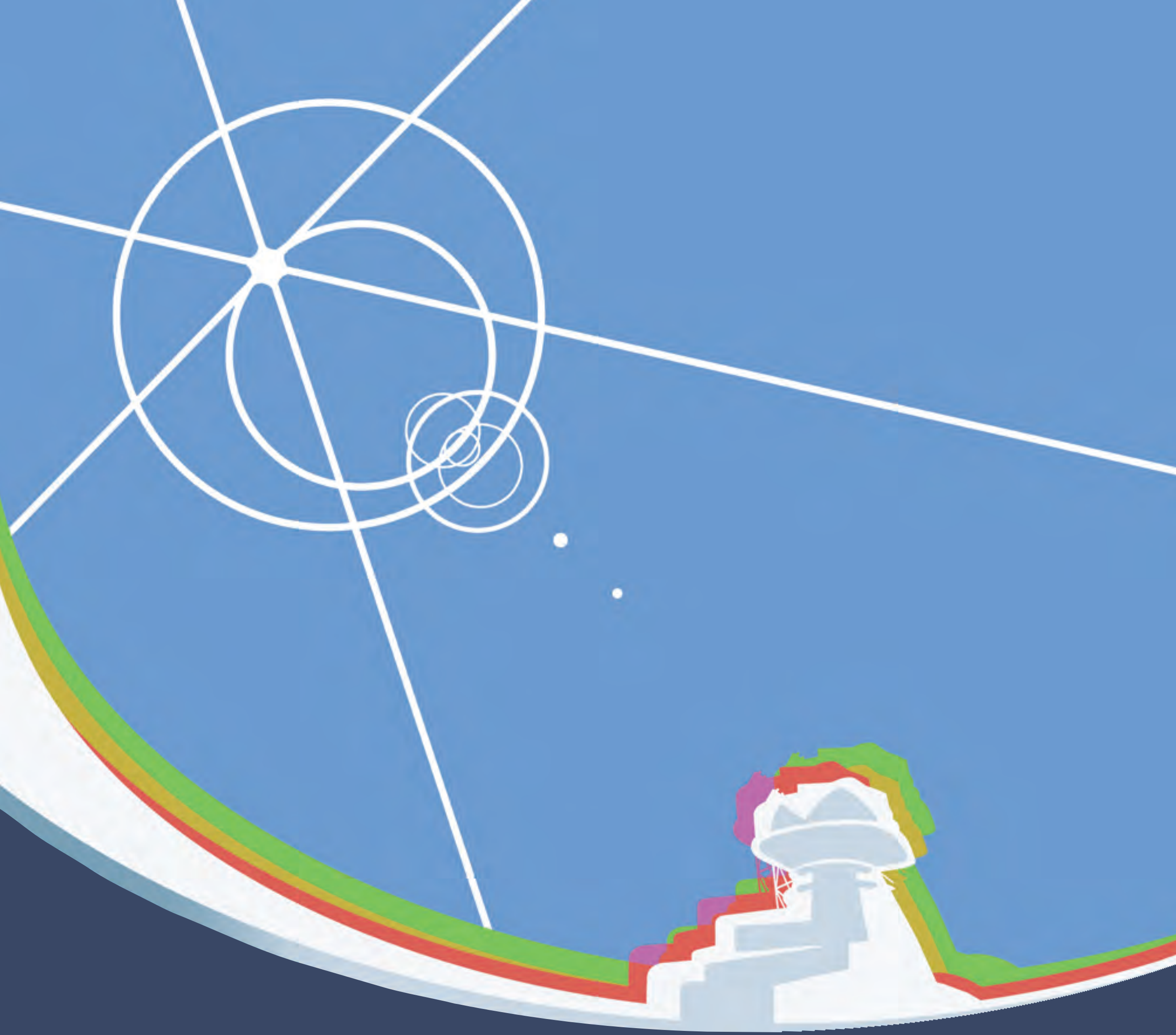

EUROPEAN LARGE APERTURE SOLAR TELESCOPE (EST) IN THE CANARY ISLANDS

REPORT ON TECHNICAL, FINANCIAL AND SOCIO-ECONOMIC ASPECT

April 2011

UNIÓN EUROPEA
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SEVENTH FRAMEWORK PROGRAMME

EST

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This report is the result of an extensive analysis and data collection on industrial and socio-economic aspects related to the construction and operation of the "European Large Aperture Solar Telescope" (EST). A Conceptual Design Study for this research infrastructure was funded by the European Commission, during the period 2008-2011 (reference FP7-212482), through its specific programme for Research Infrastructures as part of the Seventh Framework Programme for RTD 2007-2013. This report is one of the project deliverables, within the workpackage "Economic feasibility and socio-economic impact".

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We would like to thank staff at the IAC for their comments and input during the preparation of this document.

Finally we would also like to thank those who worked on the 2009 European Extremely Large Telescope (E-ELT) report, which dealt with similar aspects arising from the possible installation of this large telescope on the island of La Palma. That document has served as a valuable reference for some sections of this new report on the EST.

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EXECUTIVE SUMMARY

Today, the European Solar Physics community has a prominent role on the world stage. This is the result of the international reputation that research groups in Europe have been building and the access to the most comprehensive array of solar telescopes at the International Astrophysics Observatories in the Canary Islands that they enjoy.

The strategic advantage presented by the Observatories has helped strong relationships to develop throughout the European solar physics community, make progress in generating and developing new observational capacities, and create new opportunities for joint working on high technology projects.

The successes of recent years and the experience gained by the European scientific community in this field mean that the time is now ripe for a major technological challenge. This is the role of the EST, the largest European research instrument in the field of ground-based solar physics. Building it in the Canaries, at the Observatorio del Roque de los Muchachos (ORM) in La Palma or at the Observatorio del Teide (OT) in Tenerife, would also stimulate development in the region as well as in the rest of Spain and Europe as a whole.

This report was produced in the context of the conceptual design phase for the EST (2008-2011), which was funded by the European Commission (EC). It draws on activities carried out by the international consortium working on that phase of the project. It aims to provide a detailed description of the scientific, technical, industrial and socio-economic impact of building and operating the EST in the Canaries, and to provide information that will be helpful for decision-making when this European initiative of transnational scientific collaboration is started.

From the point of view of economy and industry it is estimated that through the collaboration of the countries involved (over a dozen Member States) they can have access to a return proportionate to the size of their solar physics community, the type of contribution they make (in-kind or in cash), their available resources for solar physics and/or their industrial capacity. For the host country, previous experience with large telescope construction projects like the Gran Telescopio Canarias (GTC), combined with the development of a competitive and specialised national industrial sector and the nature of some of the EST work-packages, allow to foresee returns over 30%. High returns can also be anticipated for any other country with much to offer to the project.

However, given the high degree of uncertainty about on which regions tenders and service providers related to this project will be located, apart from those anticipated for the host region, attempting to provide individual information on the industrial return, Gross Domestic Product (GDP) increase and job creation for the different countries involved (including Spain as a whole) would be a complex and unconvincing enterprise.

From a socio-economic perspective the Canaries would benefit on many levels, in particular from a more diverse economy, increased GDP and the creation of high quality jobs. Given the current state of the economy in the Canaries, with the wider international crisis and the Islands' dependence on the services sector, this project is an opportunity that must not be missed.

Detailed analysis of the available data suggests that financial returns from the project for the Canaries during the construction phase could be as high as €54 million, rising to some €364 million over the 30 years of the telescope's life (including induced effects on the regional economy). The effect on jobs, again including induced effect, could total some 10,565 new one-year positions in the Canaries (taking into account both, the construction period 2015-2020 and the operating phase, some 30 years). These positions are equivalent to 213 full-time jobs during the six-year construction phase and 309, also full-time, over the telescope's 30-year life.

The methodology used (based on Input-Output tables), together with high levels of uncertainty in the estimates for the extent of involvement of the different nations (including the host nation) make realistic projections for impact on GDP and employment across the European Union (EU) impossible.

The impact of a project like the EST on the reputation of the Observatories in the Canary Islands should also not be underestimated. It would confirm their position as a world-class astronomy resource, with premium sites for the latest generation telescopes and new scientific instruments, a permanent training facility for young researchers and engineers and a source of new outreach and science tourism initiatives that would benefit society.

There is no question that the Canary Islands as a location, with its good and plentiful connections to Europe, add to the strategic attractiveness of the Observatories. This is demonstrated by the constant movement of large numbers of research and technical professionals from Europe to the Observatories of the Canaries that has been occurring for many decades. Sea level support facilities (Centro de Astrofísica de La Palma – CALP and the IAC Headquarters) are equally attractive as they are already equipped with much of the basic and advanced infrastructures needed to build and operate the EST.

The Canaries are involved in planning out the development strategy for the Outermost Regions for the period 2014-2020, which gives them an unprecedented opportunity to include large research infrastructures in the priorities of the main Structural funds (European Regional Development Fund (ERDF) and the European Social Fund (ESF)).

The legal framework put in place by the European Commission for the creation and operation of transnational research infrastructures (European Research Infrastructure Consortium - ERIC) provides a functioning model with sufficient guarantees for the project to be carried out without significant difficulty in this regard.

As this report was being produced, the financial regime for economic support for the subsequent phases of the project had not been determined. It is foreseeable that the member institutions of the European Association for Solar Telescopes (EAST), via their funding agencies and using whichever legal format is finally adopted, will provide the economic feasibility for the project. For Spain this project could represent an unprecedented opportunity to lead the construction of a large European research infrastructure. Decisive support (political and financial) from this country's regional and national authorities is vitally important, together with an additional contribution greater than that of other countries, in order to steer the project through its subsequent phases with the other European partners involved.

MOTIVATION & OBJECTIVES

Modern science is entirely global, with information shared between researchers across the world virtually instantly. For astronomy and other similar disciplines there is another reason for globalisation – the high cost of the infrastructure that we need today. This means that countries must work together to plan for the future, pooling available resources across the whole of Europe. A series of European astronomy funding agencies therefore came together to form an ERA-Net type network, ASTRONET, which is financed by the European Commission and whose main aim is to identify the most important scientific goals in Astronomy for the next two decades and the infrastructure needed to attain them. ASTRONET published a "roadmap" in 2008 to prioritise the construction of infrastructure that will keep Europe in the lead.

The EST is the major project for the future of European ground-based solar astronomy and is listed by ASTRONET as a top priority amongst medium-sized ground-based infrastructures.

The EST is the key future project for *EAST*, an association with member institutions from 15 European countries. EAST does not have its own funds for building the telescope, it therefore needs financial backing from the various funding agencies in these countries.

In recent years European industry has gained the technological capacity and knowledge needed to take on a technological challenge like the EST.

Contributing to the EST is a way of helping to keep European solar physics at the forefront; it will guarantee access to an essential tool for ground-based solar research that will bring scientific benefits not only in quantity but also of the highest quality; it is a key reinforcement in the strategy of development and internationalisation for the Canary Islands' Astrophysics Observatories and will give European industry, which is very well equipped for this type of projects, a unique opportunity to make returns on its expertise in the field.

This, then, is the first aim of this document: to illustrate and corroborate the foreseeable notable benefits and high impact of the EST for a European knowledge-based society.

However, the main body of the report is an examination of the effects in all areas as well as the economic feasibility of siting the EST in the Canaries.

As a result of the International Agreements for Cooperation in Astrophysics, the Observatories of the IAC are home to a range of telescopes and observation facilities operated by many different countries. For decades the observatories have offered the combined strengths of excellent conditions for observing the sky (rivalled by very few other sites worldwide) and comprehensive infrastructure and a well-established activity.

Building the EST at either of the two observatories would bring considerable benefits for the Canary Islands. These benefits are described in detail in this report, with a particular emphasis on socio-economic impacts. The construction of the EST in the Canaries (and subsequently operating it for 30 years) would produce a large amount of economic activity and create high skilled jobs.

Although Europe is currently in the grip of an international financial crisis, which involves a slowdown in economic growth, a range of opportunities and advantages are emerging that must be grasped in order to provide firm and decisive backing for construction of the EST and to overcome the current obstacles in the path of the project.

- The EST is a vital European response to the American Advanced Technology Solar Telescope (ATST), and it will keep European solar physics in the position of excellence it deserves.
- The Conceptual Design study was completed in July 2011 and it is now essential to assure the project's continuity, with a smooth transition to the next phase, so that momentum and the progress already made are not lost.
- The partners in the EST unanimously agree that as the EST develops, plans must be made to dismantle many of the existing solar telescopes in the Canaries. Should the EST receive strong support now, it will help to clarify the situation of some of the current infrastructures, and to concentrate efforts on new technology developments for this project.
- However it is unfortunate that the EST does not feature on the European Strategy Forum on Reseach Infrastructures (ESFRI) Roadmap. It should be remembered that the EST has already drawn support from practically the whole of the European research community. However, the EST cannot yet claim to be a “project of European interest,” a status which would open the doors for negotiations between the countries involved. The Roadmap was last updated in 2008 (only for certain fields of science, not including astrophysics) and the list of projects is not expected to be updated again until at least 2013-2014. This could be too late for the EST. The risk of halting the project for at least two years could lead to a significant loss of momentum as well as a

loss of interest amongst companies, which might turn instead to other projects.

- One of the consequences of the EST not appearing in the ESFRI roadmap is that the EST does not feature on any of the lists of priorities, at either European or national level for any of the countries involved. This is clearly in contradiction to the fact that ASTRONET has considered the EST as a top priority amongst medium-sized ground-based infrastructures. It is vital for the future of the project to change this situation.

SUPPORTING INSTITUTIONS

The institutions and organisations below have formally announced their full backing for the EST project sited at the Canary Islands' Astrophysics Observatories. They appeal to the decision-making entities or to any organisations whose strategies and actions can assist this process, to take the necessary steps for the project to go ahead.

European ASTRONET Network
The Astronet Infrastructure Roadmap. A Strategic Plan for European Astronomy. 2008

EAST (European Association for Solar Telescopes)
Terms of Reference for the European Association for Solar Telescopes. 08/02/2007

Spanish National Astronomy Commission
Briefing Note 03/02/2011

Tenerife Island Council
Ordinary Plenary Session 25/02/2011

Up to April 2011 a range of organisations from scientific, political and socio-economic backgrounds are also working to formally express their support.

CONTENTS

1.

INTRODUCTION

Large science and technology infrastructures in Europe have always received special consideration at community level because of the incalculable value they bring for the European Research Area (ERA) structure and the advances they give rise to in all areas of science and technology. Over the last decade the effects that these infrastructures may have on the economy, society and industry of the Member States and their development has also come to be assessed and studied.

The various Framework Programmes have made funds available specifically to help Europe to pursue these transnationally important installations and they have also funded improvements and constant updating. The previous Sixth Framework Programme (FP6) (2002-2006) included for the first time a specific programme designed to support these installations, taking into account access to and improving existing ones and also funding the design, development and construction of new infrastructures. The current Seventh Framework Programme (FP7), which covers the period 2007-2013, retains this support for present and future projects.

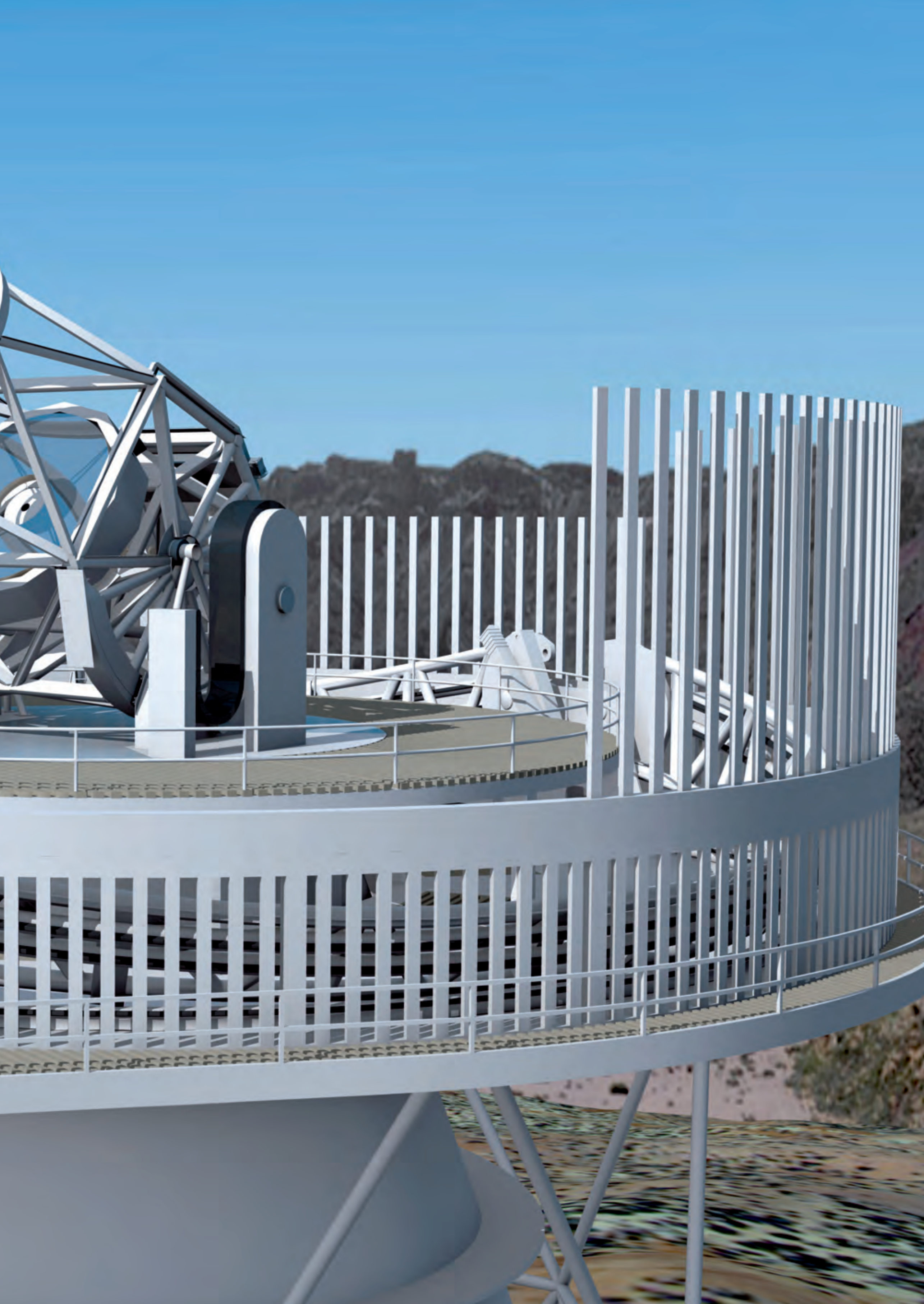
Following a recommendation by the Council, and as a further step towards better planning for the design and improvement of large infrastructures at EU level, the European Commission created the ESFRI in 2002, specifically to support the coordination of the different national and community policies on these infrastructures and to encourage multilateral efforts for their better use and development.

To help achieve these goals the ESFRI has produced a “Roadmap”, a list of projects that will receive support over the next 10-20 years to keep Europe at the forefront of international scientific excellence. In the field of Astrophysics, the European ASTRONET network is responsible for determining scientific objectives for astronomy in the next two decades and identifying the infrastructure needed to achieve them. The EST is one of the projects prioritised by ASTRONET but it has not been listed on the ESFRI “Roadmap” as yet, so the necessary steps must be taken for it to be included.

The European solar physics community is unanimous in its choice of site for the EST: The Canary Islands. The observatory that will ultimately be home to the telescope (ORM or OT) has not yet been decided.

This document gives some scientific and technical details on the EST project and presents the results of work already carried out on the economic and social impact of building and operating the EST in the Canaries. It also identifies potential sources of funding for the project.

2.
THE EST PROJECT



2.1. THE EUROPEAN LARGE APERTURE SOLAR TELESCOPE (EST)

2.1.1. Brief description and history

In 1968, solar physicists from 7 European countries formed JOSO (*Joint Organization for Solar Observations*), an international joint project by the foremost European solar physics research institutions. Its main aim was to identify and scientifically exploit an ideal site for a solar observatory. After more than forty locations in the Mediterranean and the Atlantic had been examined, two mountain sites on the Canary Islands were finally put forward: Izaña (Tenerife) and Roque de Los Muchachos (La Palma).

These observatories most closely met the strategic objectives set down by JOSO for sites for national medium-sized telescopes and for a large European solar telescope (LEST, *Large European Solar Telescope*), which was to be built jointly by the member countries.

To encourage the construction of LEST, a Foundation was created in 1983 under the auspices of the Royal Swedish Academy of Sciences (RSAS). LEST came to be known as *Large Earth-Based Solar Telescope*. Despite this telescope being strategic for the development of solar physics worldwide, the funding needed was never obtained so the project was discarded in 1998.

During the last two decades, most of the progress with infrastructures for studying the Sun has resulted from individual initiatives by the different countries operating in this field. Following the signing of the International Agreement for Cooperation in Astrophysics (1979), these countries were able to site their installations at OT (Tenerife) and the ORM (La Palma), which are both operated by the IAC. The telescopes at these observatories operate in atmospheric conditions only found at a first rate site for astrophysics observations. The two observatories are home to telescopes that can efficiently capture high-resolution images and spectra of the photosphere and the solar chromosphere, at the very limits of what is possible with current technology and the exceptional quality of the sky over the Canary Islands. Images like those taken by the SST (*Swedish Solar Telescope*) or the DOT (*Dutch Open Telescope*), which are sited at the ORM, have revealed magnetic structures in the Sun that are scarcely 100 km across and shown how their morphology evolves. To look more closely at these structures spectral and polarimetric analyses are required, as done by the Themis solar telescope and the Vacuum Tower Telescope (VTT), which are both located at the OT. Despite the Sun's closeness, however, not enough photons reach us from these small magnetic structures for us to examine them sufficiently quickly to prevent the data being affected by their rapid evolution.

These arguments have become stronger in recent years, stimulating the overriding need for a larger telescope to study this type of phenomena. EAST[1] was founded by solar physicists from 14 European countries

Figure 1. Conceptual design structure of the EST

in 2006[2] to guarantee the development of new high resolution facilities for ground-based solar observation, including the development, construction and operation of a next generation telescope called the EST, thus resurrecting plans for a large telescope that had been put forward in the past.

If it becomes a reality the EST will be the largest EU consolidated and most widely participated effort to take European solar physics to the forefront of worldwide solar research.

The first step towards construction of the EST was taken in 2007, when the European Commission approved a project for the conceptual design phase of the telescope. A total of 30 institutions, as main partners, and 7 collaborating entities from 15 countries are involved in this project, which is being coordinated by the IAC. The EST Conceptual Design Study represents an investment of nearly €7 million, with 3.2 million of funded by the EC, for a period of 42 months (2008-2011).

The design includes a 4.1 metre diameter primary mirror, a 0.8 metre secondary mirror and a focal length of 200 metres, giving spatial resolution of 30 km in the solar disc (with the aim of reaching 20 km). The diffraction limit will be 0.03 arc seconds at 500 nm. There is only one other telescope project like this in the world, currently being built on the Hawaiian island of Haleakala: the ATST that is backed and funded by the United States.

1 *Terms of Reference for the European Association for Solar Telescopes (EAST)* (Annex A1).

2 *EAST currently comprises institutions from 15 countries following Poland's entry in 2008*

Figure 2. Views of solar telescopes at the Canary Islands' Astronomical Observatories

On the basis of the current design and the construction period anticipated, the EST is expected to cost in the order of €160 million.

