

Publishable Summary

The FP7 Design Study of a pan-European Infrastructure for Large Apparatus studying Grand Unification and Neutrino Astrophysics (LAGUNA) (<http://laguna.ethz.ch/laguna-eu/>) is a collaborative project involving 21 beneficiaries, composed of academic institutions from Denmark, Finland, France, Germany, Poland, Spain, Switzerland, the United Kingdom as well as industrial beneficiaries specialized in civil and mechanical engineering and rock mechanics. LAGUNA brings together on one hand the scientific community interested in this kind of research, and on the other hand the industrial and technical experts able to help assess the feasibility of this infrastructure.

The principal goal is to assess the feasibility of a new pan-European research infrastructure able to host the next generation, very large volume, deep underground neutrino observatory. A research infrastructure able to host new generation underground neutrino detectors with total volumes in the range of 100,000 to 1,000,000 m³ will provide new and unique scientific opportunities, and very likely lead to fundamental discoveries in the field of particle and atroparticle physics, attracting interest from scientists worldwide. Europe currently hosts four world class national deep underground laboratories with high level technical expertise, which are located in Boulby (UK), Canfranc (Spain), Gran Sasso (Italy), and Modane (France). However, none of these is large enough for an instrument of the size envisioned by LAGUNA. Therefore, in addition to the possible extensions of the existing underground laboratories, the LAGUNA consortium is studying the creation of new laboratories in the region of Umbria (Italy), Pyhäsalmi (Finland), Sieroszowice (Poland) and Slanic (Romania).

The science case of LAGUNA is compelling: if built the observatory will look for the unification of all elementary forces by searching for an extremely rare process called proton decay. Although the lifetime of a proton is known to be in excess of 10³³ years, a proton can nonetheless spontaneously disintegrate itself into lighter elementary constituents if the strong, weak and electromagnetic forces become unified at very high energies. Large size detectors like those envisioned in LAGUNA are the only way to address this question. The large size of the LAGUNA observatory will, in addition, allow the detection of a sufficiently large number of neutrinos from very distant galactic supernovae to understand their explosion mechanism. The observatory will also perform precision study of terrestrial, solar and atmospheric neutrinos. In addition, the outstanding puzzle of the origin of the excess of matter over antimatter in the universe after the Big Bang, and the recent measurements of neutrino oscillations and masses, point forward to the need to couple the LAGUNA observatory to advanced neutrino beams from CERN to study matter-antimatter asymmetry in neutrino oscillations.

The impact of LAGUNA on the development of a pan-European common scientific framework is large. Several important institutions from all around Europe are involved, and among them notably the participation of academies, research institutions and industries from post-communist countries. Such a continuous interaction between the various beneficiaries originating from different European countries, and the constant strict interaction coming from the collaboration between academia and industry makes LAGUNA not only a very advanced and challenging scientific project, but acts as an instrument of integration, mobility and dissemination, strongly favoring the consolidation of an integrated pan-European scientific community, and strengthening the scientific and technological bases of the Community industry.



The goal of the design studies is to lead the project into its next phase as one of the research infrastructures identified by the European Strategy Forum on Research Infrastructure (ESFRI Roadmap). If realized in Europe, the project will greatly contribute to the enhancement of the European Research Area (ERA) by strongly supporting new ways of doing science in Europe.

The DS is subdivided into 4 work packages (WP), interconnected with each other:

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

WP1 – Management, coordination and assessment

This WP is led by the ETHZ beneficiary and is coordinated by André Rubbia (ETHZ) with the help of Federico Petrollo in charge of the administrative, financial and legal tasks. The Executive Board and the Governing Board are also involved in these activities. During the period, the management WP coordinated the contractual, financial and administrative aspects of the Design Study and oversaw the technical and scientific work of the other WPs. It ensured the production of the project milestones and deliverables. Furthermore, this WP has been responsible for knowledge management for the Design Study, coordinating the protection, use and dissemination of the knowledge generated during the period.

WP2 – Underground infrastructures and engineering

The WP2 work package exists in order to assess the feasibility of large underground caverns in the seven potential European sites to host large volume detectors of each kind; to provide the technical information, including cost estimates, needed for potential construction decision and site selection and to assess the site impact of the construction of underground tanks on the facility and estimate time of underground realization. This is a very important work package of the design study as the preliminary investigations show that LAGUNA is exceptional in terms of dimensions of the caverns to be designed, comprising great depth and huge spans, well beyond any state-of-the-art in underground civil engineering. By analyzing several scientific, technical and political criteria, a site prioritization has been performed in order to best recommend the focus of the next phase of studies towards the feasibility of the LAGUNA research infrastructure in Europe. The final list of criteria and the prioritization method has been published in the deliverable 2.8.

In this report concise overview of the work progress done in WP2 is presented. Technical partners and scientists of all the sites have carried out comprehensive work of rock mechanical studies. During the period, one Interim meeting was held in February 2010 in Munich and in addition the work package was discussed in three General Meetings that were held in September 2009 in Pyhäsalmi, in December 2009 in Boulby, and in April 2010 in Canfranc. In addition, phone conferences were regularly organized.

