to define most elements of the research infrastructure as well as (deep-)sea operations. The project has adopted open access and open data policies. Access for industrial uses will be encouraged.

[5] ESFRI Report on Indicators of Pan-European Relevance of Research Infrastructures" – Annex 2 – ex-ante indicators

Section 3. SOCIO- ECONOMIC IMPACT

3.1. What will be the direct economic impact of this RI? (e.g. economic impact from direct spending in the site/region hosting the new facility, or the headquarters and/or the main nodes of a distributed facility in the construction phase, or the establishment of a well-connected e-infrastructure enabling fully distributed new research opportunities) (maximum 3000 characters with spacing)

The additional budget needed to realise KM3NeT 2.0 amounts to 95 M€. This budget corresponds to the investment costs and will primarily be used for the procurement of the components of the research infrastructure. As such, it directly and positively affects the economy. The scientific objectives and the location of the research infrastructure impose demanding specifications on many of the components. These specifications have been worked out in close collaboration with industry. The sequence of workshops on *Very Large Volume Neutrino Telescope*s (http://www.vlvnt.nl/) started in 2003 and initiated by KM3NeT exemplifies and sustains this collaboration.

The experience gained with Phase-1 has shown that the development of a deep-sea infrastructure such as KM3NeT attracts a wide variety of companies and SMEs, for example those operating in fields of marine technology, mechanics, electronics, fibre-optics, photo-sensors and computing. Due to the size of the KM3NeT research infrastructure, this aspect also has an impact on the region. This is particularly relevant for a sector like the offshore market which is continuously developing in response to user requirements. It should be noted that the locations of the KM3NeT sites in the Mediterranean have strategic-economic value.

The experience gained with Phase-1 also provides a sound and well established basis to evaluate the impact given by the construction of such a facility on the site as well as at a regional and transnational level. One of the partners (INFN) has conducted in the past a study to quantify the economic impact of the institute activities on the local territory. This study evaluated an average return corresponding to a factor 1.8 (i.e. an induced monetary flux of 1.8 euros for each euro spent). During the construction phase the main impact will derive from direct investments in the region. During the operation phase the main impact will be given by the provision of services such as marine operations, tele-communications, infrastructure and power systems.

The planned location of the KM3NeT headquarters in the Science Park in Amsterdam places KM3NeT in the heart of business, education, research and other local activities.

Finally, the existence of a distributed deep-sea infrastructure offers unprecedented opportunities for future research and developments. The availability of user ports, electrical power and high-bandwidth in the deep sea facilitates the best use of these opportunities.

In case, you have carried out a socio-economic impact study, please upload: (maximum 1 MB)

For the aforementioned ERDF subsidy in Italy (see part A), a study of the impact on the development of new industries and a market study were made (both in Italian and available on request). The study referenced above is attached.

3.2. What are the medium-long term socio-economic benefits of this RI? (e.g. in terms of replacing/re-orientating costly infrastructures that are already in place)? (maximum 2000 characters with spacing)

Due to its inherently interdisciplinary characteristics and its high technological content, KM3NeT is a unique infrastructure of which the development is perfectly in line with the strategies outlined by the regions where the deep-sea nodes will be installed (Sicily, Italy; Toulon, France and Pylos, Greece) in terms of exploration and exploitation of the marine resources. The implementation of KM3NeT 2.0 will allow to fully utilise the infrastructures already existing at the French and Italian sites for the Phase-1 of KM3NeT. This will not re-orient their use but rather expand their usability by offering more capacity and easy access thus enlarging the potential user community.

KM3NeT will be an ideal platform to develop interdisciplinary activities in the deep-sea that will concern not just the research institutes involved in the construction but also most of the European agencies active in the field of Earth and Sea sciences. As a reference the community involved in EMSO may be considered.

It is being considered to make KM3NeT a CO_2-neutral facility, using wind or solar energy to supply the required power for the underwater system as well as the shore station. This represents not only a cost saving, but also reflects the policy to reduce global warming.

Last but not least, neutrinos are elementary particles that interact only weakly with matter. There are literally billions of neutrinos which pass through us every second unnoticed. For that reason, neutrinos are often quoted as ghost particles. The realisation of a neutrino telescope located at the bottom of the sea looking at “invisible” particles from the Universe has a significant “X-factor”. The subject has appeared a number of times in national newspapers, on radio and TV. It is also a popular topic for public seminars.

3.3. What is the estimated impact on innovation activity in the production of goods and/or services that will result from this RI ?(e.g. in terms of well trained people, knowledge transfer, access programmes, services provided, etc.) (maximum 2000 characters with spacing)

The market of marine technologies and of deep-sea technologies in particular is characterised by a strong innovative component, needed to cope with the harsh environment of the (deep-)sea and to respond to the ever growing demand for new products and systems. This applies not only to oil, gas and telecommunications but also to societal needs (pollution monitoring and warning as well as tsunami early warning may be cited as examples). There is a direct impact of KM3NeT on some key enabling technologies like photonics and materials technology for deep-sea applications. Also other key enabling technologies, like biotechnologies, may benefit from the implementation of KM3NeT. The main impact on the economy and employment connected to services and products coming from KM3NeT will certainly affect the SMEs operating in the regions were the infrastructure sites will be installed, but also on a wider scale SMEs at national and European level. This will in particular concern SMEs developing mechanics, electronics and software solutions. Although it is not possible at the moment to make a firm quantitative prediction of this impact, it is certain that both new start-ups and high-technology spinoffs will benefit from the presence of KM3NeT. For example, a start-up company (PowerMate) has been created in Marseille (with EDF, Comex, Subsea Tech and PowerSea), based on a patented idea for a new type of low cost wet-mateable connector, originally developed by KM3NeT.

Also a growth in competitiveness of the already existing companies, which will benefit from the close interaction with the research institutes, is foreseeable. It is also clear that such an infrastructure generates the need of skilled personnel with competences in cutting-edge technologies such as micro-electronics, automation and control, communication and information technologies, engineering for deep-sea applications. It is worth mentioning that such skills are sought for in an expanding sector like the off-shore.