The site for the telescope will be one of the two observatories in the Canary Islands (Figure 2). The final decision will depend on the outcome of atmospheric characterisation campaigns, as well as other technical aspects.

2.1.2. Construction and operation infrastructure requirements

Building and operating an installation as large as the EST will require specific infrastructure to be available at the site.

Listed below, based on assessments by the EAST consortium for the current conceptual design phase and information available on building and operating a science instrument like this, is a brief list of the infrastructure that will need to be considered.

- **Electrical supply line:** The EST will need a 0.3 MW supply, either from local generators or via suitable supply lines providing guaranteed continuity of supply.
- **Telecommunications:** Construction of the EST is expected to require 45 personnel (on site simultaneously for up to six years) and some 70 people during the operating phase, for approximately 30 years. These personnel will need accommodation near the site, within one hour's travelling time, with all of the necessary facilities and services.
- **Workshops and annexes:** The EST project will include construction of all of the facilities needed by the telescope,

including control rooms, offices, a maintenance workshop, etc.

- **Water supply and sewerage:** The water supply will need to be adequate for the needs of the facility and there will need to be provision for the removal of waste water and other solid residues (resulting from the presence of personnel and some maintenance activities; residues will be produced during both the construction and operation phases).
- **Operating base near the observatory:** The base must include storage, laboratories and workshops together with administrative, technical and scientific offices. The operating base will ideally be under one and a half hours from the site, guaranteeing road accessibility.

Given that installations will have to be assembled and mounted on site from scratch, workshops for machining and correcting large parts will be required. Annexes will therefore be built in the surrounding area, with a direct impact during this phase.

2.1.3. Construction and operation budget[3]

The current estimate for the cost of building the EST is approximately €135 million. This includes the costs of civil works, optics, mechanics, control systems, the dome, etc. and allows for a construction period of 6 years.

The budget also includes development of the main instruments that will operate during the life of the telescope, a reasonable allowance for contingencies and assembly and testing costs during the last year of construction.

3 Estimate made with information gathered until 31 January 2011.

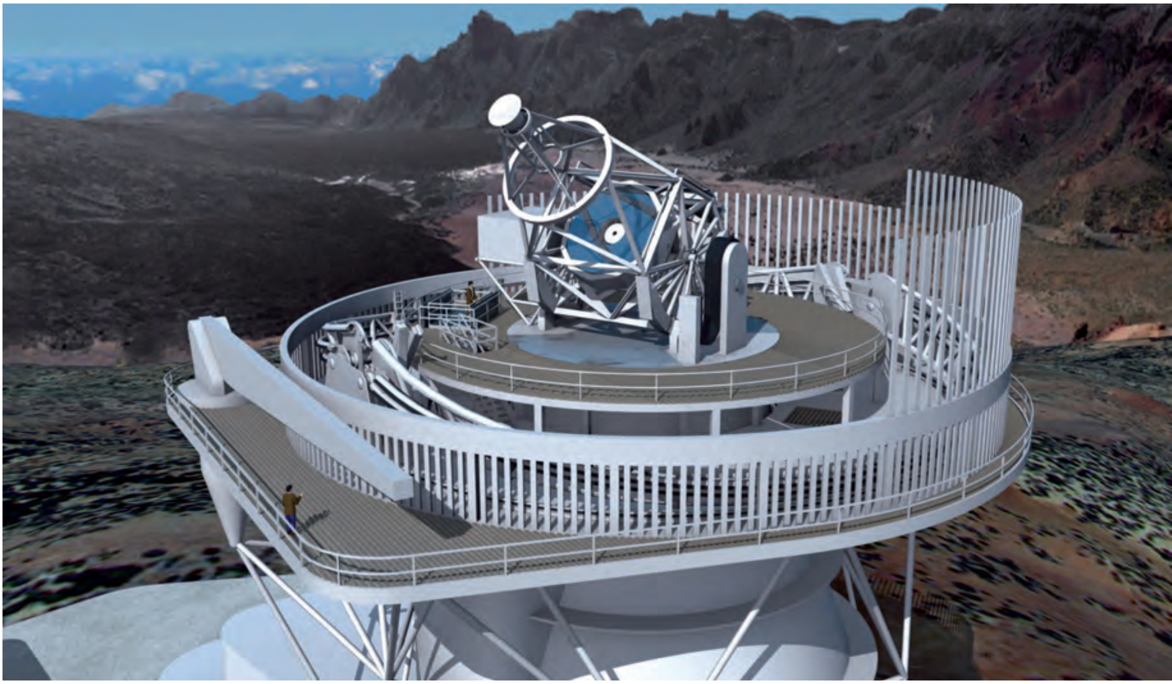


Figure 3. View of the EST from above, showing the primary mirror

The costs of the conceptual design study, preliminary design phase and preparation phase to start construction are not included. The estimate also excludes the cost of commissioning (prior to the instrument being handed over for use by the solar science community). It is estimated that these activities will cost in the region of €25 million.

To break down this draft budget of €135 million in the different budget items we consulted potential suppliers of the telescopes different parts, members of EAST and bodies that have built telescopes of a similar size and cost to the EST.

The structure of this budget is subject to some degree of uncertainty due to the process used in compiling it and also to factors inherent in the project (technological risk factors related to the appropriate item, price variation, etc.); 20% of the budget is therefore allocated for contingencies. This figure is no different to actual amounts allocated to similar projects.

A detailed statement of the way that capital expenditure has been structured and the different budget headings is given below.

Optics - Mirrors

This includes the development of the primary (M1) and secondary (M2) mirrors. The primary mirror (Fig 3) is a single 4.1 meter mirror fabricated from a type of lightweight glass ceramic material which is very stable in fluctuating temperatures. The secondary mirror is 0.8 metres and the technologies involved in manufacturing it, as a key component of the active optics system, are challenging. Active optics systems are used to compensate for deformations caused by gravity (due to the weight of the mirrors in their different positions), the wind or fluctuations in temperature providing technology to keep the primary and secondary mirrors aligned in real time. The main elements of the EST's active optics will be active support behind the primary mirror and a tip-tilt mechanism (which pitches and changes the angle of mirror) at the secondary mirror as well as a hexapod stand to compensate possible non-alignments between the primary and secondary mirrors.

Multi-conjugate Adaptive Optics

The EST will have a Multi-conjugate Adaptive Optics system (MCAO). This consists of several deformable mirrors and a number of wavefront sensors to gauge, predict and correct in real time atmospheric perturbations produced in localised layers at different known heights in the atmosphere, in order to improve the quality of the final image.

Control systems

This heading takes in all of the software and hardware used for controlling the telescope systems (including the primary and secondary mirrors, pointing, dome, electronics, data acquisition, pre-processing and presentation, graphics, etc.).

Telescope mechanics

The mechanical structure is the telescope itself, the body that will support the mirrors, its mechanisms and the instruments and associated electronics. It will weigh around 150 tonnes and will include a precision rotation system for the telescope, which is needed for optimum observation.

Heat trap

The heat trap eliminates the large amount of solar radiation that will build up when light is reflected and concentrated by the primary mirror. Light travelling from the primary to the secondary mirror which is not needed for the final image will be captured before it reaches the mirror and reflected out of the telescope. This avoids deformations in the mirrors and telescope structure caused by heat.

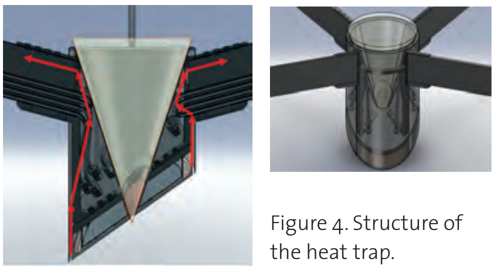
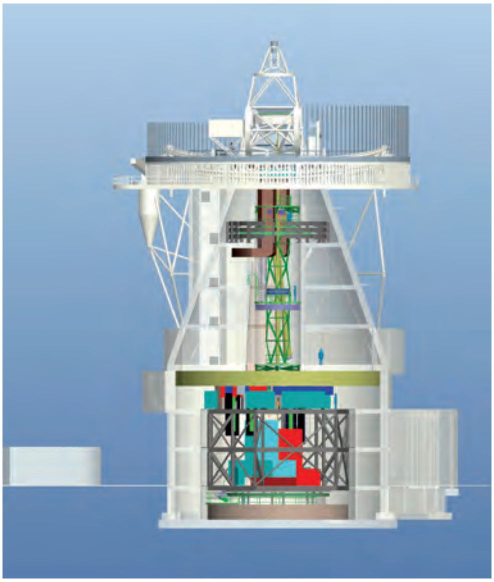
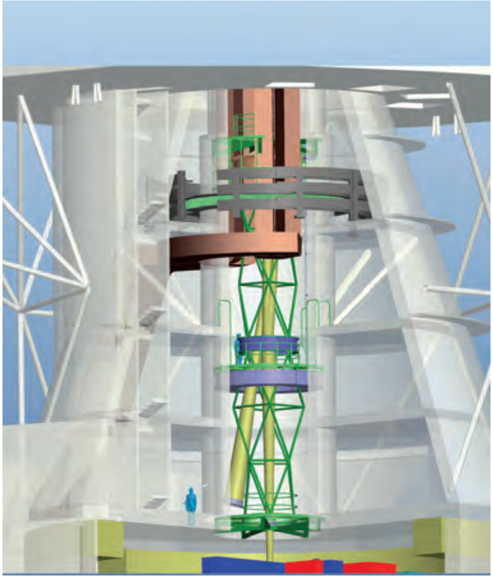


Figure 4. Structure of the heat trap.

Dome

The dome is the main element protecting the telescope and also allows for ventilation of the different components. The design for the dome of the EST is non conventional. It will withdraw completely, leaving the telescope open during observations and will use the wind to ventilate the mirrors and other elements on the telescope platform.





Scientific instruments

This includes the budget for three instruments (and their corresponding associated channels and subsystems up to twelve) whose design costs largely represent personnel costs at institutions of the various EAST countries, as well as industrial manufacturing costs. Estimates for the cost of each channel are between €1 and €5 million. The overall budget for this instrument is estimated at over €35 million.

Civil works

This will include site clearance, foundations, concrete, construction of the operations building, annex and auxiliary buildings, specific residence, water supply, electrical installations, lighting, roads and conditioning.

Project Management

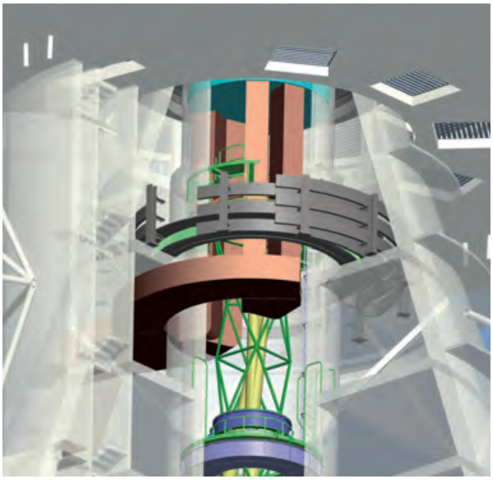
It includes all elements for controlling, monitoring and coordinating the project.

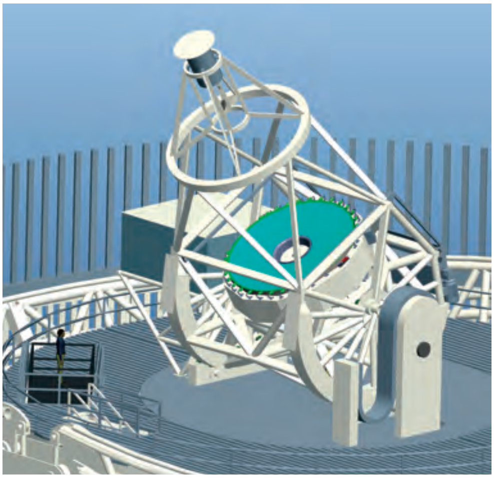
Contingencies

Allowance for any technical, human or organisational resources needed to keep the project on track. A risk analysis is needed for each sector in order to produce the contingency budget.

Assembly, testing and preparation of the telescope

Process of verifying that all of the components of the telescope are working properly, both individually and collectively.





CONSTRUCTION PHASE

A breakdown for the estimate of the EST construction budget, with elements as previously described, is given in table 1. The time allocated to each sector is also shown.

This budget is considered the same whether the telescope is ultimately built at the ORM or the OT, as there will be no appreciable cost difference (less than 2% of the total budget in any case, and well under limits allowed for in Contingencies).

Table 1. EST budget breakdown. Construction phase

Sector	Percentage (%)	Estimated cost *(at 2010 prices)* *(k€)*	Period	
			Start year	Nº of years
Mirrors	12,63%	16.973,00	1º	6
Telescope mechanics	11,26%	15.125,00	1º	6
Control systems	6,58%	8835,00	1º	6
Adaptive Optics	6,70%	9000,00	1º	6
Heat trap	0,39%	525,00	1º	4
Dome	2,49%	3342,00	1º	3
Civil works	5,38%	7231,00	1º	3
Scientific instruments	23,60%	31.705,00	1º	6
Management and scientific support	9,38%	12.600,00	1º	6
Auxiliary telescope	0,16%	212,00	1º	1
Assembly, testing and preparation of the telescope	4,76%	6400,00	5º	1
Contingencies (20%)	16,67%	22.389,60	-	-
TOTAL	**100%**	**134.337,60**		

Table 2. Annual investment profile by sector. Construction phase

Sector	Investment per year as a percentage (construction phase)					
	1	2	3	4	5	6
Mirrors	10,00%	25,00%	25,00%	20,00%	20,00%	0,00%
Telescope mechanics	15,00%	15,00%	25,00%	25,00%	15,00%	5,00%
Control systems	5,00%	10,00%	25,00%	30,00%	15,00%	15,00%
Adaptive Optics	10,00%	15,00%	25,00%	20,00%	20,00%	10,00%
Heat trap	10,00%	15,00%	25,00%	25,00%	15,00%	10,00%
Dome	5,00%	30,00%	40,00%	25,00%	0,00%	0,00%
Civil works	10,00%	20,00%	30,00%	30,00%	10,00%	0,00%
Scientific instruments	10,00%	15,00%	20,00%	20,00%	20,00%	15,00%
Management and scientific support	15,00%	15,00%	20,00%	20,00%	15,00%	15,00%
Auxiliary telescope	0,00%	0,00%	0,00%	0,00%	100,00%	0,00%
Assembly, testing and preparation of the telescope	0,00%	0,00%	0,00%	0,00%	0,00%	100,00%
Contingencies *(20% over sectors)*	15,00%	20,00%	25,00%	20,00%	10,00%	10,00%

Table 2 gives the level of investment needed per sector per year as a percentage of the overall budget according to estimates made by the consortium responsible for the conceptual design.

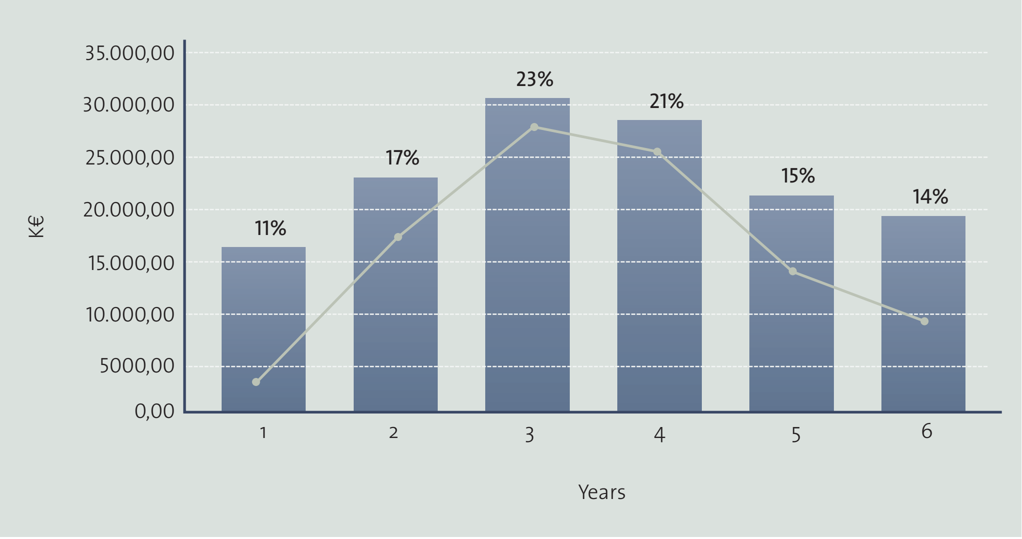
Total investment per year according to this estimate is shown in Graphic 1.

Approximately 50% of the total investment will be needed for the first three years of the construction phase. Costs will increase year on year during this first phase, with investment levels peaking during the third and fourth years, as this is when most work-packages will run simultaneously. The final year in this graphic will see investment focus on the telescope assembly and testing and preparation for observation phases. Work will also be completed on the main sectors detailed (scientific instruments, mechanics, control and adaptive optics).

The contingency budget allows for uncertainties in other sectors and is estimated at 20% based on the following considerations:

- **Technical project requirements:** at the present time there is no final specification (final design, technical requirements, etc.) for the various systems that will make up tthe EST. Some of them will inevitably change over time and so cost estimates can only be based on preliminary designs and/or prototypes and previous experience with similar components.
- **Tender preparation and response from industry:** all of the technical specifications for each tender will need to be

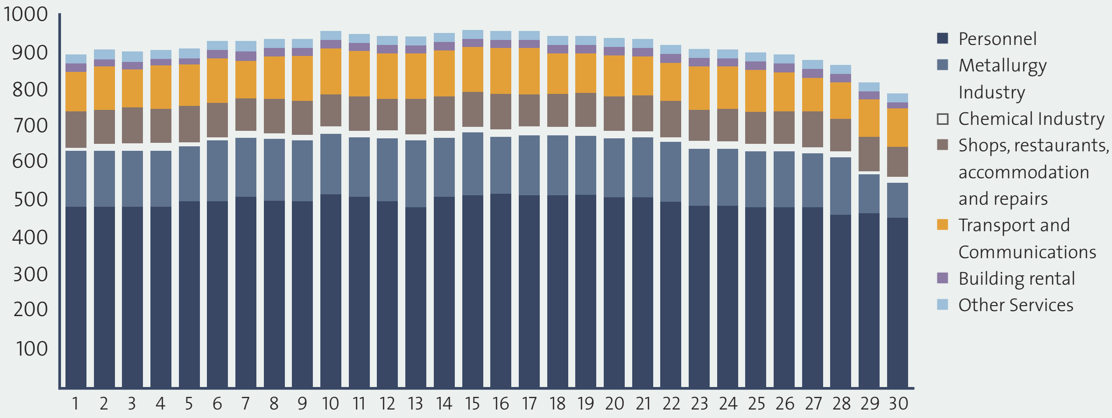
Graphic 1. Estimated investment profile for the EST construction phase



sent to companies on the tender shortlist to avoid confusion over technical details for the equipment and/or services required. Any remaining price variations will result from the responses received from industry for both technical and commercial elements (and are thus beyond the control of the project). The price ultimately paid to each entity will depend on factors like their qualifications and experience, the challenges implied by developing the technology and the degree of industrial expansion required, ownership of the designs, degree of guarantee of the deliverables requested from providers, structure and location of markets, acquisition regulations in force, etc.

- **Changes in the general economic situation and in national regulations and laws:** this factor is beyond the control of the project but has consequences for it, mainly due to increases in the cost of raw materials and other industrial materials, exchange rate fluctuations (in the eventuality of sub contracts outside the euro zone) and differences in labour laws, customs and tax regimes. Although past variations in these factors are well documented, future projections can only be roughly anticipated and limited.
- **Construction delays:** changes in timing during the construction phase will affect budget items, both in terms of annual distribution and the total amount paid for each sector.

Graphic 2. **Estimated annual EST operational costs (k€) by sectors (euros 2010)**



OPERATION PHASE

It is foreseen that EST will operate for at least 30 years after construction.

Estimated annual operating costs during the first years are put at around 7% of the total construction budget (~ €9 million). This percentage could be subject to slight variations over the lifetime of the telescope, as a result of improvements made to the operating process, repairs to keep it functioning correctly, new instrument development and various contingencies during the successive observation campaigns. Graphic 2 gives the estimated operating costs for the EST (by sector) over the 30 years following the Commissioning phase, assuming optimum operating conditions and taking into account the factors previously mentioned.

Chemical Industry

- Liquid Nitrogen
- Industrial oil
- Diesel
- Helium
- Deionised water
- Alcohols
- Liquid coolants
- Other gases

Metallurgy Industry

- Optical design
- Optical instruments
- Optical treatments
- Optical instrument maintenance
- Hardware and software
- Electrical installation
- Electrical materials
- Electrical equipment calibration
- Electronic materials
- Electronic equipment

- Electronics maintenance
- Precision mechanics
- Dimensional metrology calibration
- Mechanical design
- Hydraulics
- Climate control
- Goods lifts

Transport and Communications

- Landline telephone
- Internet
- Mobile telephone
- Courier services
- Post
- Staff sea and air travel
- Vehicle hire
- Vehicle purchase

Shops, restaurants, accommodation and repairs

- Hotels
- Restaurants
- Supermarkets
- Local service and product providers
- Vehicle maintenance

Other Services

- Fire prevention system
- Safety equipment
- Water supply and transport
- Congresses
- Training courses
- Events
- Other

Buildings rental

- Headquarters rental
- Other rentals (garages, staff apartments etc.)

2.2. RELEVANCE FOR THE EUROPEAN SOLAR PHYSICS COMMUNITY: THE ROLE OF EAST

The view that a large aperture new generation solar telescope is needed to further understanding of the fundamental processes of plasma physics in the Sun's upper layers is unanimously shared by European solar physicists.

The report *"A Science Vision for European Astronomy, 2007"* for the European ASTRONET[4] network, underlines this by advocating, as part of the range of medium size infrastructure, the construction of a ground-based large aperture 3 to 5 metre solar telescope with adaptive optics and integral field spectropolarimeters for observing astrophysical processes at their intrinsic scale. This would allow interaction between magnetic fields and plasma in the solar atmosphere to be observed.

In recent years several European research institutes have achieved a high level of competence in designing, building and operating advanced scientific instruments and this has given them a high profile in the area of ground-based observation technology. The combined experience of these institutions, together with the advanced capability of European industries in the sector, certainly make possible the design and construction of a solar telescope like the one proposed.

4 *A Science Vision for European Astronomy, 2007* (Annex A2).

Figure 5. Meeting of the EST consortium. Freiburg (Germany). 2011

It would also enhance the strengths and capacity of the organisations involved.

This framework for European collaboration, with research centres and industries working together, has already been applied in the EST conceptual design phase (figure 5).

The level of co-operation between the partners in EAST is such that it has already been agreed to focus resources from the countries involved on operating this new jointly developed telescope and, over time, to close and dismantle almost all of the existing solar physics facilities. As the EST can operate using various instruments simultaneously, it will be possible for many more groups than is usual at a solar telescope to use it during observation campaigns, thus optimising observing time, data and the scientific results obtained.

EAST is not only working on conceptual designs for the EST, from a scientific and technical perspective; it is also putting a great deal of effort into determining the financial arrangements and possible funding sources for the successive stages of the project (preliminary design, construction and operation), as well as options for the legal entity that will oversee its construction and operation. The new European legal structure, the "ERIC," is being looked at in detail (see section 7.2 for more information).