The WP2 interim meeting in Munich (February 2010) was the first where the results of all sites were thoroughly discussed and compared with each other, and the common standards were more accurately defined. Small differences in the standards between the sites were corrected and nearly final and consistent numbers were then presented in the next meeting, in Canfranc General Meeting in April 2010.

It can be concluded that each site could technically host at least one of the detector options. Also, it can be concluded that the time schedule for the excavation is not much different between the sites and that the cost of the cavern excavations are not the major part of the total costs.

The LAGUNA Consortium has visited all of the sites except the Italian virgin site as there was nothing to see. In all of the sites the local authorities have expressed a strong interest in the project and are willing to find ways to support it.

WP3- Safety, environmental and socio-economic issues

This work package exists to cover aspects of the LAGUNA sites other than that of a purely geo-technical and detector orientation. In particular to consider aspects of safety, which must be integrated into the project from an early stage, and societal and economic or political issues. All these topics have the potential to be or become critical paths or even show-stoppers for the eventual construction of such a large experiment as LAGUNA. For instance, the environmental impact of construction of LAGUNA, such as might result from the need to remove and dump large quantities of rock, could be, depending on the site, a major issue to resolve. Likewise, insufficient local political support or an inadequate safety culture at a site could become critical issues to resolve. WP3 is designed to increase awareness of these potentially major issues and determine for each site what specific aspects of these issues could be challenges that need to be addressed.

In the first period of LAGUNA the work of WP3 concentrated on the safety and risk aspects of each site, culminating in detailed reports from each site subsequently submitted for the deliverable, WP3.1. Some additional progress was made also then on the socio-economic aspect, reported as a supplement in the WP3.1 documents. The second period has focused further on the socio-economic issues at each site but also developed a more detailed analysis of the particular safety and project risk issues associated with liquid procurement. As in the first period the work, detailed in Annex I of the project proposal, has been undertaken in the context of a series of tasks.

Task 9 Assessment of hazards events and risk analysis

Task 10 Safety and monitoring of large-scale underground tanks

Task 11 Site specific impact of liquid procurement and tank filling

Task 12 Final report on safety and environmental issues

Task 13 Socio-economic impact of the research infrastructure on the sites

WP3 activity for the second period, building in the initial information gathered for the first deliverable WP3.1, has been firstly to collect and compare information on the socio-economic aspects of each site, with an attempt made to understand and address any critical path issues that arise. As with WP3.1 the approach here has been to use a series of detailed template tables for each site. These tables, together with descriptive text, have been used to produce the deliverable WP3.4 "LAGUNA Design Study, Socio-Economic Overview Report". The concept here has been to recognize two aspects: (i) that there is need to know at each site the level of understanding by all interested parties, local, regional and national, of the impact of LAGUNA at the site, whether positive or negative, and (ii) to understand, given the actual construction of LAGUNA at that site, the socio-economic impact it will have (positive and negative). The former is important, for instance, because it could be that certain interested parties, such as planning

authorities, may slow down or in fact prevent construction. The second aspect is important as a means of assessing and gathering support for the programme.

In this context many meetings and discussions have been held, both at the regular site visits undertaken by LAGUNA and through specific WP3 meetings and calls. Each site has also undertaken site-specific assessment meetings with, for instance, politicians, environmental agencies, planning authorities, site owners and others. It is these meetings that have allowed information to be accumulated into the detailed comparison tables.

WP4 – Science Impact and Outreach

This WP has explored the physics of different detector technologies at different underground laboratory sites in order to identify the best strategy for future large-scale detectors. The goal was to continue developing the science case of the LAGUNA observatory taking into account the constant evolution of the field as new results were achieved. It is not to be expected that the science case of LAGUNA will become obsolete, on the contrary, we could witness that new results from ongoing experiments helped strengthening and precisising the need for the LAGUNA observatory, in particular for what concerns the opportunities on long baseline oscillations coupled to CERN. Additionally WP4 takes care about developing the outreach means such as flyers and web site. The work in WP4, concerned tasks 14-16.

Task 14 Theoretical activities supporting experimental programme - This task was coordinated by Silvia Pascooooooooooli (U-DUR). It focused on the study of the physics reach of future long baseline neutrino oscillation experiments, on the review of the astroparticle physics searches which can be carried out with the detectors under consideration in the LAGUNA project, on the study of the information which can be extracted from the running experiments of this type and on the links with the searches for physics beyond the Standard Model carried out at the LHC and other particle physics accelerators.

Task 15 Education and Outreach – This task was coordinated by Agnieszka Zalewska. The LAGUNA web site the LAGUNA flyer and the brochure presenting the LAGUNA project in a popular way (deliverable 4.1) were realized. Apart from that LAGUNA was being popularized in different forms by the project participants in their native countries and beyond. Examples include special LAGUNA sessions at particle physics conferences in Poland and Romania, articles in newspapers, presentations in radio and television, posters at science festivals, lectures for students, pupils and physics teachers, etc.

Task 16 Investigation of synergies with the European Strategy for Particle Physics and the CERN laboratory – This task was coordinated by André Rubbia (ETHZ). In full accordance with the duties planned in Annex I, several meetings were held with the CERN accelerator experts, the CERN Management as well as contacts with physicists from the EURONU project. Additionally international contacts outside the EU were promoted, in particular with Japan (KEK, ICRR).