3.4. What role can this RI play in industry/service/societal innovation developments? (maximum 2000 characters with spacing)

KM3NeT is positioned in the heart of fundamental, curiosity driven, research. Exploration of the Universe through the detection of neutrinos in itself has no immediate application in industry, but the harsh environment of the deep sea and the high cost of maintenance have been a driving force for design innovations and intense collaboration with industry.

KM3NeT will be a unique facility in Europe, the only one able to provide direct and continuous access to the deep-sea environment with real-time data connection to shore. This will impact on a huge scientific community working on oceanography, seismology, biology and bioacoustics. In addition to the scientific opportunities, it is foreseeable to use the infrastructure for public security purposes, such as tsunami warning. It will also be a unique platform to develop new technologies for the marine environment.

The experience gained with Phase-1 has shown that the development of a deep-sea infrastructure such as KM3NeT attracts a wide variety of companies and SMEs (see 3.1). In short, KM3NeT stimulates start-up and growth of new business activities with high technological content. Due to the location, the size and the foreseen lifetime of the research infrastructure, KM3NeT can be considered an example for exploratory, challenging and sustainable developments.

3.5. How is the project going to attract resources from innovation/industrial communities? (maximum 2000 characters with spacing)

During the EU-funded Design Study and Preparatory Phase, detailed specifications of key components have been communicated to the industrial communities. Following a period of R&D and by in-depth studies of the relationship between specifications and price, various innovations have been realised in the fields of photo-sensors, deep-sea cables, micro-electronics and others. Several actions will be put in place to sustain these developments:

- Transfer of know-how from the KM3NeT Collaboration to SMEs (e.g. in the field of deep-sea technology);
- Stimulate investments by companies (e.g. through installation of new branches for production of components or supply of services) in the vicinity of the infrastructure;
- Cooperation with companies in the optimisation of production processes and logistics;
- Providing of access to user ports of the deep-sea infrastructure for testing of components.

3.6. What is the expected contribution of the RI to address Horizon 2020 Societal Challenges[6]? (maximum 2000 characters with spacing)

Oceans and seas represent more than two thirds of the Earth's surface and are still mostly unexplored. The KM3NeT research infrastructure will be a unique platform providing access to research activities that can address some of the challenges identified by the H2020 programme. Due to their nature, these activities

[6] Please consult H2020 Societal challenges: http://ec.europa.eu/programmes/horizon2020/en/h2020-section/societal-challenges

will be mostly conducted in synergy with the EMSO research infrastructure of which the KM3NeT sites constitute the deep-sea nodes. In particular, the exploitation of the aquatic living resources, developing of blue biotechnologies, fostering cross-cutting marine research, environmental protection, sustainable managing of the marine ecosystem, are all issues that can be addressed using the KM3NeT research infrastructure. In this respect, KM3NeT will represent a unique opportunity to bring together resources and knowledge coming from different disciplines. These aspects will be addressed in different ways, such as:

- Providing access to the infrastructures to companies to test materials and components for long-term operation in the deep sea;
- Providing access to researches/institutes to install sensors and/or experimental devices with real time connection to shore;
- Providing access to the environmental data gathered by the neutrino telescope.

Specific actions to be undertaken within the framework of H2020 will be identified for example in the areas of marine, material and climate research.

Section 4. e- NEEDS

4.1. What will be the data management and open data policy of the RI? (e.g. Would data become accessible from a repository to the public? Would the RI be interfaced to E-Infrastructures for science?) (maximum 3000 characters with spacing)

The KM3NeT Collaboration has developed a data policy based on the research, educational and outreach goals of the facility. The first exploitation of the data is granted to the collaboration members as they build, maintain and operate the facility and to priority users (for more details see sections 1.2.2 and 1.2.3). Accordingly, each collaboration member has full access rights to all data, software and know-how. Access for non-members is restricted, as long as methods and results have not yet been published. The prompt dissemination of scientific results, new methods and implementations is a central goal of the project, as is education. High-level data (event information enriched with quality information) will be published after an embargo time of two years (see section 1.3) under an open access policy on a web-based service. Exceptional access rights that correspond to these goals can be granted.

The Collaboration has developed measures to ensure the reproducibility and usability of all scientific results over the full lifetime of the project and in addition 10 years after shutdown. Low-level data (as recorded by the experiment) and high-level data will be stored in parallel at central places (see sections 4.2 and 4.3). A central software repository, central software builds and operation system images are provided and continuously maintained until the end of the experiment.

Data formats and meta-data structures have been chosen and developed following common practices in the particle and astroparticle physics communities: the main data format is based on the ROOT-framework, xml and plain ASCII-formats are used for meta-data. The developments aim at interoperability with different research infrastructures using available e-Infrastructures (see section 4.3) and the implementation is based on open-source software packages.

The corresponding research groups will manage the earth and sea science data. Responsibilities of the KM3NeT RI in this respect will be the feed-through of the earth and sea science data streams from the deep sea to well-defined interfaces and the provision of up-link connections for device operation and control. A temporary buffering of the data to safeguard against connection problems to the respective mass storage installations may be subject to negotiations. It will be a necessary condition for access to KM3NeT that the earth and sea science data will be made public with fully open access.

4.2. What is the plan for supporting advanced data management and how will it be funded? (maximum 2000 characters with spacing)

The storage and computing needs of the KM3NeT project are highly advanced. The Collaboration has developed a data management plan and a corresponding computing model to answer those needs. The latter is based on the LHC computing models utilizing a hierarchical data processing system with different layers (tiers). Data are stored on two main storage centres (CCIN2P3-Lyon, CNRS and CNAF, INFN); those large data centres are fully interfaced with the major European e-Infrastructures, including GRID-facilities (ReCaS, HellasGRID provide resources to KM3NeT). The main node for processing of the neutrino telescope data is the computer centre in Lyon (CCIN2P3-Lyon). A corresponding long-term and sustainable commitment has already been made by CNRS, which is consistent with the needs for long-term preservation of the data.