As will be set out later in this report, a significant percentage of the funding for the EST needs to come from the countries involved. EAST is therefore working to improve co-operation between the different funding agencies in order to obtain firm and lasting commitments that will serve as a guarantee and lead to a financial agreement for the operating period of the EST. In recent years much effort has been devoted to having the EST included on the European roadmap for large research infrastructures, known as the "ESFRI Roadmap." The roadmap lists only science and technology infrastructure projects that are prioritized by EU Member States because of their excellence and potential worldwide scientific impact. This Roadmap is expected to be updated in coming years, providing an opportunity for the EST to be added to the list of future research infrastructures that are going to be supported by Member State funding agencies.

If this option fails, European leadership in solar physics will be in serious danger due to the rapidly approaching obsolescence of Europe's existing infrastructure and the lack of access to other large international projects in development.

Scientific relevance for European solar physics[5]

If the project takes off, the European solar physics community will be able, for the first time, to look at the mechanisms in the photosphere and sub-photosphere that turn kinetic plasma energy into magnetic energy and to study how this energy is transported to the higher layers (chromosphere) and how it is again deposited in the plasma there.

This telescope will help us to solve the main problems facing today's observations and current models and theories. It will also very probably show us new, previously undetected phenomena.

2.3. IMPLICATIONS OF THE EST FOR THE HOST COUNTRY

In this section we look briefly and specifically at the implications for Spain of the construction and installation of the EST at the Canary Islands' Astrophysics Observatories.

We must be clear that Spain, with its research centres and universities, is sufficiently mature and experienced to participate in the scientific exploitation of this large telescope in the same way as the other countries. It is significant enough the fact, in this sense, that the IAC coordinated the conceptual design phase of the Project and that

5 See section 4 *for more details.*

an IAC researcher was the first president of EAST is most significant.

In addition, whichever of the two locations being considered as the site for the EST (OT and ORM) is finally chosen, there will be a direct technical and economic impact on the whole of Spain.

Science in Spain will benefit from this project but there will also be benefits in other areas like employment, economy and industry.

Briefly, the potential impacts are as follows:

- Siting the EST in the Canaries will directly result in the creation of a significant number of highly skilled jobs (around 50 highly specialised jobs). Considering the experience of international organisations like ESO (*European Southern Observatory*) and similar projects, the number of jobs taken up by local and national personnel has in many cases been over 60% of the total created.
- Siting the EST at the ORM or OT will benefit and reinforce the basic and advanced infrastructures at both observatories. The support facilities at both sites are being improved and updated every year in order to attract new research infrastructures for observational astronomy. Among the new facilities recently opened, or about to open, at these observatories, are the GTC and MAGIC II (Major Atmospheric Gamma-ray Imaging Cherenkov) on the island of La Palma, and GREGOR and the Global Network of Telescopes LAS CUMBES OBSERVATORY in Tenerife.
- Building and operating the EST at the ORM or the OT will bring economic returns for La Palma or Tenerife proportionate to consumption from these activities and will encourage the development of new infrastructure and services as they are needed[6].
- If the EST is sited in Europe, and specifically in Spain, it will encourage young people to take up scientific vocations, bolstering the training and retention of young people in highly specialised areas of physics, astronomy and engineering.

Siting the EST at the Canary Islands' Observatories will strengthen Spain's current role in solar physics and provide incentives for scientific and technological development, with quantifiable economic returns through the creation of highly skilled jobs and increases in the number of specialist services.

6 See section 9.2 *for more details.*

2.4. SCIENTIFIC FACILITIES FOR SOLAR PHYSICS

2.4.1. Brief introduction

Solar telescopes are very similar to night telescopes in terms of design and construction. However, solar observations require telescopes and instruments capable of dissipating large quantities of heat, which are received from the Sun, whilst maintaining the highest possible spatial, spectral and temporal resolution.

- Solar radiation heats the surface of the Earth and generates a layer of turbulent air that negatively affects image quality. Solar telescopes are therefore normally built in towers to reduce influence from this turbulent layer.
- Solar telescope mirrors also concentrate a large amount of light and so heat onto a very small area, and therefore need devices to ensure that the heat is dissipated to avoid degrading the image quality as well as irreparable damage to the optical systems of the telescope and its instruments.

Most of the current solar telescopes have apertures ranging from a few centimetres to approximately one metre diameter. Some of these telescopes are linked together as part of a network for obtaining helioseismological information. Others monitor solar activity and provide images of the solar disc at different wavelengths or magnetograms. These telescopes provide relevant information, which serves as a base for subsequent high-resolution studies; although for some years their importance has been reducing as a result of the continuous daily images of the solar disc provided by the Solar & Heliopheric Observatory (SOHO)[7] satellite. So, new solar telescopes for observing the solar disc provide data on a very short temporal scale and this is useful for research into short duration solar phenomena, which is of great scientific interest.

Telescopes with apertures larger than half a metre provide an observation field covering only a fraction of the solar disc at an image scale that allows images to be obtained at the diffraction limit in the focal plane. In the past, most telescopes in the half to one metre range evacuated light trajectories in order to avoid lack of homogeneity in the refraction index of the air in the interior of the telescope caused by the concentration of light from the Sun. Next generation 1.5 to 4 metre solar telescopes will be open structures, with complex cooling systems for the primary mirror optics to remove heat absorbed from solar radiation. The optical components will be made from a material that is very resistant to thermal expansion and, if possible, has maximum heat conduc-

7 SOHO (*Solar & Heliospheric Observatory*) is an international joint project between the ESA and NASA for studies of the Sun from a satellite from its deep nucleus to the external Corona and the solar wind. More information is available at: http://sohowww.nascom.nasa.gov/

ting capacity. This last property of the materials used will simplify much of the cooling process and will significantly reduce the time needed to reach thermal equilibrium.

Many of the observable phenomena in the solar atmosphere last for only a few minutes and significant changes can occur in just a few seconds. This means that high-resolution solar telescopes must be able to deliver sufficiently high levels of light to produce an adequate signal-to-noise relation. This is the key factor in obtaining information about the "weak" magnetic field in the solar photosphere. Relevant small-scaled objects are scarcely 100 km or less, which means that telescopes larger than 1 metre are needed to observe them. New generation telescopes with around 4 metre apertures will be capable of achieving high levels of light combined with short integration times and excellent spatial resolution.

2.4.2. Existing ground-based solar physics infrastructures in Europe

Over the last 25 years different European countries have built powerful telescopes that have significantly expanded our understanding of the Sun. Very few observatories have these facilities to observe our star. The Canary Islands' Observatories, both because of their geographical location (in tropical latitudes) and the transparency and excellent astronomical quality of their skies[8], are home to the largest array of European high-resolution solar telescopes.

The following is a list of all the solar telescopes and instruments currently in use at the Canary Islands' Astrophysics Observatories.

Even though a number of scientific breakthroughs of worldwide importance have been made using these European installations, new paradigms in solar physics call for a new generation of telescopes in the short and medium term, providing greater spatial and spectral resolution and light collecting capacity in order to deal with short duration physical processes and to analyse weak polarised spectral lines, for which the aperture of the telescope is critical.

2.4.3. The short- and medium-term future: the new generation of solar telescopes

In the world as a whole, three 1.5 to 2 metre solar telescopes are currently at either design or construction phase, with two of them due to enter service in 2012. The design for these telescopes is technologically innovative: the telescope tube does not contain a vacuum and is not filled with helium to prevent turbulent air entering the light's path as it travels to the instruments. They therefore represent a half-way point between current solar telescopes and the next

8 *ENO. A privileged site for astronomical observations* (Annex A3).

Teide Observatory (OT)

- **THEMIS telescope** (Heliographic Telescope for the Study of the Magnetism and Instabilities on the Sun) (Spectropolarimetry). France. Aperture: 90 cm.

  In operation since 1996, this is a joint experiment of the national research agencies of France (CNRS/INSU) and Italy (INAF), although solely French institutions currently operate it.
- **VTT Telescope** (Vacuum tower telescope) (*High resolution imaging, adaptive optics and spectropolarimetry*). Germany. Aperture: 70 cm.

  In operation since 1989, this telescope belongs to four German institutions: the Astrophysikalisches Institut Potsdam, the Kiepenheuer-Institut für Sonnenphysik (Freiburg, chair), the Max-Planck-Institut für Sonnensystemforschung (Lindau), and the Universitäts-Sternwarte Göttingen.
- **Solar Laboratory** (*helioseismology, astroseismology*). Spain.

  In operation since 1981. Currently working with six instruments. Although the owners of the different instruments are from scientific institutions outside the IAC, the IAC's "Solar and Stellar Seismology and Exoplanet Search" research group is responsible for operating them and actively participates in their scientific exploitation through the international consortia established for this purpose.

Roque de Los Muchachos Observatory (ORM)

- **SST Telescope** (Swedish Solar Telescope) *(High resolution imaging, adaptive optics and spectropolarimetry*). Sweden. Aperture: 100 cm.

  In operation since 2002, this is Europe's largest telescope and the world's number one for high spatial resolution. The SST belongs to and is operated by the Royal Swedish Academy of Science's Solar Physics Institute.
- **DOT Telescope** (Dutch Open Telescope) (*High resolution imaging)*. Netherlands. Aperture: 45 cm.

  In operation since 1997, it belongs to the University of Utrecht Astronomy Institute. The DOT is unusual as an open telescope, fitted to a steel tower and with no vacuum system as usually used to reduce atmospheric turbulence caused by the intense solar radiation being focused on the telescope. Instead, DOT uses the wind to ventilate the telescope and its surroundings, a key consideration for next generation solar telescopes.

Other European observatories are also home to solar instruments and telescopes, particularly:

- *Kanzelhöhe Observatory, Austria.*
- *Locarno Observatory, Switzerland.*
- *Observatoire du Pic du Midi, France.*

generation, which will have apertures in the 4-metre range. In today's terms, these next generation telescopes present a technological challenge whose technical feasibility is supported by two ground-breaking innovations: adaptive optics for solar telescopes and open cooled telescopes. The DOT, in La Palma, has actually served as a reference for this new generation.

The German GREGOR telescope has a 1.5 metre aperture and is sited at the Teide Observatory in Tenerife. It is an open telescope in a Gregory configuration of three mirrors with a focal length of 54 metres. Its primary mirror is made of Zerodur and is cooled on the rear. The "New Solar Telescope" is in the commissioning phase at the Big Bear Solar Observatory. It is a 1.6 metre telescope with an 88 metre effective focal length. Both telescopes will have high order adaptive optics.

In India, work has started on designs for a new 2 metre solar telescope, to be installed at the Himalaya at an altitude of some 5,000 metres.

In the United States the ATST telescope project at the National Solar Observatory is already under construction and is hoped to see first light in 2016 (Figure 6). ATST is a 4-metre class telescope which is being built at Haleakala, at an altitude of 3,000 metres, in Hawaii. It is the American counterpart to Europe's project.

The EST will take images of the Sun's magnetic field with the best available spatial and spectral resolution in the visible and near infrared ranges of the electromagnetic spectrum. The EST is expected to see first light in 2020.

Diagram 1 shows the current design for the EST compared to some of the world's most advanced existing solar telescopes, including the new ATST which is under construction.

FIRST-CLASS WORLDWIDE SITES FOR SCIENTIFIC INFRASTRUCTURES TO OBSERVE THE SUN

High quality solar observation requires locations with low levels of turbulence in the lower and higher layers. The atmosphere must also present low levels of water vapour and dust particles to minimise the amount of light dispersion. Mountainous sites on relatively small islands meet these requirements and are therefore considered to be the best sites for solar physics observations. Lakes can also provide suitable sites for observation as they inhibit local turbulence and regulate temperature gradients.

The following sites are currently considered to be the most favourable for ground-based observation of the Sun.

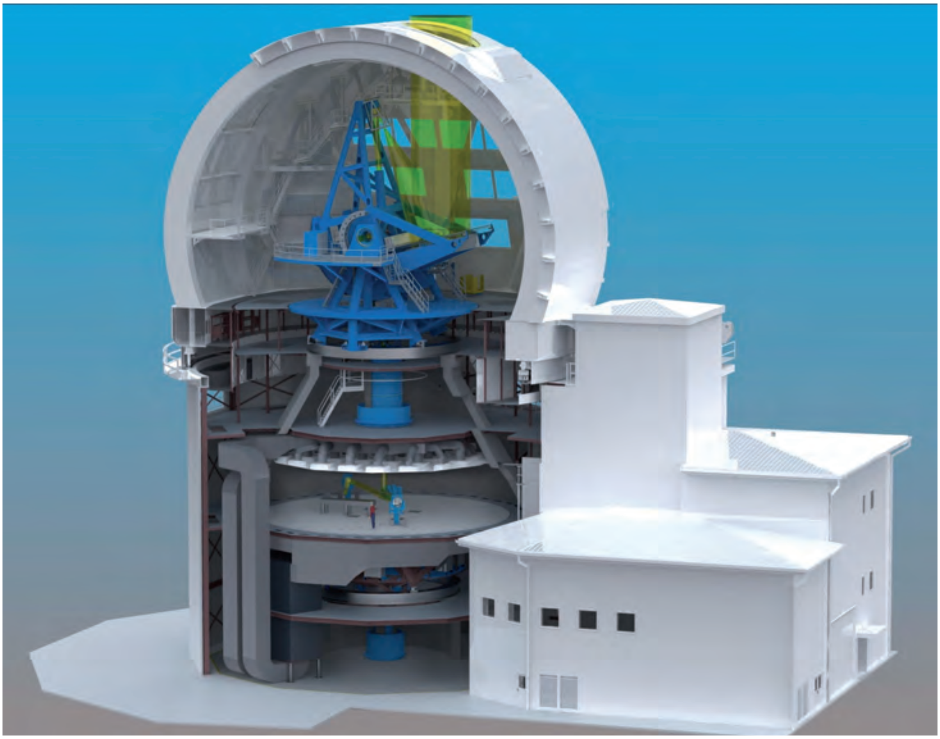


Figure 6. Artist's impression of the Advanced Technology Solar Telescope (ATST)

- Roque de Los Muchachos Observatory (ORM), La Palma. Canary Islands. Spain.
  Altitude: 2396 metres.

- Teide Observatory (OT). Tenerife. Canary Islands. Spain.
  Altitude: 2390 metros.

- Mees Solar Observatory (MSO) Hawaii. USA.
  Altitude: 3054 metros.

- Big Bear Solar Observatory (BBSO) California. USA.
  Altitude: 2067 metros.

There are also positive indications for sites in Antarctica where excellent conditions for daily seeing have been detected, although they present adverse logistical conditions given the extreme latitudes.

In the near future it is hoped that characterisation campaigns at the observatories will include determination of the number and height of turbulent layers in the atmosphere above the telescope. This will enable multi-conjugate adaptive optics systems to compensate for image degradation caused by these turbulent layers. Currently the most comprehensively and extensively characterised observatories are the Canary Islands' Astrophysics Observatories (ORM and OT).

Diagram 1. Table comparing solar telescopes currently at the ORM and OT with the ATST and EST

DOT
La Palma

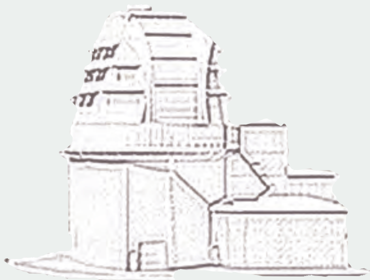
VTT
Tenerife

THEMIS
Tenerife

SST
La Palma

Telescope diameter:	0,45 m	0,70 m	0,90 m	1,0 m
Location:	ORM. La Palma. Canary Islands. Spain	OT. Tenerife. Canary Islands. Spain	OT. Tenerife. Canary Islands. Spain	ORM. La Palma. Canary Islands. Spain
Owner:	Netherlands	Germany	France	Sweden
Construction period:	1994-1997	1983-1988	1993-1996	2000-2002

GREGOR
Tenerife



ATST
Haleakala

EST
Canary Islands

1,5 m	4,2 m	4,1 m
OT. Tenerife. Canary Islands. Spain	Haleakala. Hawaii. EEUU	PREVISIÓN: OT, Tenerife or ORM, La Palma. Canary Islands. Spain
Germany	USA	*PROMOTERS:* *EAST Association*
2005-2010	EXPECTED: 2011-2016	EXPECTED: 2015-2020

Figure 7. Roque de Los Muchachos Observatory (ORM). La Palma. Canary Islands. Spain

Figure 8. Teide Observatory (OT). Tenerife. Canary Islands. Spain

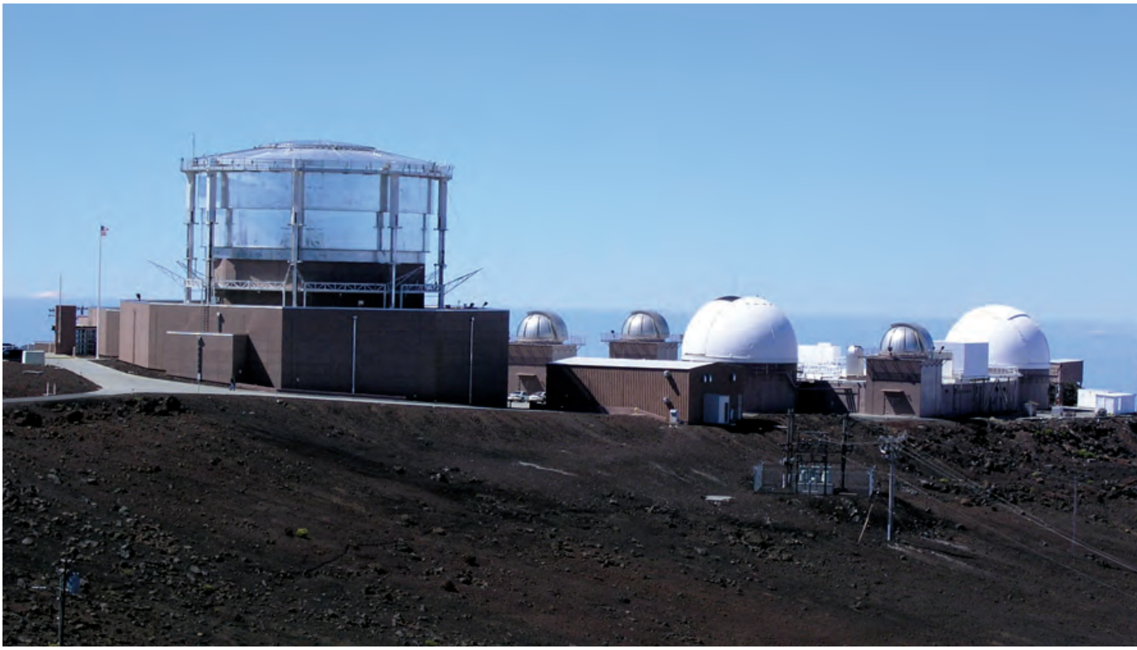
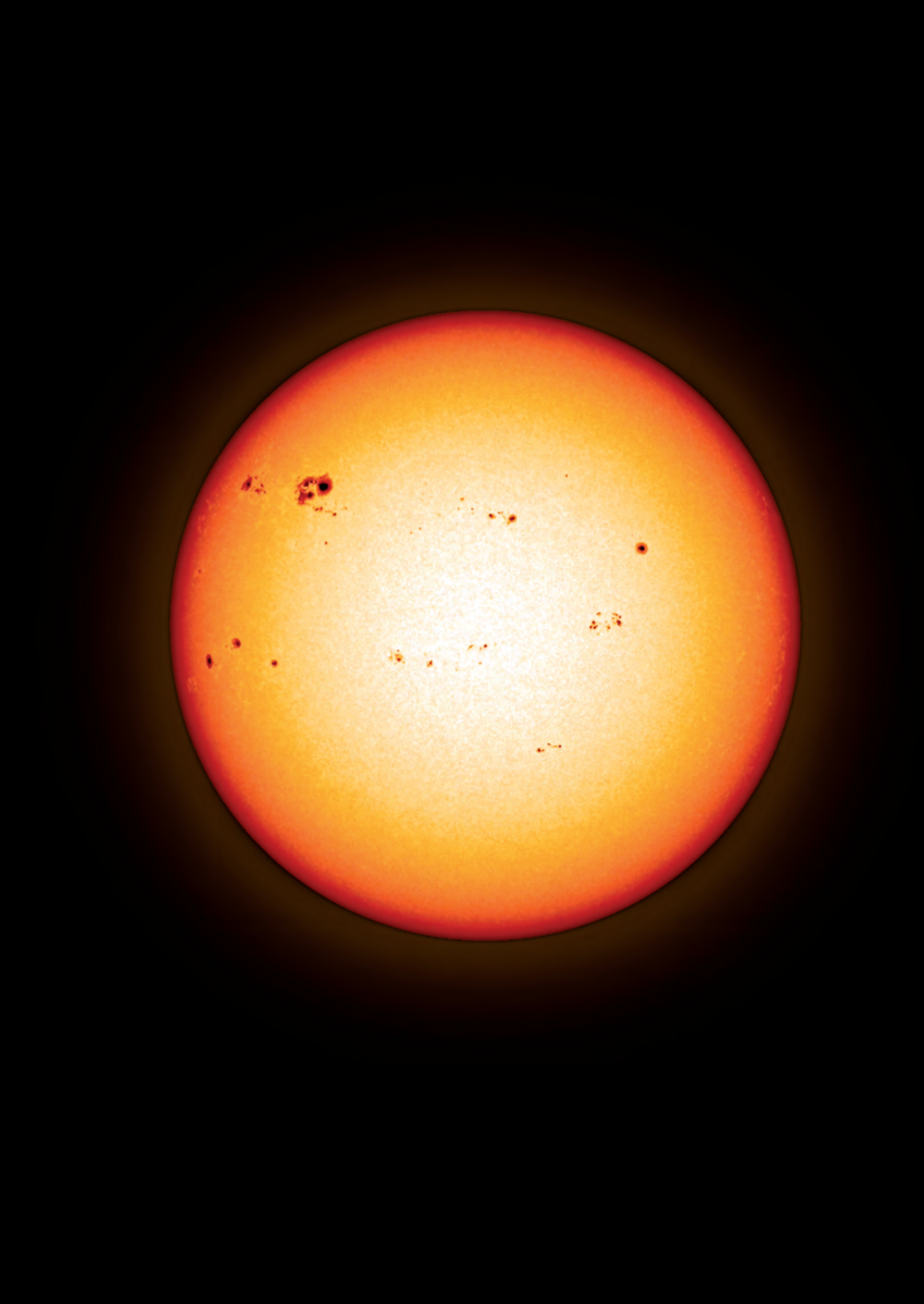


Figure 9. Solar Mees Observatory (MSO). Hawaii. USA

Figure 10. Solar Big Bear Observatory (BBSO). California. USA

3.
SCIENCE WITH THE EST



The EST is a solar telescope that will help to understand the physical processes taking place in the atmosphere of our star with details of few tens of kilometres. Understanding these physical processes is crucial for many reasons:

1. There is a fundamental link between the Earth and the Sun. The Sun is of primary importance because it maintains life on Earth. Any change in conditions in the Sun could have dramatic consequences for us. Large amounts of energy, stored in the magnetic fields, can be transferred to the plasma in very short time scales, between seconds and minutes. These transfers can accelerate the plasma to speeds of within a fraction of the speed of light and, if this accelerated plasma (in the form of a coronal mass ejection) reaches the Earth's magnetopause, it can give rise to fascinating events (auroras) and phenomena that are potentially dangerous for our environment (damage to satellites, overloading of energy lines, excessive radiation exposure for space crews or the International Space Station, etc.). This means that it is essential for us to study all of these processes to be in the position of predicting them.
2. The Sun is a basic physics laboratory (the interaction between the plasma and the magnetic field can only be studied in the Sun's extreme physical conditions).
3. The Sun is a fundamental model for understanding the rest of the Universe (all stars are suns). The EST will look at the fundamental solar processes at their tiniest scales, allowing us to analyse physical phenomena in the greatest possible detail.

Solar astronomers all over the world unanimously agree that we must increase significantly the observational capacity if we want to understand the fundamental processes that control the physics of the plasma in the Sun's atmosphere. This view is clearly stated by ASTRONET's *Science Vision group*. In their report A *Science Vision for European Astronomy* they consider the following key questions to be approached as a priority goal:

- What can the Sun teach us about fundamental astrophysical processes? Observations of the Sun reveal intricate patterns of magnetic fields and the complex dynamics of a stellar atmosphere at the physically relevant spatial scales.
- What drives Solar variability on all scales? The Sun varies on a wide range of spatial and temporal scales, displaying important energetic phenomena over the whole range. We do not fully understand and cannot accurately predict basic aspects of Solar variability.
- What is the impact of Solar activity on life on Earth? Solar magnetic activity variations induce terrestrial changes which can affect millions of humans

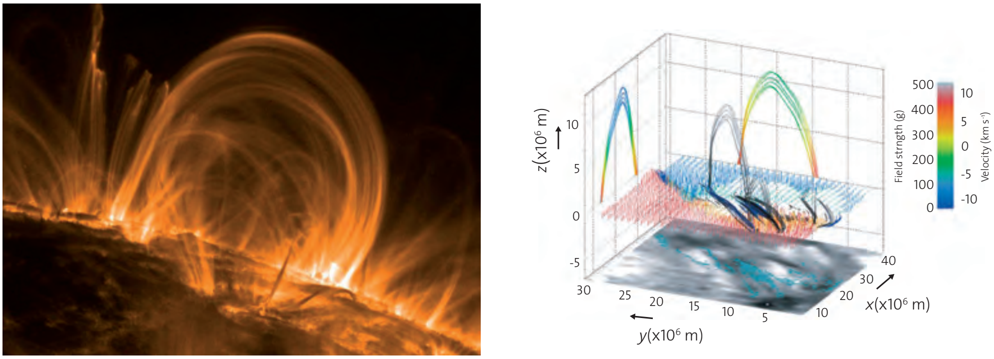


Figure 11. *Left:* Loops in the Solar Corona observed by the TRACE satellite. *Right:* Configuration of the magnetic field in an emerging region, showing similar loops to those observed by TRACE. These results were obtained using near infrared spectropolarimetric data from the German VTT of the Observatorio del Teide.

on short and long time scales. We need to predict disturbances of the space environment which are induced by the Sun and to understand the links between the Solar output and the Earth's climate.

It recommends one main infrastructure as the means to achieve this goal:

A large-aperture (3-5 m) ground-based solar telescope with adaptive optics and integral-field spectropolarimeters, with a precision of one part in 104, to resolve scales of the order of10 km in the photosphere, to observe astrophysical processes at their intrinsic scales, and thereby observe the interaction of magnetic fields and plasma motions in the Solar atmosphere

The optical design and instruments of the EST is optimised for the observation of the coupling of the photosphere and the chromosphere. It will make possible to measure the thermal, dynamic and magnetic properties of the plasma over many scales heights using imaging, spectroscopic and spectropolarimetric instruments. The designs of the EST is focused on using a large number of instruments simultaneously so that light can be exploited more efficiently than at other current or future ground-based or space telescopes (Figure 11)

In order to meet its scientific goals the EST requires high spatial and temporal resolution. The aperture of a telescope essentially determines its resolving power but, until very recently, ground-based solar telescopes have been limited by wavefront distortion induced by the Earth's atmos-

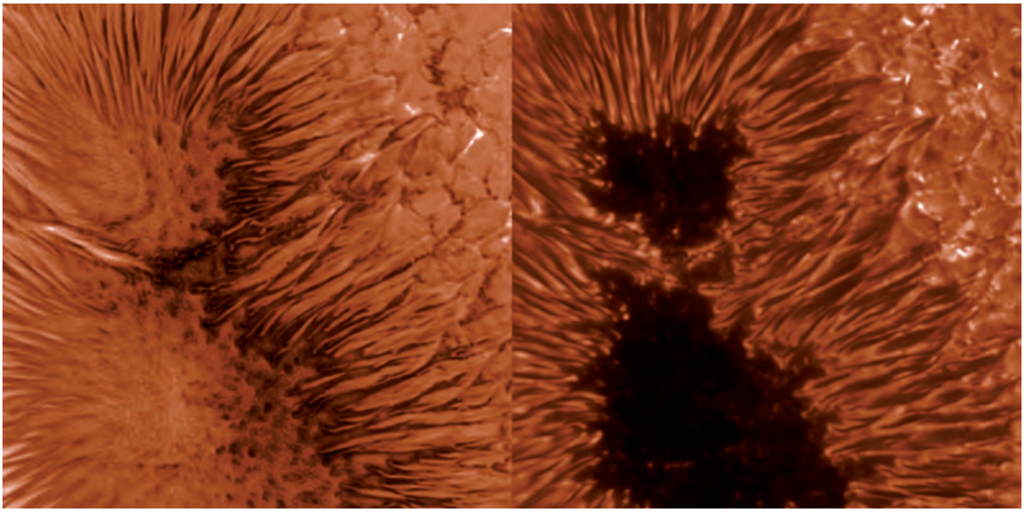


Figure 12. Sunspot observed by the SST, at the Observatorio del Roque de los Muchachos, in the blue and red wings of the Fe I magnetic line at 630.2 nm in September 2006. The image on the right shows the average intensity and the one on the left the difference between circular polarisation in the two wings. The spatial resolution of these images, which were obtained using 500 individual exposures, is due to the adaptive optics and restoration techniques used. The dark nuclei in the penumbra, discovered using the SST, are clearly visible in both intensity and polarisation (courtesy of Michiel van Noort, Institute for Solar Phsics).

phere. There now exist powerful adaptive optics techniques for correcting much of this distortion. By using them it has been possible to capture the first glimpses of the fine structure of the sun's surface, demonstrating that these correction techniques are sufficiently well developed for our observing capacity to be limited only by the telescope size and not by atmospheric distortion. We can now look for answers to the fundamental questions of the physics of solar activity and its variability.

In addition to spatial resolution, the light collecting power of a large aperture is crucial for solar research. Magnetic fields are detected by gauging the state of polarisation of light in specially chosen spectral lines. The fraction of the light that is polarised is very small (sometimes below 10^{-3}). The accuracy required of these measurements is mainly limited by the number of photons. With a large aperture, more photons can be detected from a given area on the solar surface, and this is vital for achieving the required accuracy for polarimetric measurements of one part in 10^4. The time scales determining changes in solar structures are related to the speed of sound (7 km/s), in such a way that smaller structures evolve more quickly. The temporal resolution required is just a few seconds, and this means the need for a large aperture telescope is greater.

The EST will fill a gap not covered by any other instrument, either ground-based or space mission, currently or in the immediate future: it will be able to examine the magnetic coupling of the solar atmosphere, from the deepest layers of the photosphere to the highest layers of the chromosphere, to reveal the thermal, dynamic and magnetic properties of the solar plasma at high spatial and temporal resolution (Figure 12). To do this, the EST is specialises to perform accurate polarimetry at many simultaneous wavelengths.

The Spanish solar physics community was a main contributor to the document *Spanish Science Vision of EST: Magnetic Coupling of the Solar Atmosphere*[9], a precursor for what subsequently became the EST Science Requirements Document[10].

In summary, the vision for Science with the EST is to observe simultaneously phenomena taking place at different heights in the solar atmosphere to understand how the magnetic field emerges through the solar surface, interacts with the dynamics of the plasma to transfer energy between the different regions before finally emitting it as heat or violent energetic events in the chromosphere and the solar corona. The following phenomena are of particular interest:

- Formation and disappearance of intense magnetic flow concentrations in the solar photosphere.
- Layers of current in the solar atmosphere.
- Emergence of small-scaled flow in the calm Sun.
- Magnetic cancellation in the calm Sun.
- Magnetic topology of the photosphere and chromosphere.
- Conversion of mechanical energy to magnetic in the photosphere.
- Structure of the chromosphere; dynamics and heat.
- Magnetic energy dissipation in the chromosphere.
- Physical processes in magnetised plasma (active regions, sunspots, prominences and so on).
- Solar flares and space meteorology.
- Atomic physics.

9 *Spanish Science Vision of EST: Magnetic Coupling of the Solar Atmosphere* (Annex A4).

10 *EST Science Requirements Document* (Annex A5).

4.
ASTROPHYSICS OBSERVATORIES IN THE CANARY ISLANDS

The excellent astronomical quality of the sky over the Canaries, which has been comprehensively characterised and is protected by Law, makes the two Observatories of the IAC an "astronomy reserve", which has been open to the international scientific community since 1979, as a result of the Agreements for Cooperation in Astrophysics[11] (BOE 6 July 1979 and BOE 14 October 1983).

Currently, the OT (Tenerife) and the ORM (La Palma) are home to telescopes and instruments belonging to some 60 institutions from 19 countries. The ORM and OT are the most important observatories for optical and infrared astrophysics within the territories of the European Union.

Institutions from many different countries operate at the Observatories and their activities are coordinated by the International Scientific Committee (CCI, Comité Científico Internacional). Available observation time at each installation is allocated by Time Allocation Committees (TAC). 75% of this time is generally allocated by the national Committee of the country or countries that own the telescope; 5% of time at all telescopes is allocated to large international teams and major observational projects; and the remaining 20% is allocated to Spanish researchers by Spain's TAC as the return earmarked for the host country under the Agreements for Cooperation in Astrophysics.

Both the ORM and the OT are excellent European sites for housing challenging new solar physics technology projects like the EST, which would be a strategic replacement for the current array of solar telescopes.

The observatories have been considered and are still considered by the EU as Large Research Infrastructures under the successive Framework Programmes for RTD. On a national level, the observatories are also considered Singular Scientific and Technological Infrastructures (ICTS) alongside some fifty installations for other scientific disciplines across Spanish territory. Together they form the ICTS map, a vital resource for improving and increasing the competitiveness of science, technology and innovation in Spain. The ICTS are all unique in their field and extremely costly to build and maintain. They are designed to deliver progress in experimental science and technological development, and they also stimulate business and the local economy in the areas where they are located.

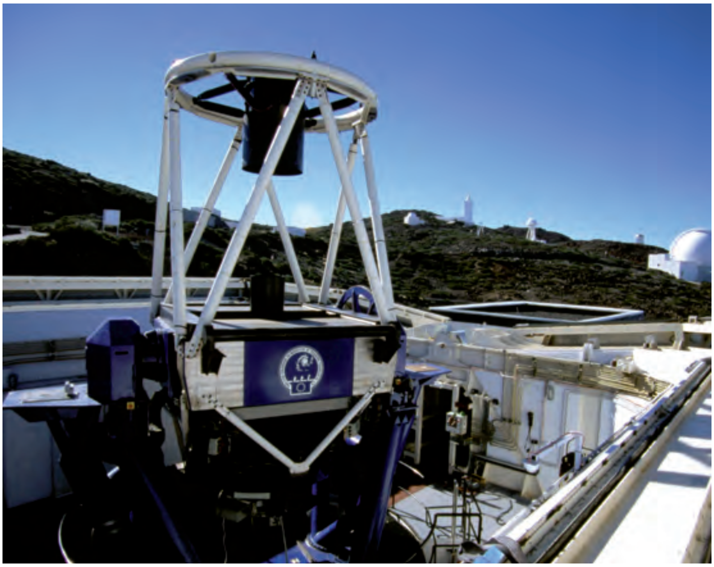
4.1. THE ROQUE DE LOS MUCHACHOS OBSERVATORY – ORM

The Roque de los Muchachos Observatory (ORM)[12] is situated in Garafía, at an altitude of 2,396 metres on the island of La Palma. It covers a surface area of 189 hectares, home to its "telescopic installations" (specialised observation instruments owned by one or a number of scientific institutions) together with other infrastructures and user services.

The most noteworthy of all the installations at the ORM is the GTC, a highly-equipped

11 *Agreement for Cooperation in Astrophysics* (Annex A6).

12 http://www.iac.es/eno/orm

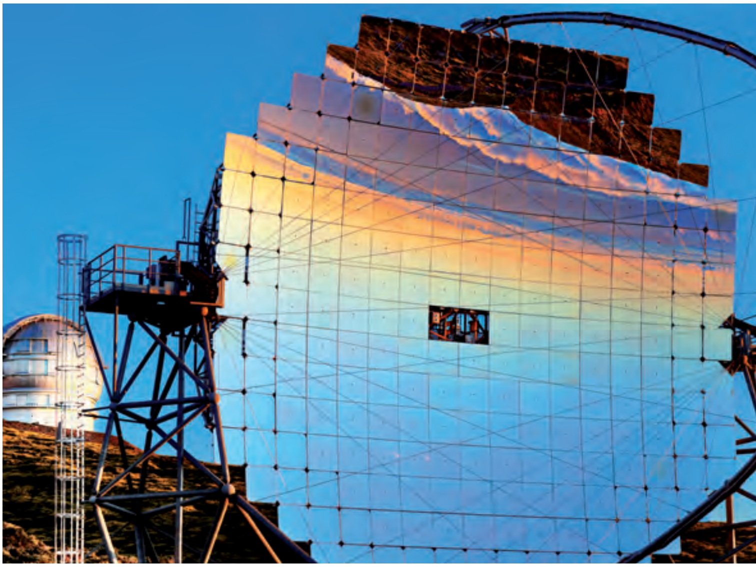


telescope with a 10.4 metre segmented primary mirror, which entered service in 2009. The GTC project is a Spanish initiative, led by the IAC with support from the Spanish national and regional governments, in collaboration with Mexico, through its IA-UNAM (Astronomy Institute of the National Autonomous University of Mexico) and INAOE (National Institute of Astrophysics, Optics and Electronics), and the United States through the University of Florida.

The "William Herschel" Telescopio (WHT), is another remarkable ORM installation, with a 4.2 m primary mirror. Its large diameter, advanced instruments and location make it one of the world's leading telescopes. Numerous discoveries have been made with the WHT including, for the first time, confirmation of the existence of a black hole in our galaxy.

The WHT belongs to the "Isaac Newton Group of Telescopes". This group, which is comprised of science organisations in the United Kingdom, Netherlands, Ireland and, through the IAC, Spain, also includes the 2.5 m "Isaac Newton" Telescope (INT). It was with this telescope that, in 1991, the brightest object hitherto known in the Universe was discovered, a quasar 12,000 million light years from the earth that is 100,000 billion times brighter than the Sun.

This Observatory is as perfect for night observation as it is for solar physics. The proof of this is the quality of the high-resolution images of the Sun obtained with the SST, a 1 m telescope owned by the Royal Swedish Academy of Sciences. Together with Norway, Finland and Denmark, Sweden is a member of the NOT Foundation, which built the *NOT*, which has a 2.56 m primary mirror and can produce very clear astronomical images. The NOT can be used for a range of different observation programmes in both the visible and infrared spectral ranges. One example is the study of rapid variation in cataclysmic stars and certain types of white



dwarfs in the visible range. In terms of infrared capacity, NOT's infrared spectrograph can be used to view everything from nearby stars to distant galaxies. It is an ideal instrument for investigating the central regions of our galaxy, which are hidden by clouds of interstellar dust, and also star-forming regions.

The DOT is also a solar telescope. Its design is innovative, incorporating high angular resolution and the ability to observe at night. It consists of an open 15 m high tower with a 45 cm aperture telescope at the top. Its open structure (it has no dome to house the telescope while operating) allows air to flow freely, keeping the air around at the same temperature and so guaranteeing the best possible image quality. This telescope belongs to the University of Utrecht (Netherlands) and was funded by the Dutch Technology Foundation.

The ORM is also home to the Automatic Transit Circle (ATC), which was operated jointly by the Observatory of the University of Copenhagen (Denmark) and the San Fernando Royal Naval Institute and Observatory (San Fernando, Càdiz, Spain) until 2006 when it became the exclusive responsibility of the IAC in 2006. This transit telescope, which is designed to plot the position of celestial objects very precisely, is the most efficient in the world (over 100,000 star transits through the meridian per year). It played a decisive role in the Voyager probe's encounters with the planet Uranus, Giotto's visit to Halley's comet, Galileo's journey to Jupiter and others, and observed star positions for the data catalogue of the Hipparcos astrometric satellite. In 1994 a pilot collaboration project between this telescope and the Space Telescope Science Institute, in Baltimore (STScI, United States) began, with the aim of establishing a dense network of guide stars for reducing data from Schmidt plates, which form the basis of the Hubble Space Telescope Guide Star Catalogue (GSC)

and thus establishing the plates' accuracy limitations.

Italy also has the Telescopio Nazionale Galileo (TNG) at the ORM, a 3.58 m telescope which entered service in June 1996. It is one of the "new technology" telescopes, which can produce higher quality images than conventional telescopes. Designed to observe the night sky, it is fitted with the best optical, computer and engineering equipment. It has an azimuth mount and Ritchey-Chrétien type optical configuration, with two lateral Nasmyth-type foci. Its optics have active control systems for the best optical quality, making the TNG a cutting edge telescope. It belongs to Italy's Consiglio per le Ricerche Astronomiche (CRA) and was built by the Astronomical Observatory of Padua (Italy).

The ORM is also home to Liverpool Telescope (LT) belonging to the Liverpool John Moores University. It is the world's largest robotic telescope, with a 2 m primary mirror. It is operated by remote control and is also used for school science outreach.

The ORM also houses two Cherenkov telescopes, MAGIC I and MAGIC II, which are the result of a joint project between universities and research institutes on high energy gamma ray and cosmic ray observations. MAGIC II, which is some 85 metres away from MAGIC I, can increase the sensitivity of the first telescope by up to three times when operated together with it.

MERCATOR (Catholic University of Louvain, Belgium) is a telescope with a 1.2 m primary mirror, which is mainly designed for projects that require a large number of night observations, such as astroseismology, or flexible time assignation, which is particularly useful for phenomena like supernova explosions.

Completing the line-up of facilities at the ORM is SUPERWASP, a small robotic telescope used for seeking planets.

This line-up confirms that the ORM is an observatory with wide-ranging international experience, which is equipped with all the essential infrastructures (roads, electricity, telecommunications, etc.) needed for successful logistics of the institutions that

it houses. The infrastructure available also includes the ORM Residence, with a range of facilities (day and night rooms, kitchen and dining room, reception, guest and games rooms) for use by all scientific and technical personnel at the Observatory.

4.2. THE TEIDE OBSERVATORY - OT

The OT is at an altitude of 2,400 m in the Izaña region of the island of Tenerife. It covers a surface area of 50 hectares and houses around fifteen telescope installations and other specialised observation instruments (Figure 13).

Astrophysics in the Canary Islands began in the early 1960s at this Observatory, which is at the juncture of La Orotova, Fasnia and Güímar municipal areas. The first telescope designed to work with zodiacal light, light dispersed by interplanetary material, opened in 1964.

The Teide Observatory's geographical position, together with the transparency and excellent astronomical quality of its sky, mean that it is generally reserved for work on the Sun and is home to the best European solar telescopes.

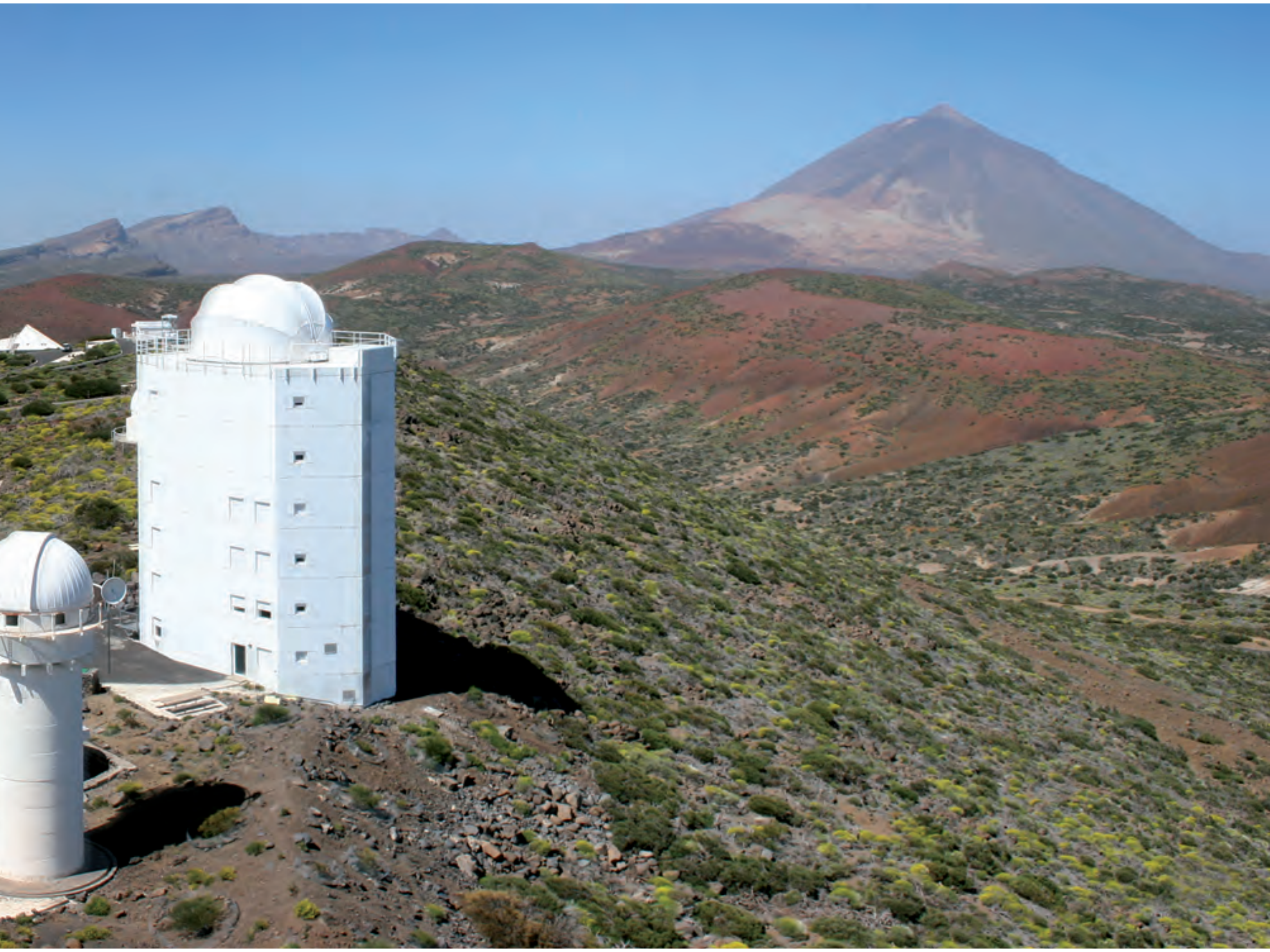
One of the most emblematic telescopes at the Teide Observatory is the VTT, a conventional solar telescope based on the celostat (two-mirror) system, which focuses light into the telescope from the top of the tower and reflects it through all of its 10

Figure 13. Observatorio del Teide (OT)

floors. Its primary mirror is 70 cm in diameter and it has a focal length of 46 m. The VTT has several optical laboratories equipped for every type of optical mount. Some of these use permanent systems but there is always room for temporary specialised instruments when they are needed for new tasks.