A specialised service group within the Collaboration will process the data from low-level to high-level and will provide data-related services (including documentation and support on data handling) to the Collaboration and partners. WAN (GRID) access tools (e.g. xrootd, iRODS, and gridFTP) provide the access to high-level data for the Collaboration. The analysis of these data will be pursued at the local e-Infrastructures of the involved institutes (both local and national). The chosen data formats allow for the use of common data analysis tools (e.g. the ROOT data analysis framework) and for integration into e-Infrastructure common services.

The central services are mainly funded through CNRS and INFN that have pledged resources of their main computing centres to the project. Additional storage space and its management are provided by the partner institutes (e.g. INFN has provided 500 TB of disk space for KM3NeT at the ReCaS GRID infrastructure, the Hellenic Open University has pledged 100 TB of disc space and 300 cores to the project). New developments in data management services (see section 4.4) have been proposed via Horizon2020 e-Infra calls.

4.3. What is needed (if applicable) from external e-infrastructure services (resources for storage, computing, networking, tools for data management, security, access, remote analysis, etc.)? (maximum 2000 characters with spacing)

In addition to the major storage, networking and computing resources provided by the partner institutions and their computing centres (as listed section 4.2), grid resources have been pledged and will be used by KM3NeT (ReCaS, HellasGRID). These will provide significant resources to be used for specialised tasks (as e.g. for special simulation needs). The major resources, however, will be provided by the partners.

External services are employed to integrate the KM3NeT e-Infrastructure into the European context of the GRID – in the fields of data management, security and access; services will be implemented in collaboration with EGI. First contacts with GEANT have been established discussing network resources. First considerations regarding common data services have been started, see section 4.4.

4.4. Will the RI contribute to the development of e-infrastructure commons[7] in the field or in general? (maximum 2000 characters with spacing)

One of the aims of the KM3NeT data management plan is to play an active role in the development and utilization of e-Infrastructure commons. KM3NeT will therefore contribute to the development of standards and services in the e-Infrastructures both in the specific research field and in general. Members of the KM3NeT computing and software working group have been active and successful in several European-wide proposals that aim at the developments needed for a common e-Infrastructure in astroparticle physics and science (amongst others through EGI and the recently approved Horizon2020 project ASTERICS). First cross-discipline case studies for data storage management have been started between ELIXIR and KM3NeT using EGI data management services.

[7] Please consult e-IRG 2013 White paper: http://www.e-irg.eu/images/stories/dissemination/white-paper_2013.pdf

In the framework of the Global Neutrino Network (GNN), KM3NeT will cooperate with the ANTARES, IceCube and GVD collaborations to contribute to the open science concept by providing access to high-level data and data analysis tools, not only in common data analyses but also for use by citizen scientists.

4.5 Will the RI policy on data include training services for “data practitioners” to enable the effective use of data repositories and data analysis tools by non-scientists? (maximum 2000 characters with spacing)

The dissemination of research outcomes is a major focus of KM3NeT. In this context, training services for scientists, university and PhD students will be developed and form the basis for the development of courses for teachers, high-school students and citizen scientists. Cooperation with the Particle Physics Masterclasses and their astroparticle-extension COSMICS has already been established and will be further pursued. In addition, dissemination projects are planned to stimulate interest of students in higher education in astro- and astroparticle physics and to introduce and further enhance these topics in the university curricula. Experience from ANTARES and IceCube shows that KM3NeT research will attract large numbers of under-graduate and graduate students who in fact will have a major role driving the science output.

In the framework of the ASTERICS project, KM3NeT will develop an interface to the Virtual Observatory including training tools and training programmes to enhance the scientific impact of the neutrino telescope and encourage the use of its data by a wide scientific community including interested citizen scientists. Data derived from the operation of the experiment (acoustics, environmental monitoring) will be of interest also outside of the field. Designated documentation and courses for external users will therefore be put in place to facilitate the use of the repositories and tools developed and used by the KM3NeT Collaboration.

PART C: IMPLEMENTATION

5. PREPARATORY WORK ACHIEVED

5.1 Concept screening

5.1.1 What level of assessment has the project already received? Please identify the stakeholders involved (e.g. government ministries, research funding organisations, EC, private sector and public bodies, scientific community).
(maximum 1000 characters with spacing)

In the framework of ESFRI, the KM3NeT project was critically reviewed by the Assessment Expert Group (AEG) in 2013. The recommendations from the AEG have swiftly been implemented and the follow-up was positively reviewed by the PSE working group in December 2013.

The funding authorities involved have installed the Resources Review Board (RRB) which oversees the project. The RRB is advised by an international Scientific and Technical Advisory Committee (STAC). The STAC is composed of acknowledged world experts in the field of neutrino astronomy and earth and sea sciences and is currently chaired by M. Spiro, former director of IRFU/IN2P3 and former chairperson of the CERN council. The project is reviewed twice per year by the STAC.

During the last year(s), it was recognised within the scientific community that ORCA is world-wide competitive and that ARCA offers the breakthrough capability of doing all flavour neutrino astronomy.

5.1.2 Is the project based on a well-established international networking activity, like I3s or other programme with external international evaluation?
(maximum 1000 characters with spacing)

From its very beginning, the KM3NeT project has been recognised, supported and advised by the European forum of funding agencies in astroparticle physics, the Astroparticle Physics European Consortium (APPEC) and its predecessors. In particular, KM3NeT was included as top priority in all roadmaps and recommendations of APPEC. Furthermore, KM3NeT is included in the Global Neutrino Network, a consortium of neutrino telescope collaborations (see e.g. section 2.2.3) . The project is reviewed twice a year by the STAC which directly reports to the RRB.