The VTT is equipped with a variety of instruments for taking high quality readings from plasma flows and magnetic fields. Some of the instruments can work together to observe different parts of the solar spectrum simultaneously, from the near infrared to the near ultraviolet. This is a unique feature in a solar telescope and allows three-dimensional studies of the of the Sun's atmosphere.

Another solar telescope of worldwide importance, a joint experiment by the national research agencies of France (CNRS/INSU) and Italy (INAF) is THEMIS. It is a solar telescope with a useful aperture of 90 cm, currently the world's fourth largest. THEMIS stands



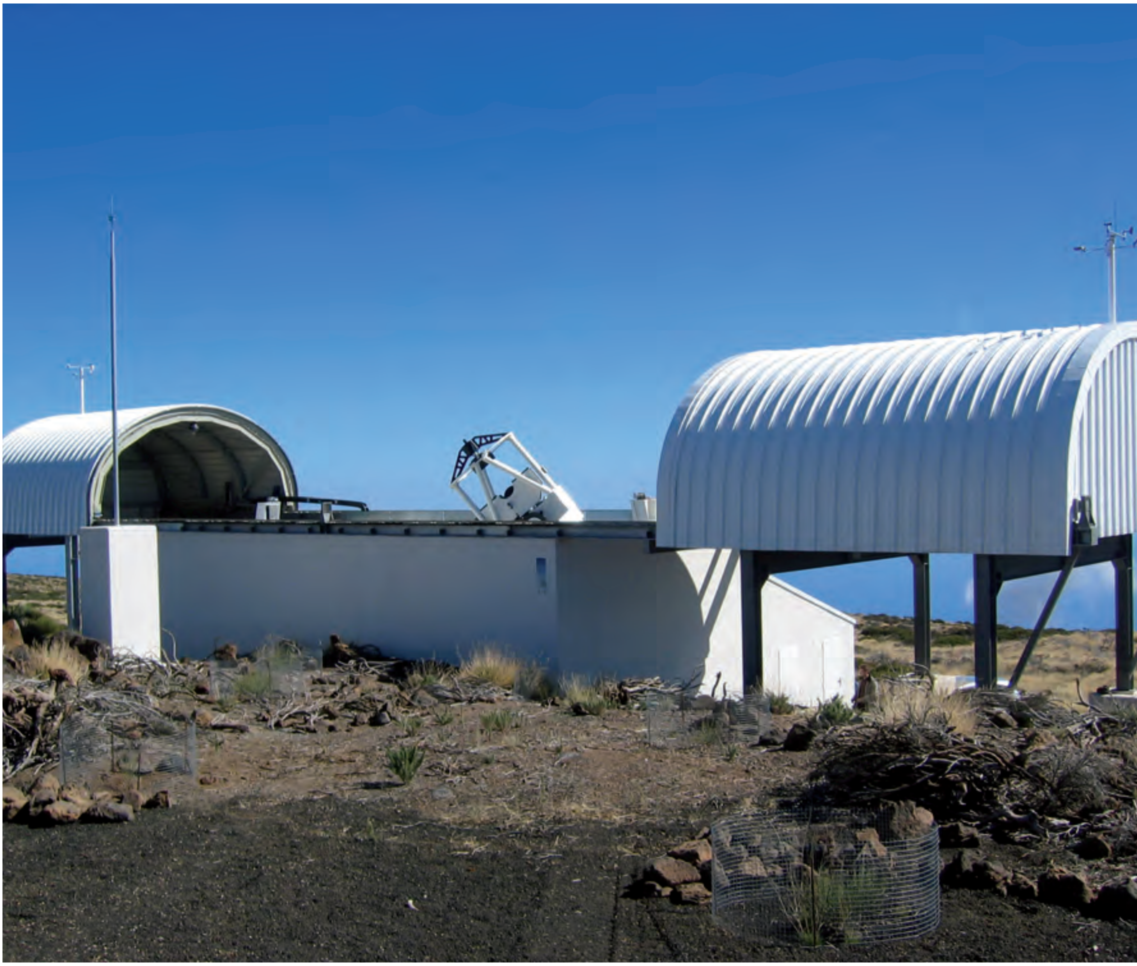
for "Télescope Héliographique pour l'Etude du Magnétisme et des Instabilités Solaires". It is designed specifically for high accuracy spectropolarimetry of the sun's surface. It is capable of measuring simultaneously the 4 Stokes parameters which measure light polarization.

GREGOR is a new 1.5 m solar telescope currently being built at the Teide Observatory in Tenerife. It is largely the work of a German consortium made up of the Astrophysikalisches Institut Potsdam, the Kiepenheuer-Institut für Sonnenphysik, the Universitäts-Sternwarte Göttingen and other national and international partners. GREGOR is designed to take highly accurate readings from the magnetic field and the movement of gas in the solar photosphere and chromosphere, resolving details of up to 70 km on the surface of the Sun, and for high-resolution stellar spectroscopy. Its inauguration is anticipated for 2012.

The Solar Laboratory, property of the IAC, is a special installation as its six component experiments (instruments) operate continuously (every day and, for some instruments, non-stop for the last 25 years) day and night. Although the owners of the different instruments are from scientific institutions outside the IAC, the IAC's "Solar and Stellar Seismology and Exoplanet Search" research group operates them and uses them for scientific work via the international consortia set up to coordinate activities at the telescope.

The **Telescopio Carlos Sánchez** (TCS) has a 1.52 m primary mirror. The TCS was designed and built under the supervision of Prof. J. Ring (ICSTM), working with other groups from the United Kingdom and the IAC. In operation since 1972, this telescope is designed for infrared night observations.

Surprisingly, in spite of its low cost, it has been one of the world's largest and most productive infrared telescopes. The TCS has also acted as a pilot to gain the experience necessary to build large telescopes.



The IAC-80 was designed and built entirely by the IAC and was the first of this class of telescope to be developed in Spain. The IAC began work on it in 1980 and it was permanently installed at the OT in 1991.

Amongst its most remarkable achievements are the discovery of Teide 1, the first brown dwarf ever discovered; a ten year observation of a gravitational lens, which yielded information about dark matter in the universe; and images of the celestial body responsible for a violent gamma ray explosion, one of the most intense energy explosions in the universe.

The Optical Ground Station (OGS) was built as part of the European Space Agency's (ESA) strategic plans for research in the field of inter-satellite optical communications. The original task for this mission, which was equipped with a 1 metre telescope, is to perform in-orbit tests of laser telecommunication terminals on board satellites in low Earth and geostationary orbits. Since 2001, the ESA survey of Space Debris in the Geosta-

tionary Orbit and the Geostationary Transfer Orbit is also being carried out with a devoted wide field camera attached to the Ritchey-Chretien focus. Furthermore, approximately a third of the observing time is used for basic astronomical research from ESA and IAC science teams with dedicated instruments either in the coudé or in the Ritchey-Chretien foci

The OT also houses several robot telescopes like the United Kingdom's Bradford Robotic Telescope (BRT) (with four tubes from wide field to deep sky); STELLA, a long-term project for observing and monitoring cold star activity with two robot telescopes; and the Optical Telescope Array (OTA), which has two automatic domes with a meteorological station, two Schmidt Cassegrain reflecting telescopes, two robot telescope mounts and an "All Sky" camera. This last telescope is the product of an agreement between the IAC and the Society of the Telescope (ST) of Delaware in the United States, on behalf of Telescope Time, Inc., for remote-control optical telescopes at the Teide Observatory for education and public outreach.

MONS, a 50 cm diameter reflecting telescope, which students from any university can use for practise, is also open to amateur astronomers.

Since 1984 the OT has been the location for numerous experiments for measuring cosmic microwave background radiation (CMB) and determining its angular potential spectrum at scales ranging from just a few degrees to several arc minutes. Of the most recent experiments, the most noteworthy are:

- The VSA (*Very Small Array*) experiment: A joint project by the Cavendish Laboratory (University of Cambridge, United Kingdom), the "Jodrell Bank Centre for Astrophysics" of the University of Manchester, and the IAC. It was installed in 1999 and began operating in October 2000. The observing technique used in the VSA experiment consists of arranging antennae as an interferometric group, a method pioneered by the Cambridge astronomers. The group measures the CMB signal, which is extremely weak and identical for all of the receiving antennae.
- The COSMOSOMAS experiment: This experiment was designed and built entirely at the IAC and commenced in 1998. It consists of two similar instruments,

COSMO11 and COSMO15, thought out for producing intermediate angular scale maps of cosmological structures and of diffuse emission in our galaxy.

In 2012 the **QUIJOTE CMB *(Q-U-I JOint TEnerife CMB experiment)*** will begin operating; it is a joint project by the IAC, the Instituto de Física de Cantabria (Santander, Spain), the Department of Communications Engineering (Santander, Spain), the Jodrell Bank Centre for Astrophysics (University of Manchester, United Kingdom), the *Cavendish Laboratory* (University of Cambridge, United Kingdom), and the IDOM company (Spain). It will consist of two similar antennae that will be used to measure microwave polarization in the sky at a range of frequencies including 11 GHz to 30 GHz and at angular scales of 1°.

In 2008 a telescope was installed at the Observatory for the future EARTHSHINE network, whose main mission will be to determine the global albedo completely calibrated from the earth and to characterise its annual variability.

5. ASSESSMENT FACTORS

5.1. ATMOSPHERIC CHARACTERISATION

Access to the best possible scientific quality for observations is the factor that ultimately decides the site for important installations like the EST. Given this, it is evident that the quality of the sky in the Canary Islands puts the Roque de los Muchachos Observatory on the island of La Palma, and the Teide Observatory in Tenerife, at the forefront of the world's leading observatories. The excellent conditions at these Observatories result from the Canary Islands' geographical location and their orography, the continuous characterisation of their skies and the measures in place to protect sky quality.

The astronomical quality of an observatory is largely determined by the **transparency** of the sky above it and the number of useful observation hours it offers each year (**useful time**). These two parameters are intimately bound up with the site's climate and geography.

The Canary Islands have excellent conditions for astronomy for the following reasons:

- They are close to the equator and out of the range of tropical storms.
- The Observatories are at an altitude of 2,400 m above sea level, over the thermal inversion layer of the Trade Winds (they form at about 1,000 m). This ensures that the installations are above what is known as the "sea of clouds", where the atmosphere is normally clear, clean and free from turbulence as a result of the stability provided by the nearby sea.

The quality of the sky over the Canaries has long been recognised. As far back as 1856 the Royal Scottish Astronomical Society performed a series of experiments at mountaintops on the island of Tenerife which led them to conclude that the sky over the Canary Islands was excellent for astronomical observations (Tenerife: *An Astronomer's Experiment, Piazzi Smyth, 1858*).

In 1968 a number of European institutions worked together on a joint campaign to gather data for characterising a number of sites for solar observation. They compared 40 different sites and ultimately concluded that the best conditions were to be found in Tenerife and La Palma (*Vistas in Astronomy, 28, 437, 1985*).

In 1979 Spain signed the "Agreement and Protocol for Cooperation in Astrophysics" with several other European countries, which led to the creation of the Teide and Roque de los Muchachos Observatories.

In 1988 Law 31/1988, commonly known as the "Sky Law" was published, with the aim of creating an "Astronomy reserve" on the islands by protecting the darkness of the sky, limiting radio frequency emissions and controlling light pollution.

Since 1990 the IAC has operated the "Sky Quality Group", whose mission is to continuously characterise the observatories, using instruments and techniques to gather data for a long-term database that can be contrasted and compared with other high level observatories. The *Site Properties Sub-Committee* (SUCOSIP) was created at the same time, under the auspices of the International Science Committee, to advise on the adequate installation of infrastructures at the Observatories. Its main purpose is to ensure that no new installation has an adverse effect on observing conditions for existing telescopes.

CHARACTERIZATION PARAMETERS AT THE CANARY ISLANDS' ASTRONOMICAL OBSERVATORIES

Among the most relevant characterisation parameters for daytime observation at the observatories, are image quality, sky transparency and useful observation time[13]. Each of these parameters is discussed in more detail below:

13 Another relevant parameter in characterising sites for astronomical observation is the "sky background." However this parameter, which defines the magnitude limit for night observations at any given wavelength is not specially relevant to solar telescopes.

Table 3. Daytime seeing values at the ORM

Number of hours/year with $r_0 > 7$ cm	
Height above ground level[14]	Number of hours with $r_0 > 7$ cm
8 metres	311
18 metres	632
28 metres	887
38 metres	1093

Number of hours/year with $r_0 > 12$ cm	
Height above ground level[15]	Number of hours with $r_0 > 12$ cm
8 metres	54
18 metres	136
28 metres	225
38 metres	324

Table 4. Night seeing at the ORM

Nº hours (per year)	Seeing value
648,8	< 0,45" (first quartile)
1297,6	< 0,64" (second quartile)
1946,4	< 0,90" (third quartile)

Image quality

Image quality is limited by atmospheric turbulence and its integrated measurement is defined as the typical size of a point source in the focus of an ideal telescope; this is known as *seeing*.

Seeing is a key parameter for evaluating the atmospheric quality of an observatory and especially for obtaining the best results from very modern technology like adaptive optics. It is in this area, image quality in day- and night-time observations, where the Canary Islands' Observatories excel. This can be seen from the high spatial resolution images achieved by its telescopes.

14 r_0 is the Fried parameter used to measure turbulence in the atmosphere over the observatory; a minimum of 7 cm is needed for the AO/MCAO to operate.

15 $r_0 > 12$ cm indicates periods of excellent *seeing*.

At the Canary Islands Observatories, the number of hours of a particular seeing per year is very well known, as it is based on statistics from over decades. This allows a very optimised observing planning for Flexible Scheduling, the model increasingly being used for large telescopes.

Seeing values for daytime observations were documented during the site-testing campaign for the ATST telescope at the ORM and are given in table 3.

Sky transparency

The transparency of the sky is measured using an astronomical parameter known as "atmospheric extinction" (Figure 14). Extinction is the process of absorption and dispersion of light in the Eartho's atmosphere and is classified according to its extinction coefficient. The main causes of loss of transparency in the sky are clouds and aerosols (including dust).

Most of the masses of air flowing into the Canaries archipelago come from the North Atlantic. They are marine aerosols, in other words, ultraviolet absorbent chlorides, which do not affect visible-infrared astronomical observations. A second group is anthropogenic in origin and of little significance. A third group is made up of masses of air from the Sahara, which normally contain airbor-

Figure 14. An impressive example of the transparency of the Canary Islands' sky. n this photograph, taken from the ORM (La Palma) in the evening, Mount Teide (Tenerife), 143 km away and the highest peak in Spain, can be seen clearly together with the National Park that it stands in.

ne dust. This phenomenon, known as the calima, affects the eastern and western islands differently, causing drainage at high levels and showing considerable seasonal variation: there are noticeable differences between the summer influxes, which can reach the summits (high calima) and the winter ones which frequently affect the low troposphere (anticyclonic calima).

The anticyclonic calima is associated with strong anticyclonic and stationary conditions caused by the build up of dust between the ground and the thermal inversion layer. The calima helps to lower the inversion layer and dust retention by the sea of clouds (sea of dust) and very often preventing it from reaching the summits where it could affect astronomical observations. Characterising these features of the climate and orography in the Canaries requires very high spatial resolution satellite data combined with site readings.

Measuring atmospheric extinction (astronomical techniques)

The traditional method consists of calculating the loss of light at a telescope focus. The Canaries has the most comprehensive atmospheric extinction database, obtained by the ATC telescope (previously called Carlsberg) at the ORM on the island of La Palma, which has been operating automatically and continuously since 1984. The median extinction coefficient value for photometric nights is 0.19 mag (at 480 nm), 0.09 mag (at 625 nm) and 0.05 mag (at 767 nm).

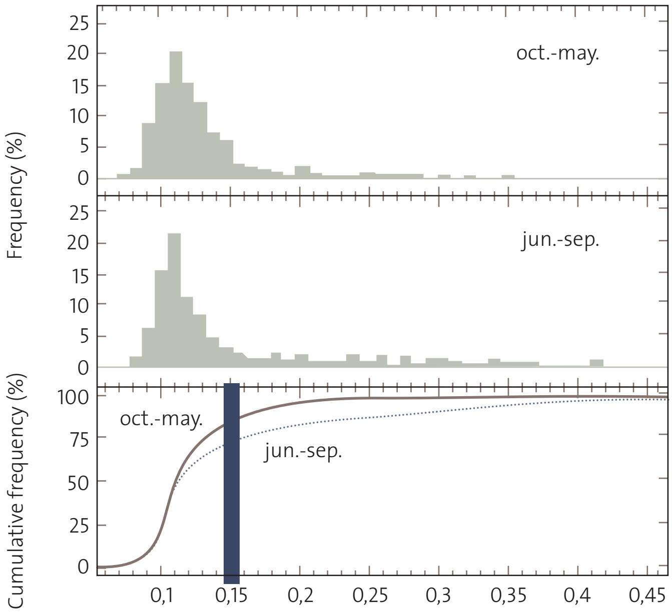


Figure 15. Extinction frequency over the ORM in winter (above) and summer (centre). In both cases the modal value is 0.11 mag/air mass. The corresponding cumulative frequency is also shown (below). The vertical line indicates the limit from which dust can arise (K_V=0,153).

The lower part of the graphic shows that 90% of time during the winter months is dust-free. For the summer months the percentage is around 75%.

The ATC telescope can also be used on nights with aerosols (Saharan dust) to estimate the effect of dust on atmospheric extinction. The results are given in figure 15 for winter (above) and summer (centre).

Useful time

The quality of an observatory is clearly dependent on the number of useful hours it provides each year. Useful observation time is the amount of time during which observations can be undertaken without the restrictions imposed by adverse weather conditions. The definition of "adverse conditions" varies from one telescope to another but, in general, the criteria include: wind speed, humidity and aerosols in the atmosphere and snow or ice.

The ORM for example, is estimated to deliver an average of 3,197 hours of useful observation time per year for solar telescopes, with the amount of time that observation is restricted by adverse atmospheric conditions at around 20%.

Implementation of Adaptive Optics techniques; important parameters

New generation telescopes need to use Adaptive Optics techniques (AO) to improve image quality and attempt to bring it up to the telescope's diffraction limit. Turbulence in the atmosphere degrades the image, breaking the image produced at the focus up into speckles and causing detail in the structures that can be observed on the Sun's surface to be lost. This speckling (*seeing*) is measured using the Fried parameter r_0, which gives the size of the largest telescope that does not "see" atmospheric turbulence.

Starting from defined reasonable seeing conditions (around 2 arc seconds, or a Fried

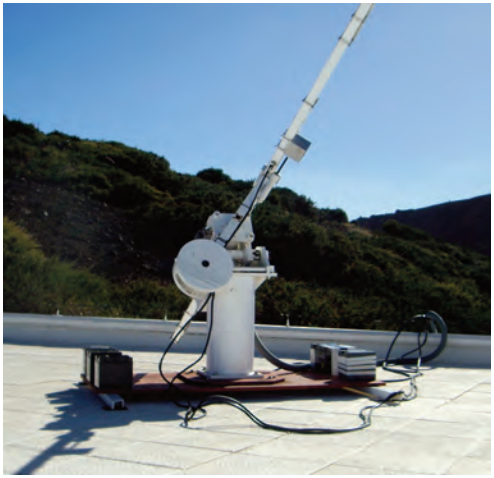



Figure 16. The SHABAR instruments installed at the ORM and OT respectively.

parameter of 7 cm) techniques can be used to correct the distortion that the atmosphere causes to incident wave fronts. Atmospheric turbulence is caused by a range of different phenomena and, based on them, the atmosphere is usually separated into layers: the superficial layer (SL), the bound layer (BL) and the free atmosphere (FA). The free atmosphere, which starts approximately one kilometre above the ground, is affected by global effects such as shearing caused by vertical gradients in wind speed. The bound layer is continuously interacting with the ground, local orography and phenomena; it is typically located less than 1 km above the ground. Inside it is another much thinner layer which makes surface contact with the ground and is directly affected by day/night temperature fluctuations; it relies almost exclusively on the thermal stability of the site and the properties of the ground (thermal inertia – conductivity).

During the sky characterisation campaign for the EST several SHABAR (*Shadow Band Ranger*, Figure 16) were designed with half and three metre arm. This instrument measures the degree to which the Sun's light sparkles, as a result of atmospheric turbulence, at different heights above ground level. Two of these long SHABARS are routinely employed on solar campaigns at the ORM and OT.

5.2. SKY PROTECTION IN THE CANARY ISLANDS

The Spanish Government, at the request of the Canary Islands Parliament, passed the Law for the Protection of the Astronomical Quality of the IAC Observatories (Law 31/88)[16] on the 31st October 1988, and on the 13th March 1992 the Regulations enforcing it (R.D. 243/1992)[17].

16 *Law 31/1988 of 31st October, for Protection of the Astronomical Quality of the Observatories of the IAC* (Annex A7).

17 *ROYAL DECREE 243/1992, of 13th March, giving approval to the Regulations of Law 31/1988, of 31st October, on protection of the astronomical quality of the Observatories of the IAC* (Annex A8).

The Law contains a range of measures designed to assure the outstanding quality of the observatories of the Instituto de Astrofísica de Canarias, as recommended by the International Astronomical Union.

Light pollution is a generic term used to describe all of the undesirable effects of artificial light. One of the most damaging effects for astronomy is the glow or glare of light in the night sky. It is caused by artificial light reflecting on and being diffused by particles of gas and air. It generally results from poorly designed streetlights, which shine light directly towards the sky or outside the area requiring illumination, and also by excessive illumination.

Any lighting installation within the area covered by the Sky Law must comply with some basic standards:

1. Outdoor lighting must not shine above the horizon and must use lamps that produce the least possible disruption to astronomical observations.
2. The spectral profile of the light emitted by outdoor lighting will be in such a way that the global radiance for all wavelengths under 440 nm will be lower than 15% of the total radiance.
3. Only sodium vapour lights may be used for road lighting. Colour corrected mercury vapour and metallic halogen lights are prohibited.
4. Any type of lamp can be used for ornamental lighting on public buildings and at sports and recreation facilities, but they must be turned off after midnight.
5. Low pressure discharge lamps and incandescent lighting can only be used for advertising if they are turned off after midnight. Projectors and lasers may not be used for advertising, or recreational or cultural activities.
6. Finally, a total luminous flux limit is in force in certain areas of the island of La Palma.

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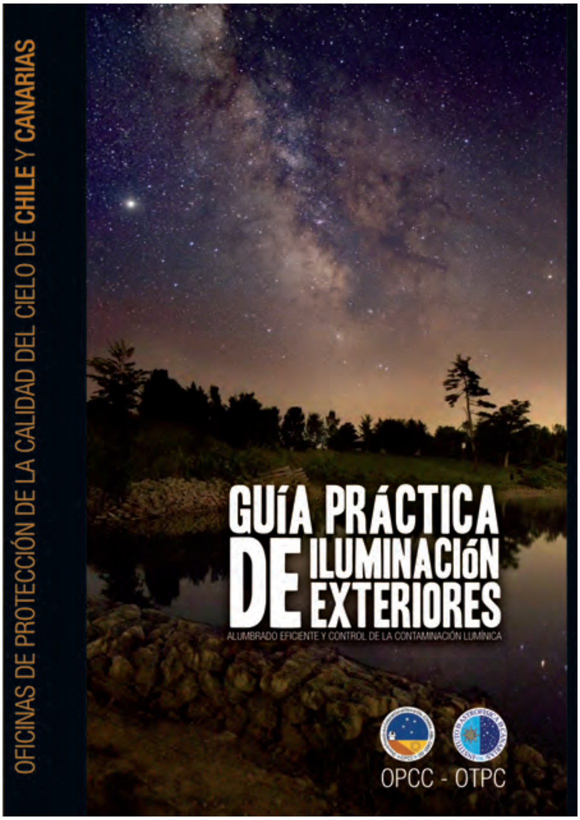
Radio electrical pollution includes electromagnetic radiation emissions. The law also sets down limits for electromagnetic radiation to prevent interference with equipment and readings at the astronomical observatories.

A power flow density limit has also been set, calculated from the EIRP (equivalent isotropically radiated power) in the direction of the observatories, to ensure that levels within them are never higher than 2x10-6 W/m^2 for each frequency, equivalent to an electric field with an intensity of 88,8 dB μ V/m.



The combined effect of multiple interference produced by radio-communication stations has also been taken into account, using the quadratic sum method defined by the International Radio Consultative Committee.

In order to control radio electrical pollution, an agreement has been reached with the General Telecommunications Secretariat for periodic readings of the radio frequency background to be taken at both observatories.

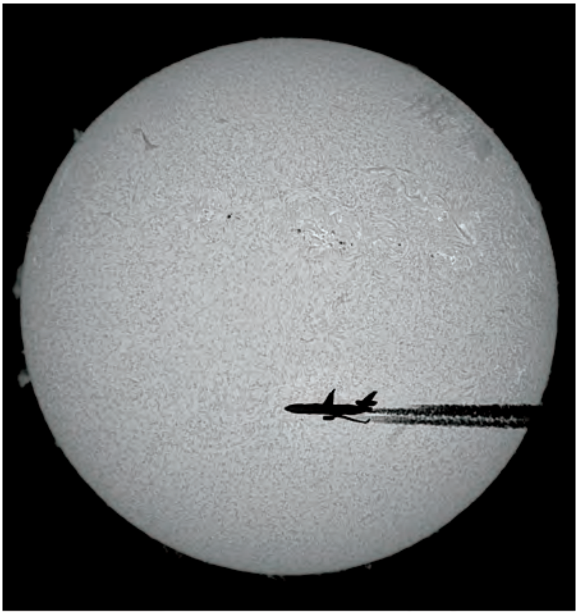
Atmospheric pollution is one of the fastest growing environmental problems. Gases released into the atmosphere as a result of human activity produce noxious effects on atmospheric patterns, with consequences for the health of people, animals and plants. Deterioration in the quality of the atmosphere brings with it deterioration in astronomical observations.

The Sky Law imposes controls on activities that could damage the atmosphere in the area surrounding the observatories. No industry, activity or service that could cause atmospheric pollution is permitted to operate above an altitude of 1,500 metres.

As the area surrounding the observatories abuts a National Park it is governed by environmental regulations and so has a higher level of protection than normal (in the same way as natural protected spaces and national parks).

Aviation routes can cause interference and impact on sky transparency. The interference is in the form of clouds created by the condensation of aeroplane exhaust and combustion gases.

One of the IAC's major achievements in its endeavours to protect the observatories



potential sources of pollution are in force across the whole island.

To support the application of the law and to preserve the astronomical quality of the Canary Islands' Observatories, the IAC created the Sky Quality Protection Technical Office (OTPC) in 1992[18].

The OTPC's work has served as an example for other similar offices. Lastly it should be remembered that the island of La Palma is, in its entirety, a UNESCO (United Nations Educational, Scientific and Cultural Organization) biosphere reserve, a denomination awarded on the 6th November 2002.

was the declaration, on 17th May 1998, of an "Ecological Protection Zone" covering airspace over the observatories.

Aeroplanes must fly outside 10 degrees above the horizon as seen from the observatories and must not fly within 5 km of them horizontally. The area with effective protection is defined in AIP España reference ENR 5.6-6 of the 17th May 1998 with the identification F11-IZAÑA and F12-ROQUE DE LOS MUCHACHOS.

The area where this national law is in application includes the whole of La Palma. Lighting restrictions in Tenerife are in force across three quarters of the island (to protect the ORM) and restrictions on all other

5.3. GEOLOGICAL RISK

The Canary Islands' astronomical observatories, at Roque de Los Muchachos on La Palma and Teide on Tenerife, are in geologically active areas, particularly with regard to volcanoes. The last volcanic eruptions were in 1971 on La Palma, and 1909 on Tenerife. The orography sculpted by this geological activity is, in large part, responsible for the excellent local atmospheric conditions.

Large day and night telescopes (specifically solar telescopes), whether existing or

18 *IAC. Protecting the sky over the Canaries. Sky Quality Protection Technical Office* (Annex A9).

planned (30 and 50 metre class night observation telescopes and 4 metre solar telescopes) must be designed to not only withstand seismic and/or volcanic activity but also to minimise operating time lost to the mechanical and optical misalignment it can cause.

Seismic and volcanic activity poses a range of risks to an astronomy observatory but for the purposes of this report only those that pose a direct threat to telescopes, like seismic risk, lava inundation, volcanic ash and geological changes in the landscape, are considered.

A risk assessment methodology has been developed for observatories, based on the probability of an event occurring in the forthcoming 50 years, the anticipated lifespan of a new telescope or solar tower.

The figures and tables below give verified, comparable data for the two observatories. The tables use the most recent available information, which has been verified with the help of leading national groups in the field of geological risk. This atmosphere of collaboration has been very productive and has provided confirmation of the reliability of the results.

In 2010 a detailed seismic risk assessment was carried out at the ORM/OT[19]. The study was undertaken on the recommendation of the *Global Seismic Hazard Assessment Program* (GSHAP)[20], which employs a probability method which uses data about past seismic, tectonic, geological and volcanic activity to define the statistical laws that regulate seismic phenomena in an area. Results from the GSHAP give the peak ground acceleration (PGA) rate and the probability of it increasing by 10% in the next 50 years. Data for the Canaries were interpreted by González de Vallejo et al. (2006) and the results are shown in figure 17 and table 5.

Lava flow risk is the probability of an area being affected by lava flow following volcanic activity. For all volcanic risk, the research team liaised with the Alicia Felpeto group at the CSIC Natural Science Museum in Madrid, to map the areas susceptible to basaltic eruptions (mafics) and more explosive eruptions (felsics) on the island of Tenerife. The resulting maps are reproduced in figure 18 and show the areas with the greatest risk of volcanic activity. In La Palma, it is the extreme south of the island (the Cumbre Vieja volcano) that could erupt. The probability of lava invasion is given in figure 19 and shows that the risk at the Roque de los Muchachos Observatory is negligible as the last eruption in the area took place over 400,000 years ago.

Ash risk is the risk of an area being covered in ash from volcanic activity nearby. Ash fall is determined by the direction and strength of the wind and the explosiveness of the volcano, measured using the Volcanic Ex-

19 Geological Hazards at the Astrophysical Observatories of Roque de los Muchachos and Teide, Canary Islands, Spain (Annex A10).

20 Website: http://www.seismo.ethz.ch/GSHAP/global/.

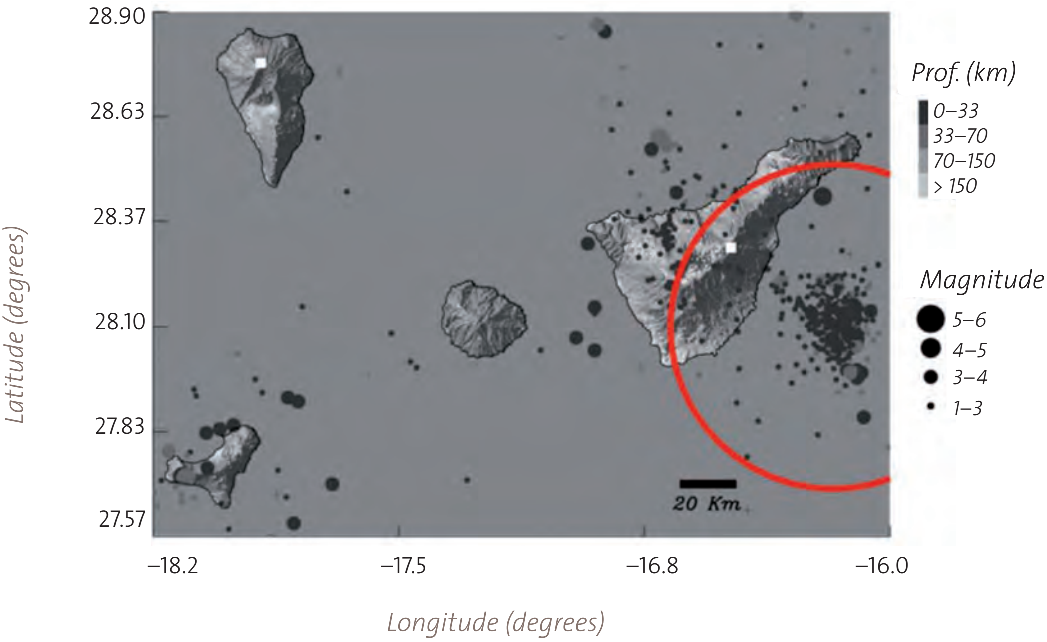


Figure 17. Distribution of seismic activity in the western Canary Islands from 1973 to 2010 obtained by the NEIC (US GEOLOGICAL SURVEY (USGS) HTTP://NEIC.USGS.GOV). The depth and magnitude of earthquakes are shown as circles in different shades of grey and of different sizes, respectively. The red circle contains the area where the probable seismic risk is PGA=0.06g; for the remainder the PGA=0.05g, where PGA refers to the maximum peak ground acceleration rate.

Table 5. **Approximate estimate of magnitude with a 10% probability of being exceeded in the next 50 years within 100 km around the observatories. Data based on the results shown in Figure 17**

Observatory	*Peak Ground Acceleration* (PGA)	Anticipated magnitude at 100 km (Richter scale)
La Palma	0.5 m/s²	5.80
Tenerife	0.6 m/s²	6.00

plosivity Index (VEI), which gives values between VEI=2 for a small scale basaltic eruption to VEI=4 for a sub-plinian eruption (Figure 20). The risk at the ORM is negligible due to the fact that the prevailing winds blow East, rather than North, and the fact that a VEI=3 has never occurred in La Palma. On Tenerife risk is not negligible, largely because the frequency of large explosive eruptions is unknown.

Risk of changes in the ground looks at inclines that could appear in the ground at the observatories if volcanoes became active, which would affect the alignment of mechanical and optical components, pointing and tracking systems in telescopes. The risk

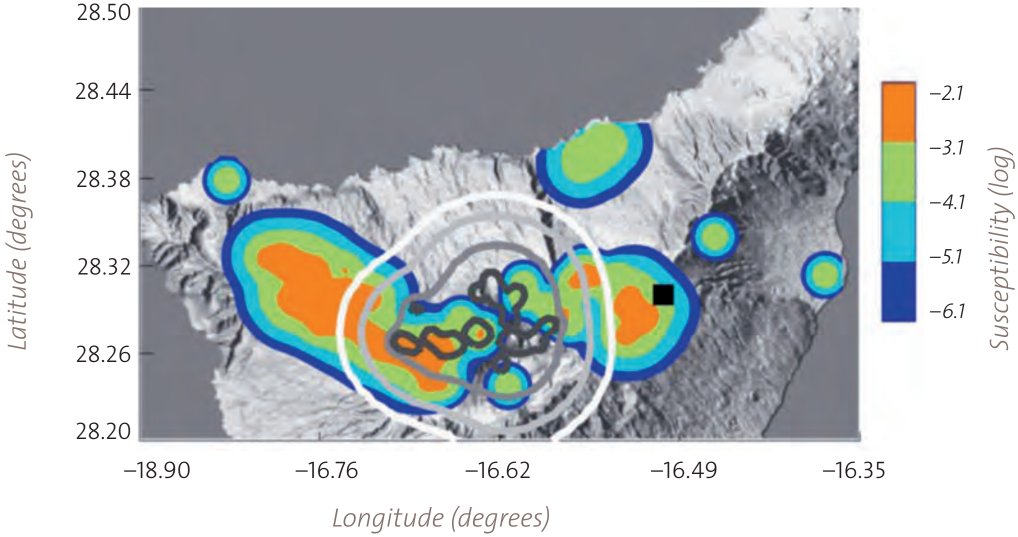


Figure 18. Logarithm of susceptibility to mafic (coloured areas) and felsic (grey contours) eruptions. The four contour lines correspond to colour codes, with the dark grey line equivalent to the orange colour of the mafic eruptions and the lightest contour line equivalent to the dark blue.

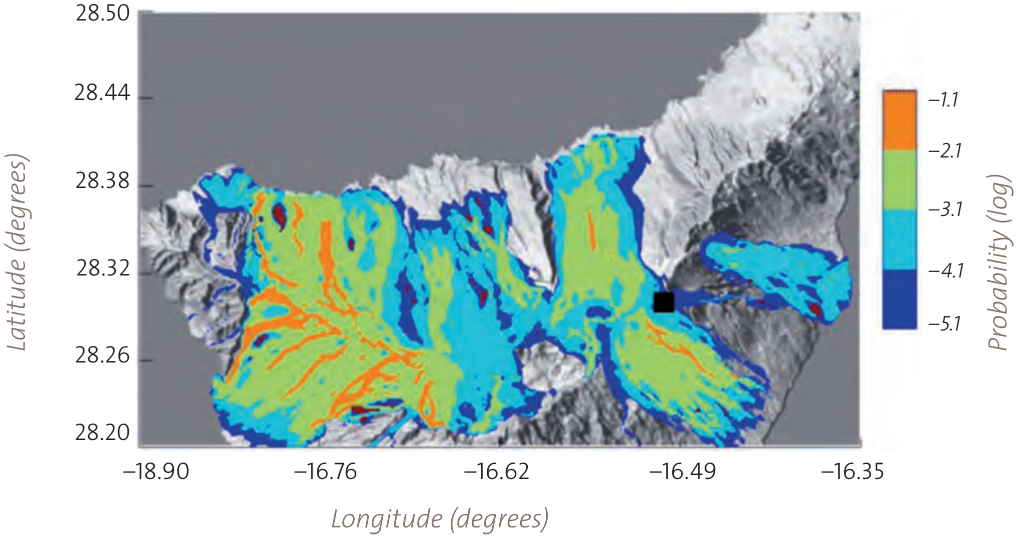


Figure 19. Probability (logarithm) of lava invasion from the mafic areas shown in the previous figure.

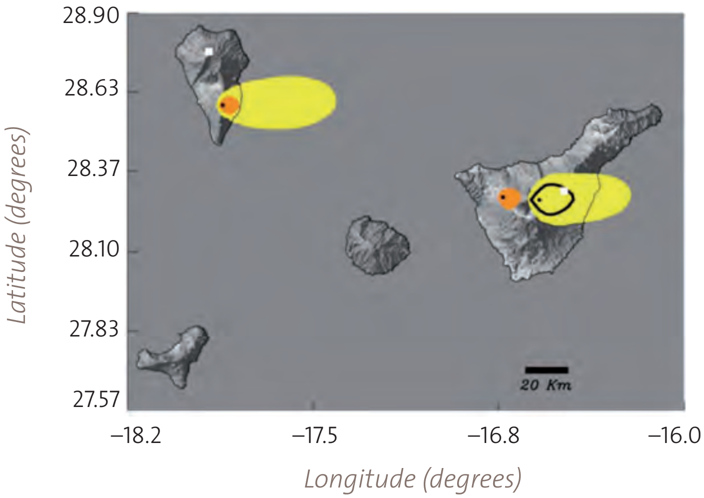


Figure 20. Spatial distribution of ash deposits (at least 1 cm thick) following an eruption of the eruptive centres (black circles). The observatories are represented by white squares. The orange and yellow areas in Tenerife represent the extent of the ash after VEI=2 and VEI=4 eruptions respectively. The black contour line represents the distribution of ash deposits at least 10 cm deep. The orange and yellow areas on La Palma represent the distribution of ash deposits at least 1 cm deep for VEI=2 and VEI=4 eruptions of the Cumbre Vieja volcano.

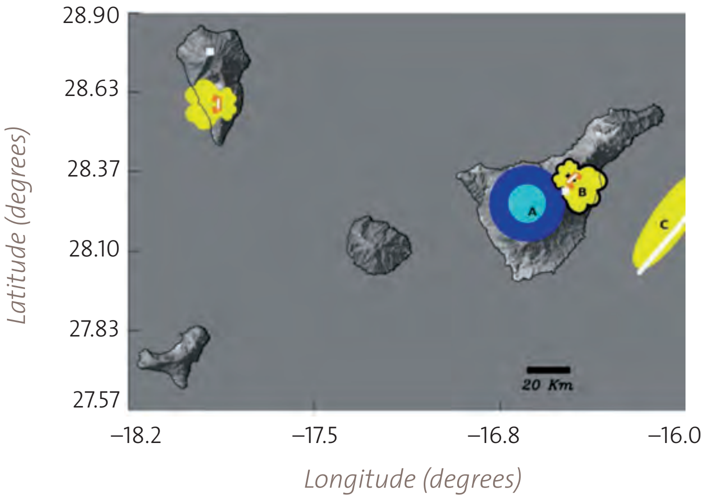


Figure 21. Spatial distribution of ground deformation in terms of inclination caused by vertical rising. Areas with deformation of at least 20 arc seconds or 2 arc minutes are shown in yellow and orange or dark and light blue. The observatories are shown as white squares, with the fault lines projected on the surface as white lines. Three types of subsidence are projected for Tenerife: subsidence due to activity in the magma chamber (A), dyke injection (B) and tectonic faults (C). For La Palma, subsidence caused by dyke injection at Cumbre Vieja is projected.

of changes in the ground caused by the presence of a magma chamber under Teide, or dyke injection or fault reactivation has also been assessed. (Fig. 21). It can be seen that the only potential risk is from reactivation of the magma chamber under Teide, although this is only possible in very superficial or high-pressure chambers. Once again the frequency of such events is unclear.

Table 6. Summary of risk factors at the Observatories examined

	Teide Observatory	Roque de Los Muchachos Observatory	Comments
Seismic Risk	PGA=0.06g	PGA=0.05g	*PGA is the peak ground acceleration rate with 10% probability of it increasing in the next 50 years*
Lava Flow Risk	Negligible	Negligible	Probability of lava invasion in the next 50 years
Ash risk (VEI=2)	$P_A=10^{-4.3}$	Negligible	Probability of at least 1 cm of ash. Frequency for Tenerife 10,000 years
RAsh risk (VEI=3)		Very low	There has never been a VEI=3 eruption in La Palma.
Ash risk (VEI=4)	$P_A=10^{-2.2}$		Probability of at least 10 cm of ash. Frequency for Tenerife 3,000 years
Risk of changes in the earth (magma chamber)	Very low		*Probability of inclinations of at least 20 arc seconds in the ground in the next 50 years due to reactivation of the magma chamber*
Risk of changes in the ground (dyke injection)	$P_A=10^{-4.3}$	Negligible	*Probability of inclinations of at least 20 arc seconds in the ground in the next 50 years due to dyke injection. Frequency 10,000 years*
Risk of changes in the ground (tectonic fault)	Negligible		*Probability of inclinations of at least 20 arc seconds in the ground in the next 50 years due to fault activity*

5.4. STRATEGIC POSITION WITHIN EUROPE

It is estimated that 90% of the number of astronomers and technicians likely to work on the EST in some way during the operating phase, either as an employee or a visiting user, will come from a European Union country. The remainder will be visiting researchers from countries with particular strengths in the field of solar physics, like the USA or Japan. This makes a strategic location for the EST in Europe very important for most of the personnel who will be involved in the project. The proximity of the Canary Islands to continental Europe, with the excellent air links that largely result from tourism in the Islands and the fact that they are a European Union territory, being part of Spain, would make it easy for technical and research staff to travel to the EST.

The Canaries are part of Europe. A European environment facilitates personnel movement

In 1992 the EU created a "single market" for all of its members (allowing the free movement of people, goods, services and money). This means that people can travel and do business across the whole of Europe on exactly the same footing as they do in their own country. This market has reduced bureaucracy, simplified trade, cut prices and generally made Europeans better off. Everyone benefits from increased competition within the EU, for example through cheaper flights, lower telecommunications costs and lower energy prices. In 2007 the Schengen area was created, covering 29 countries[21]. This Agreement allows nationals and legal residents of any of the "Schengen area" member countries to travel freely between them. This means that a citizen of any of the countries mentioned can travel to Spain with a valid national identity document, although citizens of Ireland and the United Kingdom must carry a valid passport. Nationals of non- Schengen countries must obtain a transit visa or temporary resident's permit if this is required for citizens of their country of origin. Countries whose nationals do not require a visa include Australia, Canada and the United States; countries that have an important relevance in astronomy.

Siting the EST in the Canaries will therefore cause no difficulties for citizens covered by the Agreement, whether they are visiting the installations or contracted to work on them during the construction or operating phases. In fact the Canaries, which are in EU territory, provide maximum legal assurance for research and technical personnel.

The fact that the European Union considers the free circulation of persons very important cannot be overstated. It is the reason that campaigns have been mounted to inform EU citizens about the advantages and disadvantages of geographical and labour mobility, labour market mobility, the experience of working in another country, changing jobs or careers, and the rights of immigrant workers. These campaigns have also given rise to an exchange of good practices on the part of authorities and public institutions, official organisations and the private sector, and studies have been produced on professional and geographical mobility inside the Union.

In the field of health, a pan European strategy for removing even more barriers to the circulation of patients and professionals, simplifying procedures and improving the quality of access to treatment across borders, is being drawn up. At the present time, a European citizen can use the health system

21 Germany, Austria, Belgium, Bulgaria, Czech Republic, Cyprus, Denmark, Slovakia, Slovenia, Spain, Estonia, Finland, France, Greece, Hungary, Iceland, Italy, Latvia, Liechtenstein, Lithuania, Luxembourg, Malta, Norway, Netherlands, Poland, Portugal, Romania, Sweden, Switzerland

of the country he or she is in thanks to the agreements that already exist between Member States.

In education, the European Higher Education Area, which was set up with the 1999 Bologna Declaration, also relies on the harmonisation of university systems across the Member States, so that there are no barriers to the movement of persons across the EU for this purpose. This is a particular benefit in terms of being able to employ the best professionals without being caught up in the endless process of accrediting qualifications.

Similar considerations apply to the tax-free import and export of materials for the construction, operation and maintenance of the EST. Building this telescope in the Canaries will simplify the process of transporting the different installation components to the site.

The Canaries are a secure and stable environment

The European Union has brought many benefits for its Member States (amongst them Spain and with it the Canaries) which can be summarised as a stable and peaceful Europe, the creation of the "single market" and the continuity of a united Europe.

As well as providing and protecting a stable and peaceful environment, the EU has played an important role in safeguarding peace and security in the European regions and extending it to neighbouring countries.

A free, safe and lawful area like this is the most desirable environment for housing and operating a large and complex installation like the EST.

From the safety perspective, a safe environment is as important as a safe workplace.