5.2 Design study

5.2.1 Has a design study been carried out with formal national, European and/or international support?
(maximum 1000 characters with spacing)

A EU-funded Design Study has been made (2006–2009) in the framework of FP6. The list of key deliverables includes a Conceptual Design Report (ISBN 92-79-02694-1) and a Technical Design Report (ISBN 978-90-6488-033-9). An important outcome of the Design Study was a new technology which has improved the cost effectiveness of the detector by a factor of about four. So one can safely say that the Design Study has paid off. The list of other results includes proof-of-concepts of (real-time) data processing and qualification tests of various components and procedures.

Please upload references and outcome. (Maximum 1 MB)

5.2.2 Concerning the Technical Design Report (TDR): are all the relevant technologies available or substantial R&D is needed (how many years) in order to assess the full technical feasibility and draw a reliable cost-book? (maximum 1000 characters with spacing)

The feasibility of neutrino astronomy with a detector in the Mediterranean Sea was proved by the successful deployment and operation of the ANTARES detector. In the framework of Phase-1, two prototypes of the new technology have been deployed offshore Toulon, France (April 2013) and Capo Passero, Italy (May 2014) at a depth of about 2500 m and 3500 m, respectively. The results obtained with these prototypes confirm the design specifications (EPJC, 2014, 74:3056). All relevant technologies are now available and validated. Following the successful deployment and operation of these prototypes, the construction of the research infrastructure has started. The prices and the delivery times of all components for the research infrastructure are consistent with earlier cost and time estimates, respectively.

5.2.3 Is industrial capacity already in place (EU or international market) or does it need to be developed/installed in relation to the project (spin off companies, joint-ventures)? (maximum 2000 characters with spacing)

As a result of the Design Study and Preparatory Phase, solid relationships between KM3NeT and key suppliers have been established for the development of new products or new production methods. This has led to improved quality control, reduction of prices and/or shorter delivery times. Although some of these developments have the potential to generate spin off companies, the intellectual property is, so far, maintained by existing companies. The list of new innovations include a new generation of photo-sensors, a low power high-voltage generator (potentially useful for night vision) and a zero-weight (in water) pressure-balanced oil filled cable. The on-going developments cover a wide area from low price wet-mateable connectors and auxiliary tools for light weight remote operated vehicles (ROVs) to high-performance temperature and seismic sensors (e.g. for detection of oil or gas reservoirs).

5.3 Business case

5.3.1 What is your planned business case and has it already been reviewed? (maximum 1000 characters with spacing)

The additional budget of 95 M€ corresponds to investment costs including sea operations. These costs will be supplemented by the corresponding funding authorities to cover personnel, facilities and (additional) travel costs. The human resources and the facilities will be provided by the member institutions. The overall costs of the project have been optimised by making use of the existing facilities, the scientific and technical support of the participating institutions and the involvement of industry. The investment costs include procurement of components, usage of test equipment, logistics and quality assurance. The spending profile is primarily governed by available funds. To guarantee a good starting position for the scientific capitalization of the research infrastructure, a considerable effort has already been made in the areas of simulations, data analysis, computing and training of (junior) researchers. The business case has been reviewed by the STAC and endorsed by the RRB.

5.3.2 Have you assessed the Cost-Benefit Analysis (CBA) of the RI and what are the results? (maximum 1000 characters with spacing)

A cost-benefit analysis of KM3NeT was made by the Astroparticle Physics European Consortium (APPEC). One of the outcomes of this analysis is that “*CBA requires the expression of long-term costs and benefits in monetary terms and discounting them back to present values. This is inherently difficult in scientific projects because it is difficult to estimate future benefits. A number of studies have shown that investment in science and technology leads to greater economic welfare in the long-term.*”. KM3NeT has pushed various innovations. The wealth of data that will be collected offers a rich source for analyses which will lead to new insights in different fields of research. This will trigger the development of new deep-sea infrastructures, continuing the push for innovations. The most important benefit may be to satisfy mankind’s curiosity in the workings of the Universe and the relevance of neutrinos that travel through it and that would otherwise pass the Earth without being noticed.

6. SITING

6.1 What is your strategy for site selection and for siting? If the RI is single sited, how will the site be chosen/was chosen? If the RI is distributed, will there be a central hub and how will its location be decided? (maximum 1000 characters with spacing)

Siting of the KM3NeT research infrastructure has been decided and agreed following the activities performed in the framework of the EU-funded Design Study and Preparatory Phase projects. The KM3NeT 2.0 research infrastructure will be a distributed infrastructure with two deep-sea nodes located offshore Capo Passero (Italy) and Toulon (France). These installation sites are supported by major laboratories of INFN (LNS) and CNRS (CPPM), respectively. The ultimate goal is to fully develop the research infrastructure including a third site located offshore Pylos (Greece). These sites have been selected and characterized for their excellent water properties (light transmission, optical background, deep-sea currents, etc.) and the availability of local expertise in deep-sea technologies (boats, ROVs, cable deployment and maintenance, etc.). The central headquarters will be located in Amsterdam (The Netherlands) and the central data repository in Lyon (France).

6.2 Is the proposed site a 'green-field'? Is this proposal part of a broader plan of site development that includes synergetic initiatives?
(maximum 1000 characters with spacing)

n.a.

or

6.3 Will the RI be installed in the premises of pre-existing facilities? Where these of similar or different scope? What is the 'value' transferred to the new project in this case in terms of general infrastructure/services and human capital?
(maximum 1000 characters with spacing)

For what concerns the deep-sea nodes, the infrastructures for Phase-1 of KM3NeT already exist at the Italian and French sites. These infrastructures include on each site a shore station and a main electro-optical cable. Upgrades to fulfil the needs of KM3NeT 2.0 will be needed. The central hub will be hosted in Amsterdam. The data repository will be located in the CNRS computing centre in Lyon. Other facilities for data handling will also be available in the other countries. Just a few cabled deep-sea research infrastructures exist worldwide and none reaching the depths at which KM3NeT will be installed. The unique characteristics of KM3NeT required the development in the past decade of the technologies and skills needed for its implementation, which are now under the full control of the KM3NeT Collaboration.