- Safe environment: The Canary Islands offer a calm and peaceful environment and a relaxed atmosphere to promote a sense of safety and well-being.
- Safety in the workplace: Spanish labour law provides a secure working environment with an emphasis on worker protection. Any person contracted to work within Spanish territory is protected by the law governing contract working and is entitled to the benefits it confers: social security, unemployment benefit, severance pay relative to length of service, a maximum limit on working hours, right to take paid holiday etc.
  In addition, employers must comply with the relevant health and safety at work regulations for its business and provide a safe working environment for all employees.

In conclusion, the Canary Islands, as EU territory, offer a safe, stable environment for research and technical staff both socially and economically.

Proximity of the Canary Islands to mainland Europe

The Canary Islands can be reached from any European location within a day. For example, no European capital is more than 5 hours non-stop flying time from Tenerife. As direct flights are tourist flights and do not operate every day, it is sometimes necessary to take an indirect flight. Where this is the case, connections are normally available from Madrid, Barcelona, Tenerife or Gran Canaria. The average length of an indirect flight is around 6 hours. Flights between Spain and the Canary Islands are subsidised for island residents (there is a 50% discount).

People working with the EST would benefit personally and professionally in the following ways.

- It is easy for personnel from abroad to relocate to the island.
- It is easy for personnel from abroad who are working on the island to stay in contact with their families and friends in their home countries. This normally leads to higher levels of satisfaction amongst staff working abroad and thus helps to create a stable workforce.
- Work trips (for technical or scientific purposes) for EST personnel or visitors to the EST from continental Europe would be more straightforward and cheaper.

Time difference between the Canaries and continental Europe

There is just one hour's difference between local time in the Canaries and most of continental Europe (Figure 22). Working hours would therefore be practically the same at the EST and the various European organisations involved in its construction, operation and maintenance.

Sharing the same working day has the following benefits.

- Any work-related consultations or queries that arise between personnel located at the EST and at other European organisations can easily be resolved without the delays that occur across different time zones. This will also impact positively on the hours of availability of the installation.
- It will make it easier to organise remote meetings (video conferences, conference calls, etc.).
- It will improve the ergonomics of travel between the EST and other organisations in continental Europe (there will be no jet-lag from travelling across time zones).

In conclusion, if the EST is sited in the Canaries there will be many logistical, economic and social benefits.

As an EU territory, the Canaries are a safe, socially and economically stable environment. Residency and travel would be simple to arrange for citizens of EU member states and transporting materials would be straightforward.

The Canary Islands are closer to mainland Europe than other leading observatories, making journeys shorter and cheaper and staff travel easier, whether for business or pleasure.

The time difference between the Canaries and most of the countries of continental Europe is just one hour, making it easier for work groups at different locations to cooperate and communicate.

Figure 22. World Time Zones

5.5. BASIC AND ADVANCED INFRASTRUCTURE AT THE ORM AND OT

The Canary Islands' Observatories basically have all the infrastructures needed to build and operate the EST. This cannot be overstated as it means that the project would be logistically viable and avoid budget overspends for new support infrastructure.

All of the existing general purpose infrastructures at the OT and ORM are maintained by IAC central services, simplifying logistics for the scientific institutions working at the observatories.

Access

The roads leading to both the OT and the ORM and the access roads within them are all paved, in good condition and properly signposted. The Canary Islands' Observatories can be accessed with any type of vehicle whereas entry to other leading observatories requires special vehicles (off-road vehicles, etc.).

The local authorities maintain the roads. No special requirements are anticipated for the construction and operation of the EST, meaning that only routine maintenance and upgrades will be needed for everyday vehicle traffic. However, the Regional Government is working on a Land Transport Modernisation and Restructure Plan and this could cover any specific work if needed to support the EST.

Telecommunications

In 2009 the IAC completed an upgrade of telecommunications between its observatories and offices. The improvements led to a Gbps bandwidth increase.

At the end of 2007, the ORM and the CALP were already connected to the IAC headquarters at La Laguna on the island of Tenerife, by a 10Gbps circuit providing a high speed digital communications network for scientific research activities. The same upgrade process has also recently been completed on Tenerife.

In terms of connection to national and international networks, the Ministry of Science and Innovation announced, at the end of 2008, an investment of €130 million, financed jointly with Structural Funds, for the fast implementation of a new dark fibre network connecting all of the country's universities, public research centres using RedIRIS and especially (the result of a commitment to Spain's Autonomous Regions) all of Spain's Singular Scientific and Technological Installations including the OT and ORM. This new project, RedIRIS-Nova will be a huge improvement to the existing communications infrastructure.

Electricity

Red Eléctrica de España provides the electrical transport network throughout Spain, operating the electricity system that carries electricity from power stations to the consumer. The company that supplies power to the mountain sites of the Canary Islands' Observatories is Unelco-Endesa.

At the ORM, the main supply comes from a substation at an altitude of below 1000 metres. Aerial cables bring it close to the Observatory and it travels the final few kilometres underground. When the supply is interrupted, which can happen two or three times a year for up to 24 hours, generators at the telescopes provide a back-up. As power cuts are infrequent the capacity of the back-up supply at the telescopes is minimal, just sufficient to turn off the installation correctly, equipment cooling or heating and similar needs, but not enough for them to operate continuously throughout the power cut.

Several years ago a dual circuit Medium Voltage Line was connected to the Hoya Grande sub station (Garafia).

The current capacity of the installation and therefore the potential demand of power at the ORM is 3 MW. However, consumption does not currently exceed 0.8 MW even with the arrival of the GTC.

In preparation for the future, the Canary Islands Regional Government and the Island Council of La Palma are already planning to upgrade the electricity supply. The most likely option at present, supported by the electricity supplier, is to bring an overhead 66 kV line from Punta Llana through non-protected areas to the Pico de las Nieves and from there underground to the ORM. A medium voltage substation at the observatory will assure the power supply. This new line will give the ORM the electrical infrastructure and power supply needed for up to 10 MW capacity.

At the OT, the main supply comes from a substation near the Izaña Military Detachment. The line originates in Güímar and is overhead until the limit of the Teide National Park, where it goes underground. The

Observatory has three sub-stations near to the THEMIS telescope (ET1, Power 400KVA), the TCS (ET2, Power 250KVA) and the Residence (ET3, Power 100KVA). The power available at the OT is 1 MW although current demand does not exceed 0.3 MW.

When the power supply is interrupted generators located at each of the substations are used. The telescopes are equipped with battery backups (UPS) which provide sufficient energy to turn them off correctly them and their cooling, heating and similar needs whilst the generators, which can run independently for up to two weeks, power up.

Water supply and sewerage

The ORM residence and telescopes have eight water tanks to meet the needs of personnel and other users. Annual consumption is currently around 4,000 m³.

For waste water and sewerage the observatories have a purification plant to treat the water before it is discharged onto the land. Waste water is only produced by ORM personnel as no industrial or other activities are undertaken at the site. The amount of waste produced annually at the observatory is about the same as a dozen families, and there is virtually a purification plant for each family. No other mountain site in the world, astrophysics related or other, has so many purifiers for such a small amount of water. This shows that the commitment of the Canary Islands' Observatories to environmental protection is beyond question.

The OT has ten water tanks (total capacity 150 m³) to meet the needs of its personnel and other users at its residence and telescopes. Annual consumption is currently around 2,100 m³ (Residence -1,500 m³, Telescopes – 600 m³). The annual cost is €41,000 (€20 / m³).

For waste water and sewerage at the OT the observatories have purification plants to treat the water before it is discharged onto the land. As at the ORM, waste water is only produced by personnel as no industrial or other activities are undertaken at the site.

Residence

The ORM has a residence with accommodation for up to 34 people in 23 single and 6 double rooms, and an annex with a further 30 rooms of which 21 are doubles. Average annual occupancy is over 9,500 stays.

As the GTC is currently operative, the residence is to full capacity and it will need to be extended if the observatory is chosen as the site for the EST. In light of this, work has already been carried out to determine what would be needed to house personnel for another telescope the size of the GTC or larger.

The OT Residence has 14 double rooms for visiting scientific and technical staff. It also has 6 rooms in annex buildings and rooms for its own staff. Average annual occupancy is over 4,500 stays.

Both residences are open 24 hours a day, seven days a week. The residences provide breakfast, lunch and dinner during the wor-

king hours of the institutions using the observatories.

Both observatories also have general use facilities including a fax, photocopier, computer room, meeting and video-conference rooms, wireless network and entertainment facilities including television rooms and a small library.

Support installations

The ORM and OT both have support facilities and services such as refuse collection, workshops, stores, garages, ambulance, emergency fuel depot (ORM), four heliports (ORM) and vehicles for users, etc.

The fire service manages fire risk at the observatory to ensure that it is minimal (in line with advice and directives from the local authorities). IAC central services maintain a fire tender in case of fire and provide fire training for the user institutions.

Additional controls are also being considered to ensure that the risk of injury from the movement of people and vehicles at isolated locations is as low as possible. At the

OT a GPS vehicle monitoring and warning system is being used. This system is also being looked at for the ORM.

5.6. SEA LEVEL FACILITIES

Headquarters of the IAC at La Laguna. Tenerife

The Astrophysics Institute in La Laguna is the IAC's headquarters. It houses most of the IAC's workshops, technical rooms and laboratories as well as offices and other observation and post-observation resources needed for its role as the administrative base of the International Observatories.

The headquarters building in La Laguna is the main workplace for most IAC staff, a meeting point for the international astronomical community, a technological research and development institute and a training centre for researchers, engineers and technicians. It is also a dynamic centre for public education.

The city of San Cristóbal de La Laguna is 9 km from the provincial capital, Santa Cruz de Tenerife, in the north of the island.

Centro de Astrofísica de La Palma (CALP). La Palma

The telescopes at the ORM generally have offices at sea level from which most of the staff who do not need to ascend the mountain for work. This is the case for the *Isaac Newton Group of Telescopes*, the Galileo Galilei Foundation and CALP.

At the CALP there are offices for the astronomers and telescope management staff of many of the institutions that use the ORM and also a library, meeting and conference rooms and computer and telecommunications equipment. There are also workshops, laboratories and store rooms for maintaining and developing instruments.

CALP is located at Breña Baja together with the headquarters of the Galileo Galilei Foundation, very close to Santa Cruz de La Palma (4.2 km) and the airport (3.6 km).

The availability of this sea level headquarters building will be an asset for the construction and operation of the EST. If the current capacity proves insufficient for a large project like the EST there are also other sites available nearby.

Supercomputing: CALP is equipped with a high capacity supercomputer. It is connected to the Spanish Supercomputing Network (RES) and will be connected in the future to the large European Supercomputer Network PRACE (*Partnership for Advanced Computing in Europe*), an ESFRI priority project.

The current nodes in the network, apart from CALP, are located at the BSC-CNS (the main node; the *Barcelona Supercomputing Center* - National Supercomputer Centre), CeSViMa (Supercomputing and Visualisation Centre of Madrid) and at the Universities of Cantabria, Málaga, Valencia, Zaragoza and Gran Canaria. Each of these supercomputers can exchange enormous quantities of information, distribute tasks and optimise resources at high speed. The RES gives Spanish researchers access to massive computations, using unique, interconnected infrastructure, for the first time. The RES is funded by the National Government and co-ordinated by the National Supercomputer Centre.

The La Palma node currently comprises 512 processors giving a performance of 4.5 TFlops. Apart from its calculation capacity it is interconnected with RES which allows exceptional calculation needs to be taken up by the network as a whole. When its computing power is connected to the RES, exceptionally complex computing tasks can be shared across the whole network, along with other resources like massive storage capacity. Once a new upgrade of the MareNostrum computer has been completed the power of the La Palma computer is expected to double.

The power of this computer is a giant step forward for the astrophysics community, as its high speed calculations make research projects much quicker. The installation of the supercomputer on La Palma was a strategic decision to provide support for observations at the ORM, which was recently enhanced by the addition of the GTC, and to telecommunications development on the island.

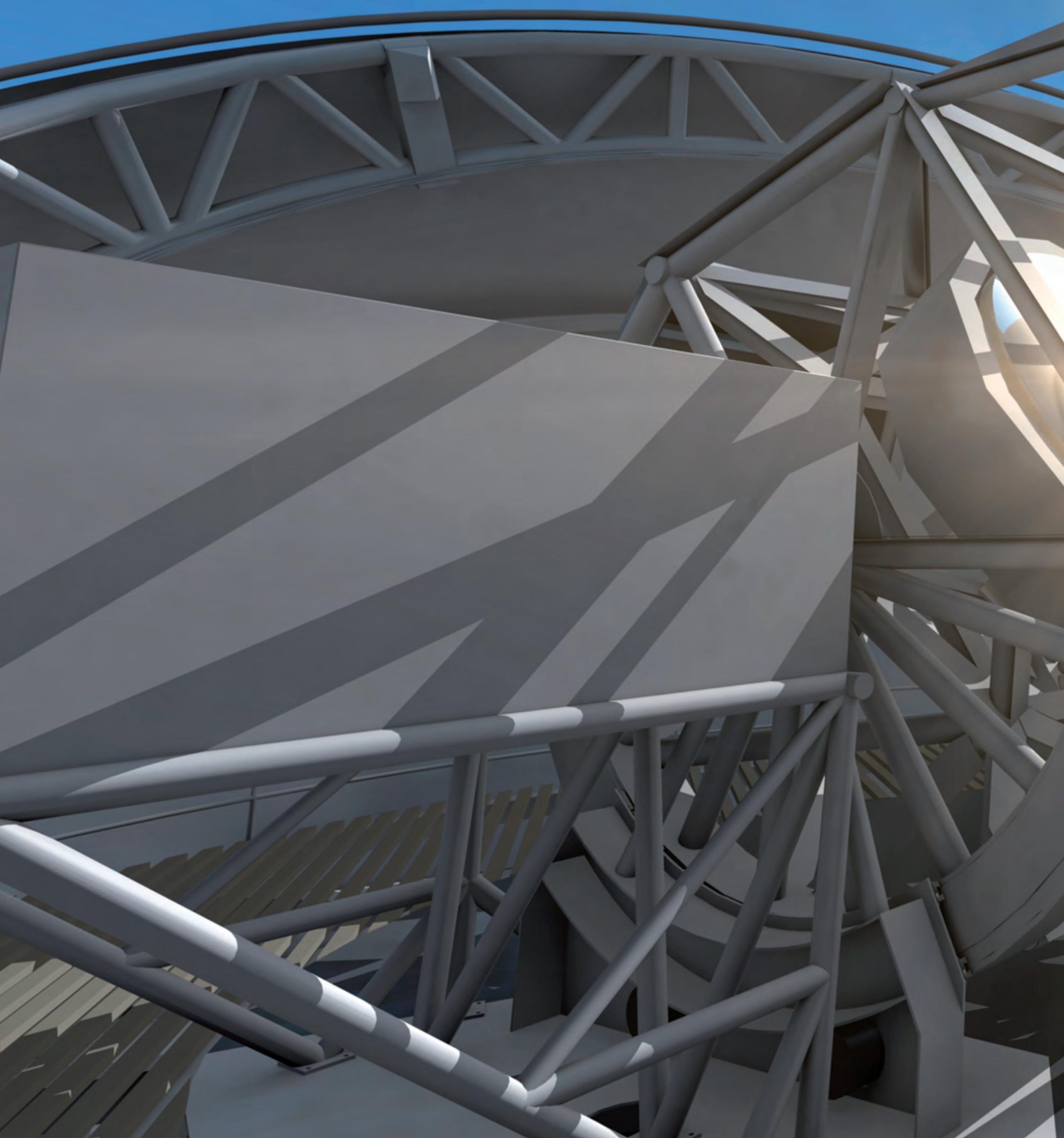
PRACE will provide Europe with a cutting edge computer, one of the five most powerful in the world which, through regular upgrades, will give scientists permanent access to the most up to date technology available.

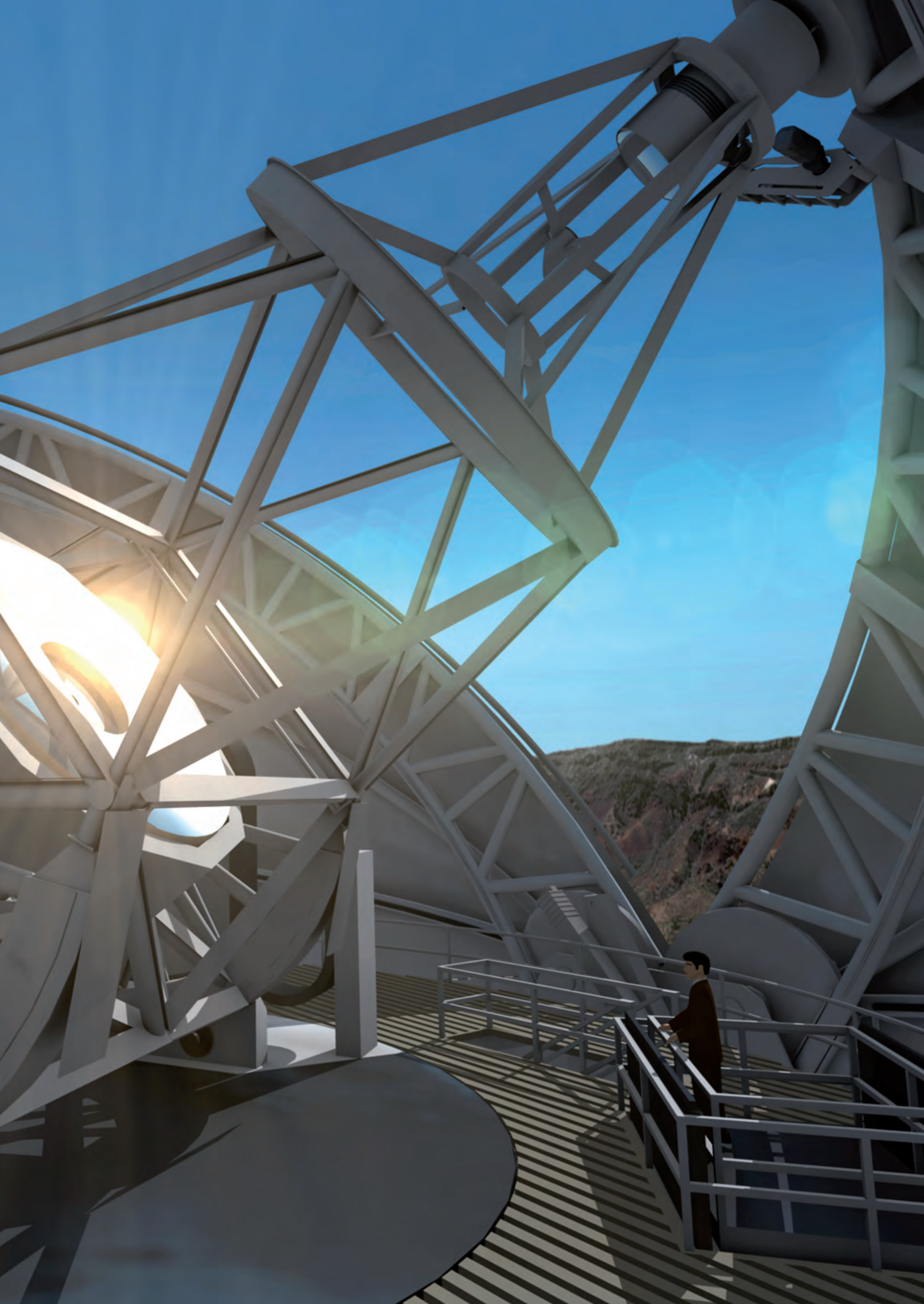
The EST will generate more data than conventional computers can deal with. The presence of an on-site supercomputer would be enormously useful for pre-processing this data as well as handling and distributing it.

The direct link between this supercomputer, the other nodes of the RES and PRACE will make massive processing of this information possible, together with comparisons between real and simulated data, and this will deliver new results for science.

6.

FINANCIAL FEASIBILITY OF THE EST





Like any other priority large European research infrastructure, the EST will need a considerable amount of investment to guarantee its feasibility for its design, construction and operating phases and its ultimate dismantling. For work to begin on the EST project, there could be two types of contribution: cash contributions (quotas from member countries and institutional backers, subsidies from other sources, loans, etc) and in-kind contributions (site, resources of partner organisations, technological developments, infrastructure elements, etc).

As it is a transnational infrastructure in which many different agencies are expected to take part (European Commission, Member States and the private sector), with complex processes to carry out the project (such as calls, tenders, negotiations, etc.) and an equally sensitive framework of national and EU policies, it is essential to agree and formalise the appropriate legal framework for this project before any kind of initial investment is made

The conceptual design study has been carried out individually (from a legal point of view) by a number of public and private European institutions, albeit in a coordinated way as part of a joint project with funding from the European Commission. However, the establishment now of a legal, transnational global entity, with legal capacity to act as a single body, appears to be the most appropriate vehicle for the next steps towards the construction and operation of this large telescope.

Three key factors need to be taken into account for the project to be financially feasible. The first, which is already in place for the EST, is backing from the majority of European scientific institutions for solar physics, not just agreement that a new shared facility is needed, but for more specific elements of the project like the most suitable conceptual design, cost estimates for the different phases and construction time. The second factor is identification and consideration of the sources and types of income anticipated for the project. The intention is to assure the flow of funds (national, European and third party contributions, user fees, etc.), through a firm agreement between the funding agencies to be involved in the project. The present report is intended as a starting point for putting this second factor in place.

Finally, the ability of the "EST Organisation" to keep spending within the limits imposed by contributions or sources of income must be given careful attention and this very much depends on good practice in financial and economic management. In this context, an organisation is financially feasible if it produces sufficient value[22] to maintain the commitment of its direct investors (funding agencies) in its continued existence.

The new era of research infrastructures requires a legal framework that fits its needs and assures effective governance, resource management and optimal operation for the infrastructure. The European Commission has implemented the "ERIC)", a legal framework to satisfy these requirements. All organisations working together to develop a transnational research facility can opt for this legal formulation (see section 7.2).

6.1. SCIENTIFIC INFRASTRUCTURES AS A DRIVER OF SOCIO-ECONOMIC DEVELOPMENT: THE ROLE OF ASTROPHYSICS IN THE CANARIES

The European Commission as a whole and the different Member States individually stress that large research infrastructure projects are important not only because of the progress they bring in knowledge and technology but also because they are major boosters of social, industrial and economic development in their immediate surroundings, not only in geographical terms but also in technological, industrial and, ultimately, social terms.

Research infrastructures meet these aspirations for the ERA and cascade them onto the other sectors and economic and social activities. These effects are amplified considerably in the EU's Outermost Regions. In these areas, large science and technology infrastructures established there act as a point of economic, social and territorial convergence and cohesion with the rest of Europe:

- they create new, attractive and competitive international working environments;
- they lead to the provision of new basic and advanced infrastructures (basic supplies and telecommunications) which benefit the whole region;
- they open up new technological, industrial and economic markets and increase growth and diversity in existing markets by creating demand for all types of service;
- they provide a global view of cohesion with the rest of Europe, strengthening the excellent and unique characteristics of these regions thus reducing their distance and isolation from the rest of the EU.

The Canary Islands' Observatories are a clear demonstration of ERA structuring and a point of territorial, economic and social convergence.

These observatories house the most advanced telescopes and installations for astrophysics in any European Union Member State. More than 50 prestigious scientific institutions from around 20 countries operate their facilities here. The socio-economic impact that the Observatories have had on this EU Outermost Region since the day they opened to the international community in 1979 is a fact.

22 The value of the project may be assessed by the funding agencies using indicators like efficient financial management, scientific and technological outputs, financial returns obtained, benefits for higher education, creation and continuation of highly qualified employment and social perception among others.