7. PLANNING

7.1. What is the overall timeline for the project? Please describe all phases, i.e. pre-construction, decision-making, construction, start of operation for users, ramp to full capacity, full exploitation, eventual decommissioning and independent project evaluation. (maximum 1000 characters with spacing) If applicable, please insert timeline (Upload PDF limit 1 MB)

It has been agreed to continue the Phase-1 Collaboration for the subsequent phase(s). As such, Phase-1 covers the pre-construction phase of KM3NeT 2.0 and provides a smooth ramp-up to its full capacity. The commissioning of the infrastructure will take place as the construction proceeds. So, this will not delay the utilization of the infrastructure. At present, the first phase of the construction is on-going (Phase-1). The decision for the next phase (i.e. KM3NeT 2.0) is expected before 2016. After completing its construction, the KM3NeT 2.0 research infrastructure will be operated for at least 10 years, with the possibility to continue thereafter. The ultimate goal is to fully develop the KM3NeT research infrastructure to comprise a distributed installation at the three foreseen sites (Italy, France and Greece). The eventual decommissioning will be done by the KM3NeT Collaboration. The project is continually monitored by the Scientific and Technical Advisory Committee (STAC).

7.2 How do you plan to implement the RI once added to the ESFRI Roadmap? Please indicate the first steps and the five most important milestones until construction / operation start, and the five most important milestones in the first two years after construction / operation start. (maximum 1000 characters with spacing)

The KM3NeT technology allows for a phased and distributed implementation of the infrastructure. The operation of the neutrino telescopes will start with the deployment of the first detector elements and will continue during construction. The performance of the telescope and hence the science output of the project will steadily improve with the increasing size of the infrastructure. The primary need is therefore stable data taking to enhance the statistical significance of the expected signals.

✓	Phase-1	Memorandum of Understanding	2014
•	Phase-1	construction completed	2016
•	KM3NeT 2.0	formal start	2016
•	KM3NeT 2.0	ERIC established	2017
•	KM3NeT 2.0	construction completed	2020

•	KM3NeT 2.0	access to user ports provided	2017
•	KM3NeT 2.0	start continuous operation of infrastructure	2018
•	KM3NeT 2.0	open data access established	2019
•	KM3NeT 2.0	confirmation of cosmic neutrino signal	2021
•	KM3NeT 2.0	measurement of neutrino mass hierarchy	2022

7.3 If you intend to apply to a Horizon 2020 Preparation Phase type-1 contract, what will be the main objectives and “deliverables” of your project? What aspects of readiness-to-implement will be within reach of a 2-3 years H2020-Preparatory Phase?
If you do not intend to apply for a Horizon 2020 Preparation Phase type-1 contract, please explain why. (maximum 1000 characters with spacing)

Although the basic organisation structure for the implementation of the KM3NeT research infrastructure is implemented, there are several items which would benefit from support through a Horizon 2020 Preparation Phase type-1 contract, such as the realisation of open access, the start-up of the foreseen ERIC, and the preparation of legal contracts with other research infrastructures (such as EMSO).

7.4 How do you rate the probability to reach the firm decision of implementation by the involved stakeholders and the financial commitment by a critical mass consortium within the permanence time on the ESFRI Roadmap, i.e. maximally ten years? (maximum 1000 characters with spacing)

At present, the Collaboration counts about 240 members from 41 different institutions and is steadily growing (four new institutes joined the Collaboration since 2014). For the review by the PSE-WG in 2013, the Resources Review Board (RRB) wrote “*The KM3NeT project critically depends on the progress of KM3NeT Phase-1 … Once achieved, the RRB will vigorously start the process to collect the required funding for KM3NeT*;”. Now that the necessary progress has been realised, the probability to realise KM3NeT 2.0 within the timelines of the ESFRI roadmap of 2016 can be considered very high.

8. GOVERNANCE, SCIENTIFIC AND LEGAL MANAGEMENT

8.1. What is the chosen or preferred legal structure? (maximum 1000 characters with spacing) Please upload statutes (or draft statutes) and/or related documents. (Upload PDF, maximum 1 MB)

The chosen legal structure for KM3NeT 2.0 is that of a distributed ERIC. The choice for a KM3NeT-ERIC was the outcome of the KM3NeT-PP and is subsequently formally documented in the Memorandum of Understanding (MoU) for Collaboration in the implementation of the first phase of KM3NeT signed by the same funding authorities that are now partners in this proposal (see attached document). We quote: "*Art. 1.7 This MoU is the first step toward the intended establishment of a KM3NeT-ERIC (European Research Infrastructure Consortium).*". The signatories of the MoU have agreed to host the KM3NeT ERIC in the Netherlands.

8.2. What is your envisaged governance model? Please explain how the roles of the Chair, Director, Supervisory, Ethical Boards, etc. are defined to ensure good governance and control. (maximum 1000 characters with spacing) Please upload an organisation chart of governance. (maximum 1 MB)

The current governance model will be maintained (see attached MoU for organisation chart of governance). This complies with the one outlined by ASPERA for large European astroparticle physics infrastructures. The Resources Review Board (RRB) appointed by the ministries of the member countries approves major decisions implicating financial and human resources and authorises transitions of the project from one phase to the other. The RRB is assisted by three external advisory committees: The Scientific and Technical Advisory Committee (STAC) reviews the science program and the technology of the infrastructure. The observation committee evaluates requests for use of KM3NeT 2.0 infrastructure. The ethics committee monitors the compliance to regulations for the environment during construction and lifetime of the infrastructure. The collaboration board comprises the leaders of the KM3NeT 2.0 research groups and supervises the implementation of the strategies set out by the RRB.

8.3 Please describe your project organisation, with clearly defined responsibilities and reporting lines/structures, measurable and credible Key Performance Indicators (KPIs). (maximum 2000 characters with spacing) Please upload an organisation chart of project. (maximum 1 MB)

The project organisation of KM3NeT 2.0 is the one implemented for Phase-1 and extensively documented in the MoU (see attachment). The collaboration board installs a management team and a steering committee for the day-to-day management of the KM3NeT 2.0 research infrastructure. The collaboration board elects the spokesperson as the chair of the management team. The spokesperson acts as the director of the research infrastructure and reports to the collaboration board. As the elected leader of the Collaboration, the spokesperson has the authority to represent the Collaboration in relations with the scientific community. As director, the spokesperson is assisted by a deputy spokesperson and managers supervising specific domains: the technical project manager for all planning, procurement, logistics and maintenance aspects during construction and operation of the infrastructure; the physics and software manager for data, software and computing management; and local site managers appointed by the local institution supervising the site infrastructure. The spokesperson chairs the steering committee composed of the members of the management team and the technical and scientific working group leaders of subtasks which evolve with the progress of KM3NeT 2.0 from construction via operation and data taking to decommissioning. For the quality control of the whole project, the collaboration board appoints a QA/QC manager.

To ensure high quality of knowledge dissemination the collaboration board installs a publication committee and a conference and outreach committee.

The leading KPIs for KM3NeT 2.0 are (i) the confirmation of the cosmic neutrino signal with ARCA (50% probability of a 5-sigma signal within 1.5 years of operation); (ii) the predicted potential of a measurement of the neutrino mass hierarchy with ORCA (50% probability of a 3-sigma signal within 3 years of operation); (iii) demonstration of operation of a distributed research infrastructure in the deep-sea.

8.4 What is your plan for independent scientific monitoring of the RI when in the operational phase? (maximum 1000 characters with spacing)

The RRB will initiate regularly (every 3-5 years) reviews by internationally well-known scientists to monitor the scientific output and relevance of the research infrastructure in the research field. More frequently, typically once per year, reviews will be conducted by the STAC formed of international well-known science experts that are not a member of the KM3NeT Collaboration. The Astroparticle Physics European Consortium (APPEC), as the European consortium of national government agencies and institutes responsible for coordinating and funding national research efforts in astroparticle physics, regularly reviews and updates its roadmap of research infrastructures of which KM3NeT is a prominent one.

8.5 Has a Funding Agreement and MoU been concluded? (maximum 1000 characters with spacing) If Yes, please upload Funding Agreement and MoU

The MoU for the construction of the first phase of the KM3NeT research infrastructure has formally been concluded and signed in 2014 by the funding authorities which are partners in this proposal (see attached document). This MoU includes a funding agreement of the committed total investment budget of 31 M€ and defines the Collaboration between 41 research groups and a total of more than 240 scientists. The execution of this MoU started in January 2013 with the instalment of the oversight, governance and project management structure extensively described in the MoU. The additional funds needed for KM3NeT 2.0 are supported by the RRB and future funds will be included in the present funding agreement. The chosen legal structure for KM3NeT 2.0 is that of a distributed ERIC, replacing the current MoU.

9. HR POLICY AND PROJECT MANAGEMENT

9.1. Please analyse the availability of relevant competences for construction and exploitation of the RI? (maximum 1000 characters with spacing)

The leading scientists and engineers in the project management of KM3NeT 2.0 have been active in the ANTARES project; the EU funded Design Study and Preparatory Phase; and KM3NeT Phase-1. The utilisation of the ANTARES detector continues to provide valuable information for KM3NeT 2.0 (e.g. data analyses, documentation, reliability estimates). This information is directly communicated at management level or collaboration wide at joint meetings. The operation of the KM3NeT research infrastructure will further add useful experience. In view of their track record in ANTARES and KM3NeT Phase-1, the competences of the management and scientists are without doubt excellently complying with the requirements for KM3NeT 2.0. The fact that KM3NeT is a distributed research infrastructure does not change these requirements as the detectors in the deep-sea are remotely operated from anywhere in the Collaboration and the data are directly streamed to the central data and computing centre.

9.2 Describe plans or established procedures for gathering the necessary competences, project managers' selection and staff hiring. Describe the secondment policy (potentially relevant in particular for distributed infrastructures) if any.(maximum 1000 characters with spacing)

Staff carrying out the scientific and technical programs for KM3NeT are provided by the collaborating partners; cost related to this staff will be borne by the providing institutions and will wherever necessary be accounted for as part of in-kind contributions. The policy and internal rules for direct hiring of staff for KM3NeT will be defined by the Resources Review Board (RRB). The additional local staff needed for the construction of the research infrastructure will be provided as in-kind contributions of the host countries. Once the infrastructure is operated remotely and data are directly streamed to the central computing centre, staff for operation at the installation sites is limited to local people to safeguard the on-shore facilities and to occasionally execute some maintenance work in the on-shore station. Secondment related to specific projects or for training purposes is possible and will be accounted for according to the specific project agreements.

9.3 Describe parameters to gauge project success (KPI), planned project Work Breakdown Structure (WBS) and related responsibilities, major item procurement schedule, coordination methods within the project and among the partners and timeline with milestones.
(maximum 1000 characters with spacing)

The ultimate KPIs are the timely confirmation of the cosmic neutrino signal and the mass hierarchy of neutrinos (see section 7.2). As in KM3NeT Phase-1, the technical participation of the collaborating research groups and their funding authorities will be described in detail in the MoU following the WBS and PBS of the project. Scheduling major item procurement is in the hands of the project management team assisted by the project steering committee. The technical project manager in the management team sets up and regularly updates the project planning with timelines with milestones and supervises the work of the technical workgroup leaders. In the case of significant cost variations or delays or in cases that a research group fails to fulfil its timely commitment, the collaboration board will be informed. The collaboration board will then propose solutions and seek the endorsement of the RRB.

Please upload the Conceptual Design Report (CDR), if applicable. (maximum 1 MB)

A conceptual design report (CDR) was produced in the framework of the EU-funded design study. This CDR is in parts superseded by the current MoU and the document summarising the science case (both attached). The science case is detailed in two scientific letters of intent (one for ARCA and one for ORCA). These letters of intent are under scrutiny of the Scientific and Technical Advisory Committee (STAC) and will be published this summer.

9.4 What is your policy for gender balance at all levels of activity and responsibility, and in career planning? (maximum 2000 characters with spacing)

As scientific and engineering staff for the KM3NeT research infrastructure at every level will be provided by the participating institutions and research groups, all issues regarding diversity and gender balance in the activities and responsibilities of the KM3NeT Collaboration will follow the relevant policies and rules defined in these institutions. Within these regulations, the collaboration board will be charged by the RRB to stimulate the participating research groups to provide female staff for the leading positions in the project management team, the project steering committee and the collaboration board itself thus providing visibility to fuel a career in academia or elsewhere in society. The chairperson of the collaboration board will report regularly to the RRB on the result of the stimulation program.

For a personal career in (astro)particle physics, it is important to contribute to the data taking, data analyses and dissemination of scientific results. The remote operation of the research infrastructure, the use of video conferencing and Ethernet based communication allow for an active participation with a personalised work-life balance. This avoids a discontinuation or termination of the career of male and female scientists in case of paternity or maternity, respectively, most notably during the critical post-doctoral phase.

10. FINANCIAL ASPECTS AND COMMITMENTS

10.1 What are the current cost estimates and budget projections, construction/implementation, operation and, if applicable, for decommissioning? Please indicate the confidence levels of your estimates. Please indicate if they are based on suppliers' quotations.(maximum 4000 characters with spacing)

The construction and operation of the research infrastructure allows for a phased and distributed implementation. The investment budget for the construction of the first phase of the KM3NeT research infrastructure amounts to about 31 M€ which is fully funded. During 2015–2016, 31 strings equipped with 558 optical modules will be assembled and deployed at the French and Italian sites. The strings at the Italian site will be configured for ARCA and the strings at the French site for ORCA. The overall size of the initial arrays corresponds to about 0.2 building blocks. The next phase (i.e. KM3NeT 2.0) comprises a complete ARCA and ORCA detector, consisting of 2 and 1 building blocks, respectively. The additional budget for KM3NeT 2.0 is estimated at 95 M€. The ultimate goal is to fully develop the KM3NeT research infrastructure to comprise a distributed installation of 6 building blocks at the three foreseen sites (Italy, France and Greece).

The cost estimates of KM3NeT 2.0 are based on the actual prices of Phase-1. As a result, the estimate of the total cost of KM3NeT 2.0 can be considered accurate.

The cost for operation and decommissioning of the infrastructure have been evaluated in the framework of the Design Study. The latest estimates amount to about 2% per year and 5% of the total investment, respectively. The costs to ramp up the Phase-1 detector to the KM3NeT 2.0 infrastructure are covered by the available budget for Phase-1. Hence, the total cost for 10 years of operation and decommissioning of the KM3NeT 2.0 infrastructure adds about 25% to the total budget.

Please upload cost models and cost-book analysis, if available. In case of distributed RI, please take into account estimates for hub, national nodes and main upgrades (maximum 1 MB).

The cost model of KM3NeT is the same as that of other large astroparticle physics projects in Europe and other particle physics projects at CERN. In this, the quoted costs correspond to the investment costs. These costs are supplemented by in-kind contributions from the partners (human resources, facilities, etc.). The costs for the hub (i.e. central computing centre) are covered by an in-kind contribution from CCIN2P3-Lyon. The quoted costs are consistent with the actual prices of Phase-1 and there are no additional costs for national nodes or main upgrades that are not included in either the investment costs or the in-kind contributions.

10.2 What is the essence of your Investment plan and to what set/subset of stakeholders was it presented? (maximum 2000 characters with spacing)

The investment plan covers the cost for the construction and operation of the KM3NeT 2.0 research infrastructure. The investment plan has been reviewed by the Scientific and Technical Advisory Committee and to the Resources Review Board (see Memorandum of Understanding for Phase-1).

10.3 What is the current level of financial commitment to the project? Please elaborate on the (conditional) intentions to (co-) fund the construction costs and access, site-premium and indicate what kind of formal investment commitments (in cash and/or in-kind) have been made. What are the plans to fund operating costs?

Today, the total budget for the construction of the first phase of the KM3NeT research infrastructure has already been committed. For KM3NeT 2.0, there are on-going funding requests in France (12,4 M€) and Italy (70 M€). Furthermore, a proposal is being prepared for additional funding in the Netherlands (10 M€). Possibly, there will be funding request in other countries (e.g. Spain and Germany). These investments are supplemented with in-kind contributions from the member institutions. These contributions include salaries of (senior) scientists and technicians; travel expenses; usage of (local) facilities; office space (including personal computers). The salaries of PhD students and post-docs are usually covered by various personal grants or national programs.

The low operational costs alleviate the funding needs for the long term future. The corresponding funding authorities of the host countries support the usage of local infrastructures and the operational costs of the main computing centre are covered by the French funding agency CNRS. The remaining operational costs (such as electricity and human resources for the shore station) are covered by the common fund of the Collaboration. The annual fee of a full member (excluding PhD and master students) of the collaboration amounts to about 5 k€, depending on the size of the collaboration. A paying member then has the right to sign all KM3NeT publications and to present KM3NeT at conferences. The corresponding group has also a seat in the collaboration board. In view of the low annual fee, it is foreseeable that the financing of the common fund can readily be sustained with various grants.

Please also indicate whether you intend to apply for loans of the European Investment Bank, or equivalent national credit systems, and/or use the Financial Instruments under Horizon 2020. (maximum 3000 characters with spacing)

n.a.

Please upload relevant supporting documents. (Maximum 1 MB)

10.4 Is the RI going to replace existing RIs that will become obsolete? How will you ensure that funding and users transfer from the obsolescent infrastructure (-s) to the new one and what political steps may be needed to ensure this?
(maximum 2000 characters with spacing)

The predecessor of KM3NeT (ANTARES) is still operational but will be decommissioned in due time. Part of it will then be recycled for use in KM3NeT. The decommissioning of ANTARES is already laid out in the ANTARES Memorandum of Understanding and no additional (political) steps are needed to ensure an efficient transition.

10.5 Is the project consistent/mentioned with/in (a) Smart Specialisation Strategy (-ies) of Member States interested in hosting it and thus eligible for European Structural and Investment Funds (ESIF)? If appropriate and relevant, please explain.
(maximum 2000 characters with spacing)

The construction of a large deep-sea infrastructure fits very well in the Smart Specialisation Strategies of the host countries. For example, the project is included in the pole of excellence “Technopole de la Mer” of Toulon-Provence-Mediterranean. Also, the Sicilian Regional Government has established a RIS3 devoted to sea research and based on cabled observatories. A forum, with the participation of INFN (one of the KM3NeT partners), has been setup to define the strategy. It is expected that the contents of this RIS3 will be detailed during 2015. Some design innovations have attracted interest from industries in the field of telecommunications, deep-sea technology and light sensing. As such, this project fits well in the top sector “High-tech systems and materials” defined by for instance the Dutch government. As a result, KM3NeT is eligible for European Structural and Investment Funds.

10.6 What is the strategy for assuring the coverage of operational costs in the medium-long run?
(maximum 1000 characters with spacing)

In analogy with large projects at CERN and other large astroparticle physics projects world-wide, the operational costs of KM3NeT will be covered by financial contributions from the corresponding funding authorities. The estimated operational costs of KM3NeT are relatively low (about 2% per year of the total investment) which reduces the risk of cost overruns to a minimum. Finally, the annual fee of full members of the collaboration assures sustained funding of the operational costs.

10.7 What kind of accounting principles have been agreed with partners and shareholders?
(maximum 1000 characters with spacing)

A Resources Review Board (RRB) has been set up by the corresponding funding authorities to supervise the KM3NeT project. The role of the RRB includes *1)* monitoring the general financial and human resource support and *2)* endorsement of the annual budget. The management administrates the overall construction and operation budgets and reports twice a year to the RRB. The detailed accounting of the expenditures is handled by the administration of the corresponding institution, including the treatment/exemption of VAT. KM3NeT profits from the support of the legal departments of the funding authorities involved.

11. FEASIBILITY AND RISKS

11.1 Are there scientific developments or competing projects elsewhere that could affect the research foreseen at the infrastructure? (maximum 1000 characters with spacing)

Neutrino astronomy is a rapidly growing field of research which extends traditional astronomy by the observation of neutrinos from the cosmos. These observations are supported by three large research infrastructures in the world, namely: IceCube (South Pole), KM3NeT (Mediterranean Sea) and GVD (Lake Baikal, Russia). Of these, IceCube is led by the US, GVD by Russia and KM3NeT by Europe. A platform for the interoperability of the existing neutrino telescopes has been setup: the Global Neutrino Network (GNN). After the discovery of high-energy neutrinos from the cosmos by IceCube in 2013, the cooperative observation of the cosmos by neutrinos is right and timely. To this end, ARCA foresees a measurement of the IceCube signal with different methodology, improved resolution and complementary field of view. There are ideas to develop a long baseline neutrino beam to KM3NeT. This could significantly extend the science scope and lifetime of the ORCA detector.

11.2 What are the risks that in your view could delay, increase costs of or make realisation of the infrastructure tasks impossible? Do you have any specific technical risks? Have you undertaken a technical options analysis? (maximum 1000 characters with spacing)

The planning of the construction of the research infrastructure is based on the experience with the ANTARES prototype and the ongoing construction of the Phase-1 detector. The main risk is an interruption of the construction when going from Phase-1 to KM3NeT 2.0. The resulting delay may become larger because key suppliers could orientate their production capacities to other customers and institutes/institutions could relocate their resources. In short, the phased implementation alleviates the constraints on the budget (c.q. spending profile) but introduces a risk when the project is discontinued during too long a period.

11.3 What are the main schedule uncertainties?
(maximum 1000 characters with spacing)

The Phase-1 proceeds according a planning which was set in early 2013. The appropriate delivery schedules for the components for KM3NeT 2.0 have already been negotiated with key suppliers. The main uncertainty of the KM3NeT 2.0 schedule is then the time when funds will become available. The prospects for future funds are good and it is expected that shortly after the release of the ESFRI road map of 2016, sufficient funds are committed so that the construction can proceed from Phase-1 to KM3NeT 2.0 without interruption.

11.4 Please identify the main technological and construction/operation-related challenges and how the RI will tackle them. (maximum 2000 characters with spacing)

The main technological and construction/operation-related challenges can be categorised in terms of specifications, logistics, quality control, deployment and operational stability. Specifications, delivery schedules and quality control of all components have already been worked-out with key suppliers and participating institutes. The deployment of deep-sea cables proceeds according well established procedures and a designated launcher vehicle has been developed for the deployment of detector elements. The operation of a deep-sea neutrino telescope with the required stability has already been demonstrated by the ANTARES project.

The KM3NeT technology has been successfully demonstrated with two prototypes, deployed in the deep sea in April 2013 and May 2014, respectively. An analysis of the available data confirm the specifications.

The construction of the Phase-1 detector proceeds at different sites. This strategy will be extended for KM3NeT 2.0 to allow for optimal use of the available resources and to avoid unwanted bottle necks. The deployment of detector elements at the two sites will proceed in parallel.

The resources needed for the operation of the infrastructure are limited. A crew of two persons is adequate for local presence in the shore stations. As a result, the training of personnel does not pose a challenge.

In general, the maintenance of the deep sea infrastructure depends on the risk of failures. The main conclusion of a complete risk analysis is an acceptable degradation of the research infrastructure after 10 years of operation without maintenance. This eliminates the challenges associated with maintenance of the deep-sea infrastructure.