The use of these facilities by the international scientific community means that several thousand astronomers travel to them every year. Developing new installations and instruments, like the GTC, which has been operating since 2009 and is the world's most advanced telescope, together with the IAC's cutting edge research activities, require large scale movement of people and create jobs for highly skilled workers in the Islands.

The basic and advanced infrastructure that this astrophysics complex needs to operate and run properly has brought considerable improvement to these infrastructures which benefits society in the Canary Islands as a whole: improved quality of basic supplies; advanced telecommunications networks between the Islands and Europe, allowing broadband connections; and access to other large infrastructure resources, like the recent supercomputer. This progress with support infrastructures enables greater growth and competitiveness throughout the area and creates the right conditions for economic growth in other sectors.

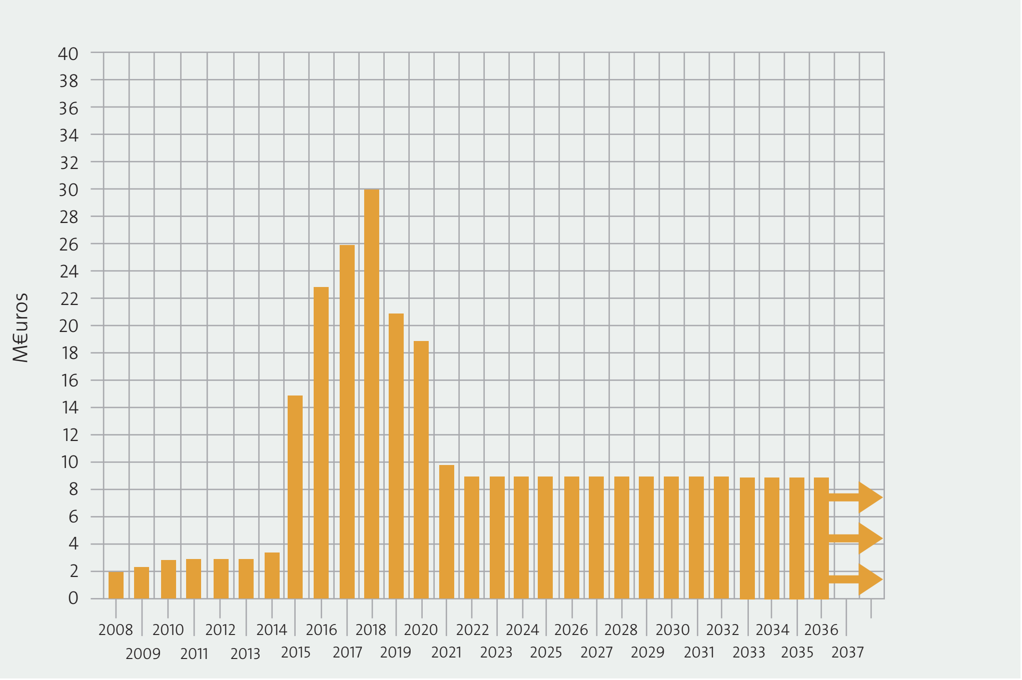
Astrophysics research in the Canaries has also opened up new markets for businesses across the country, like the notable growth and increased value that Spanish industry has accrued through working on the GTC, putting it in a strong position to access new international high technology projects.

Astrophysics research has also, from the very beginning, been high profile and of interest to the media, the world of education and to society and culture in general. Society in the Canary Islands is aware of the important asset it has within their territory which brings them closer to Europe, not only as a privileged tourist destination but also as a reference in astrophysics worldwide.

Since they were opened to the international community over 30 years ago, the Canary Islands' Observatories have proved the value of giving firm backing to scientific infrastructure projects in the remoter parts of Europe for the economic and social growth that they deliver. In fact the European Commission itself, in its publication *"Developing World-class Research Infrastructures for the ERA. Report of the ERA Expert Group"* (March 2008), underlines the important role of scientific infrastructures as a driving force of regional development.

Cohesion with Europe's Outermost Regions is an expression of solidarity between the Member States and their regions and promotes balanced growth, reduces structural differences and provides true equality of opportunity for individuals. In 2007-2013 this economic and social cohesion will be focused more on the principal development issues of economic growth and employment. Scientific infrastructures like the Canary Islands' Observatories are a clear example of what can be achieved and a source of development for the coming and subsequent periods.

Graphic 3. Estimated investment needed for the different phases of the EST project based on construction beginning in early 2015. Estimate in Euros at 2010 rates



6.2. FINANCIAL SCENARIO: NATIONAL CONTRIBUTIONS, SUPPORT INSTRUMENTS AND FUNDING PROGRAMMES

Budget estimates for the EST project according to the EAST in early 2011 are €10 million for the preliminary design phase and approximately €135 million for construction. This second figure includes the cost of the initial instruments (approx. 30% of the total cost) and a contingency allowance (20% of the base budget). Annual operating costs are estimated at €9 million. The graphic below (Graphic 3) gives a breakdown of the estimated annual expenses for each phase.

As there is no single international organisation (with the support of funding agencies) backing the project as yet, no funding is available for phases after the Conceptual Design phase, which means that the financial scenarios being considered for the EST must meet 100% of the investment needed.

The investment must especially take into account a number of specific different needs during the project's lifetime:

- **Construction:** The funding agencies for EST must provide, for the construction phase, funding at a level and in sufficient time for this phase to run without interruption, with payments correctly scheduled to avoid the expense of bridging loans and also uncertainties that could paralyse the project. These payments could be made in cash, to a joint budget, or in-kind. The consortium

Figure 23. Countries with institutions and companies involved in the EST Conceptual Design study. Spain, Germany, France, Italy, United Kingdom, Netherlands, Sweden, Norway, Czech Republic, Poland, Slovakia, Switzerland, Austria, Hungary and Croatia.

itself will need to decide on the appropriate method for each of the cost headings for the telescope.

- Upgrades, alterations and dismantling: These elements must be planned from the beginning to ensure that financial as well as technical resources are in place in time. As well as providing for proper maintenance of the facilities, the cost of withdrawing and updating the equipment and instruments as they become obsolete must also be considered. Although these funds will not be needed until a later stage in the project, funding agencies should agree in advance both the accounting measures and payment schedules.
- Operation: Successful operation of the EST (as with any other large scientific infrastructure) will depend on the financial stability of the project. Apart from expenses related to construction financial planning will be needed to make sure that funding is available (contributions from funding agencies and other income) for ordinary expenditure on immediate and future activities.

In view of the nature of the EST project, whose considerable costs will need to be met with cash contributions, any in-kind contributions from partner organisations, for the construction and/or operating phases of the telescope, must not represent a significant proportion of the total project budget.

6.2.1. Financial scenario: starting position

It is logical to expect that national funding agencies with institutions with an interest in the project (Figure 23) will attempt to negotiate the best possible return for their investment in all regards: scientific, technological, industrial, economic and social.

Funding source	% contribution
**Common funds (membership quotas) of the partners*	*30%-40%*
A. EU funding	10%- 20%
B. Additional contributions from member countries based on the highest returns for socio-economic benefits, technological opportunities, economic weight of the country and number of scientists working in the field.	40%- 50%
C. New EST partners	< 10%
D. Other contributions: sponsors, user fees, etc.	< 10%

They will look for medium- and long-term benefits proportional to their contribution, not just in terms of scientific progress but also in terms of the actual opportunity to get industrial contracts, in high value technological sectors, and stable job creation. They will also hope to benefit from the potential of the new technology in order to improve the competitive edge of their national economy, and boost the skills base of their scientists, engineers, technicians and students. To safeguard their interests, they will seek maximum influence in the project's decision-making governance structure.

It is also expected that they will demand that the project and the funding assigned to it must be very efficiently managed, with robust and transparent procedures to protect it from budgetary delays and deviations. The national funding agencies are aware that the transfer of national funds to projects governed by international consortia implies that their degree of control, as wide as it may be, is always limited and this means that they will be keen to ensure that the project is managed as efficiently as possible.

It may also be envisaged that a minimum contribution will be agreed for participating funding agencies, in order to act as a single transnational entity and promote the EST project. This contribution may be a fixed amount for all countries or a variable amount based on an economic indicator like GDP of the country concerned or the size of each country's solar physics community (potential users of the facility), etc. Whichever method is chosen, the initial contribution will be a set percentage (to be determined) of the investment needed to fund the construction and operating phases. The remaining funding will have to be obtained from other sources.

A brief list of potential sources for additional funding for the EST, which have funded similar projects in the past, is given below. An outline estimate for potential contributions is also provided, based on literature from similar projects, to give an idea of the level of commitment that each of these funders could have. The values shown are simply for reference and should absolutely not be taken as prescriptive.

As some of these contributions may not be consolidated in time for the start of the EST construction phase, it may be appropriate to consider a long-term preferential rate loan from the European Investment Bank, which is willing to back this non-consolidated investment, provided that a transnational ERIC personality has been created for the project.

A. EU funding

Siting the EST in the Canaries means that a range of financial support mechanisms will be available from the EU, which should be listed and explained to the funding agencies.

European funding is currently discharged through a variety of management structures[23]. The EC administers 22% centrally and delegates, via an agreement known as "shared management," approximately 76% of funding to the Member States. The remainder (2%) is distributed jointly with international organisations or third party countries.

Centralised funds

Regarding EU funding through centralised funds the main funding vehicle for future large astrophysical observation infrastructures and related companies and research centres, is currently the Seventh Framework Programme for R&D 2007-2013 (FP7), with over € 53,000 million.

It is also important to mention that the EST project has already received funding from this Framework Programme through the "Research Infrastructures" part of the Capacities programme. The European Commission has co-financed the conceptual design of the project with an investment of €3.2 million. In the immediate future funds may also be available from this source through the Integrated Infrastructures Initiative (I3).

FP7 also allows for joint financing of the "Preparatory Phase" prior to construction, but this is only available for infrastructures listed in the ESFRI Roadmap. The map currently lists 44 large installations for all branches of science and technology, and these projects are candidates to receive EU support. Given that the EST is seen as an astrophysics (ASTRONET) priority within the ERA-Net initiative, efforts must continue for its inclusion on the next ESFRI Roadmap update.

Access to EU FP7 funding is not dependent on the site chosen for the EST. However, all of the other means of financial support listed below are dependent on the EST's site, with an Outermost Region like the Canaries attracting the maximum amount.

Regarding the next EU Research Framework Programme (FP8 2013-2020) it should be highlighted that it must continue to work towards the goals set out in the Europe 2020 Strategy and the creation of the European Research Area, goals which European states and regions have made their own. Specifically, a proposal has been made for a new EU fund aimed exclusively at research infrastructures, which would fit with the European philosophy proposed for the EST.

23 R&D Pluri-regional Operational Research Programme for and by Enterprises - Technology Fund (2007 - 2013). Ministry of the Treasury (2007) for Spain.

Decentralised funds

The Canaries can access these funds through the Operational Programmes. Europe is providing the Canaries with over €100 million for RTD activities through the ERDF Canary Islands Operational Programme 2007-2013[24].

Some of its main priorities are:

1) Building the knowledge economy

The Canary Islands Research, Development and Innovation Plan 2007-2010[25] sees regional investment in research and technology as a priority, including from the private sector, in order to continue to diversify economic activity and reduce reliance on tourism.

The programme supports research and development at the Canary Islands' universities and technological centres and the resulting technology transfer to small and medium sized enterprises (SME), the dominant producers in the region (89% of firms have between one and five salaried staff). In particular, the programme will create a centre for business service innovation and sector groupings to encourage joint working across companies.

2) Business development and innovation

This priority seeks to encourage entrepreneurship in the Canaries, providing opportunities for economic activity, adapted to local conditions where necessary, and help to target international markets.

These initiatives are mainly aimed at SMEs. Special efforts are being made in ecological innovation and in identifying new ways for business to access finance.

This total could increase considerably in the Pluri-Regional Research and Development Operational Programme for and by Enterprises - Technology Fund (2007-2013) (*aimed at phasing-in regions*) with a return for the Canaries of some € 50 million during the period it covers, 2007-2013.

Funds management will be the responsibility of Spain's Ministry of Industry, Tourism and Trade, which manages almost half of the Operational Programme Funds of around € 977 million, and of the Centre for Industrial Technology Development (CDTI), which looks after € 793 million destined to fund consortium projects. The CDTI must devise new kinds of projects and funding methods: the projects that make up and support the Innovative Business Groups.

It is important to highlight that the Operational Programme is designed to encourage research, development and innovation capacities within enterprises, particularly small and medium enterprises in the Spanish regions that are covered by the convergence objective as they are considered to be most in need of aid.

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24 ERDF Canary Islands Operational Programme 2007 -2013.

25 The new Canary Islands Research and Technological Development plan for the subsequent phase is already drafted.

Outermost Region Status

The Canary Islands enjoy a special position within the EU legal framework as a result of their designation as one of the Outermost Regions. The EU recognises that these regions have different geographic and economic realities from the other European regions: remoteness, isolation, smaller surface area, economic dependence on a limited number of products, etc. These realities are a barrier to sustainable development, which the EU is trying to overcome through the various programmes and actions to foster economic and social convergence in these regions.

Nonetheless, EU policy on these regions has always seen them as "regions of opportunity" with great development potential.

Of the seven Outermost Regions in the EU, the Canaries are the most densely populated and economically active. Although investment in RTD in the Canaries is lower than the national average, increasing competitiveness is seen as a mid to long-term priority, given weight by the potential that the Canary Islands hold for RTD in areas like maritime research, renewable energy, biotechnology and astrophysics. The Canary Islands Government's current RTD policies are firmly aimed at significantly increasing these activities, mainly in the private sector, and at diversifying the market, which currently relies heavily on the service sector, principally tourism. Examples of new public measures for developing RTD in the Canaries, where business participation is favoured, include: calls aimed at enterprises for RTD projects; assistance with placing scientific and technical staff in the production sector; and technology bonds.

Although initiatives for supporting RTD in these are largely the preserve of FP7, the European Commission and the European Council are working on a new strategic development plan for 2014-2020, which aims to make them more competitive and more cohesive with the other European regions, and guarantees them dedicated budget allocations.

This demonstrates the EC's understanding of the cascade effect that research infrastructures have on other economic and social sectors and activities, which is even greater in the Outermost Regions where large scientific and technological infrastructures are a bridge for economic, social and territorial convergence and cohesion with the rest of Europe. The EC made this explicit recently in its report *"The outermost regions: an asset for Europe"* (October 2008), highlighting the positive impact of the Canary Islands' Observatories and the IAC on development and structuring in the Canaries.

The European Commission will also adopt, in 2012, a Communication putting forward the European Union's new strategy for the Outermost Regions during 2014-2020. There is therefore a clear opportunity for the Canaries Government to influence funding priorities for large research infrastructures.

Synergies between the FP7 and the Outermost Regions status

Whilst the EU RTD Framework Programme has been running since 1984, the FP7 has for the first time given priority to Outermost Regions like the Canaries, with a specific initiative as part of the Capacities programme aimed at tapping research potential in these regions and helping them integrate into the European Research Area. A budget of €340 million has been allocated, focused largely on cross border cooperation between research personnel, contracting experienced researchers, acquiring and developing research equipment and organising and hosting conferences and promotional activities aimed at raising the profile of research centres in the Outermost Regions.

The FP7 also envisages complementary measures like special finance initiatives for the construction phase of large infrastructure projects under its Capacities programme. The construction phase of large infrastructures will therefore receive financial backing through, amongst other measures, compatible national and EU funding instruments (like the Structural Funds or the European Investment Bank). The programme also will take into account the scientific excellence potential of the outermost regions as sites for these projects to make funding available for priority projects with critical funding needs, (like direct subsidies, a European Investment Bank loan, using the Shared Risk Funding Mechanism, etc.). The EST will benefit from this if it is sited in the Canary Islands.

The economic investment needed for new generation solar telescopes has grown in proportion to their diameter and the technology employed, rising from an average cost of €5-10 million for existing 1m class telescopes (THEMIS, SST, etc), to an estimated cost of some €150 million for future 4m class solar telescopes. As this is more than any single European country's entire solar physics budget, new funding means and frameworks for international joint working are needed if they are to become reality. The ability to access specific funding sources, like those available for the Outermost Regions, would act as a lever for this project and could also be a deciding factor in getting it off the ground.

The financial support needed from partners in the EST project will be backed by a favourable EU framework of economic and political measures for regional development and by the assistance provided under the Canary Islands' Fiscal and Economic Regime for technology innovation and development enterprises, such as the Canaries Special Zone (ZEC) and tax incentives provided through the Canary Islands Investment Reserve (RIC) for enterprises locating to the Canaries.

B. Additional contributions from member countries based on highest socio-economic returns, technological opportunities, economic weight of the country and number of scientists working in the field

Alongside scientific returns, the funding agencies backing the EST will look for additional benefits for their countries (*like access to a pioneering world-class solar physics facility, the opportunity to take part in research projects and training opportunities for young scientists, as well as excellent scientific outputs*). Successful contract bids from enterprises within their country of origin are an important measure in this respect.

It may be appropriate to consider the principle of "fair return" in this context, which would see each country recovering (through contracts and services) the investment it makes in the project. However, this could prove counterproductive when it comes to awarding industrial and service contracts on a "price-quality"[26] basis and be an obstacle for the efficient progression of the different phases of the EST project. Having said this, the "fair return" principle does also have positive aspects that should be considered. The funding agencies could use it as an opportunity to help stimulate domestic industry and increase its capacity if necessary. It is for the funding agencies themselves to decide whether this principle is appropriate and if so, how it should be applied (rigorously or flexibly, envisaging approximately proportional returns over a number of years).

If the "fair return" principle were used it would be important to understand that, although a full record can be kept of each country's contributions, assigning a national character to contracts and other expenditure (goods, services or personnel) could prove complex. Put simply, assigning a nationality to a commercial entity is not always straightforward. In the global economy, manufactured goods (not to mention raw materials or composites) come from many different countries, and only a few of them are partners in the EST project. Further complexity comes from the fact that services may be needed from companies that do most of their business online.

Finally, the funding agencies must be aware that, in certain cases, some contract awards will need to be weighted towards maximum quality, unique ability or very competitive price rather than applying the fair return principle.

Role of Spain as the host country

Spain will provide the site for the telescope and for the headquarters of the EST Organisation, in the event it also comes to the Canaries. Although the EST Organisation and its staff will be subject to domestic law (for example in the areas of safety and labour laws), their rights and responsibilities within the "EST Organisation" will need to be clearly defined, especially if it is constituted as an international legal entity. The European Commission has created a new

26 Applying the "fair return" principle would allow countries with high manufacturing costs to avoid competing under the "best bidder" (lowest offer) requirement and guarantee a minimum return.

transnational legal format especially designed for large research infrastructures, called ERIC (see section 7.2 for more information). If this is the status agreed for this infrastructure, the "ERIC-EST" will be exempt from a range of domestic legislation (including tax and customs, etc.).

It is expected that Spain's contribution will be considered differently from that of other countries so that the provision of the site and basic and advanced infrastructure is accounted for alongside the industrial and socio-economic returns expected to accrue to the country. A concrete estimate of the percentage contributed by Spain must be produced in negotiation with the other partners, and it is neither practicable nor realistic to suggest a figure in the current document.

In-kind versus in cash contributions

For the EST to be feasible it is vital to have proper balance between in-kind and in cash contributions.

In-kind contributions

Assigning a financial value to in-kind contributions is a complex task and expert advice is often needed to properly quantify the value of the contribution, especially when it is in the form of devices of high technological content.

To avoid compatibility issues between different in kind contributions, technical specifications must be very precise and there must be careful monitoring by the Project Office.

In cash contributions

In view of the nature of the EST (*technical requirements, nº. of institutions involved, new technology needed and the large nº. of systems to be integrated*) it is considered essential for most of the budget to be received as in cash contributions to ensure that the construction phase can be centrally managed for successful completion. The greater the proportion of in cash contributions from the funding agencies, the more flexibility the EST Organisation administrators will have to manage the project throughout its different phases. The great advantage of this "cash intensive" project model is that it will enable managers to exercise a greater degree of responsibility, rigour and transparency over the contract procurement and other financial operations. It will also provide the funding agencies with a single central source of up to date project information.

In those cases where some funding agencies only wish to provide cash contributions for the project, they are likely to want the 'fair return' (juste retour) principle to apply for their participation. In this case, special attention will need to be paid to any loss of competitiveness that this may imply depending on which project elements (development, supply and service contracts) they wish to return.

Cash contributions must be managed by the EST Organisation itself, overseen by an Executive Committee set up for the purpose. The expenditure that this joint fund is expected to cover includes staff, goods, services, low technology industrial contracts (civil works, transport, etc.), ordinary operating costs and the costs of new technical/technological developments.

One of the most significant costs for the EST in the construction phase, which will have to be funded by cash contributions, is setting up a team of specialists to integrate all of the project systems, especially if some of these systems are acquired as in kind contributions.

It will be important to minimise the risk of setbacks from budget overspends and delays by the EST Organisation in executing the project, by drawing up a comprehensive risk management plan. This plan must be financially backed with a contingency budget received as a cash contribution.

As contributions from international partners cannot be ruled out (outside the EU and the Euro zone), consideration must be given (should they be involved) to the effect of exchange rate fluctuations from year to year on any cash contributions they make, by perhaps setting a maximum acceptable variation level (positive/negative) regardless of exchange rates or requiring contributions in a single currency (Euro) with the partner bearing the variations.

C. New EST partners

Although the EST has attracted a good number of partners, with institutions from 15 European countries involved, as a transnational project its doors will remain open to others from within the European Union or outside it.

The strategy for attracting new partners should not be undertaken until the EST Organisation has been agreed and constituted by the funding agencies.

Contributions from new partners will also be either in kind or in cash, as allowed for in the membership rules agreed by the EST Organisation.

Among the countries around the world with institutions with scientific interests in solar physics that are not currently involved in the EST project but may wish to be, are: Belgium, Denmark and Greece (within the European Union). Internationally the list includes China, South Korea, USA, India, Japan, Russia, the Ukraine and others.

D. Other contributions: sponsors, user fees, etc.

Alongside the standard funding mechanisms for building and operating large research infrastructures, consideration should be given to the following sources, all of which have been successfully accessed previously:

Philanthropic organisations

Some of the largest telescopes in the world, either existing or being designed, have received support from philanthropic organisations. The main examples are in the United States where, amongst others, the two 10m Keck telescopes in Hawaii, the new generation Thirty Meter Telescope (TMT), Giant Magellan Telescope (GMT) and the *Las Cumbres Observatory Global Telescope Network*, currently in the design and construction phases, have all received financial backing from this source.

It is not a very usual practice in Europe and it is unlikely that there will be the right conditions in the short to medium term. However, this alternative source of funding should not be discarded and an information package should be created outlining the key aspects of the EST project for philanthropic organisations in Europe and elsewhere in the world. Such a funding strategy would seek financial backing from these organisations with no return from the project other than its scientific and technological outputs.

European Investment Bank (EIB)

The European Investment Bank (EIB) is an autonomous EU institution set up to fund investment projects to promote balanced development across the European Union. The EIB acts as a "politically motivated bank" in pursuit of the European Union's political aims. As a major international lender with an impeccable credit rating (AAA), the Bank accesses huge amounts of funding on international financial markets at the best available rates. One of the EIB's strategic priorities, particularly for its risk capital arm, the European Investment Fund (EIF), is promoting innovation through its Innovation 2010 ("i2i") Initiative. Whilst the EIB provides funding in the form of loans, the EIF invests in innovative enterprises as part of its risk capital portfolio.

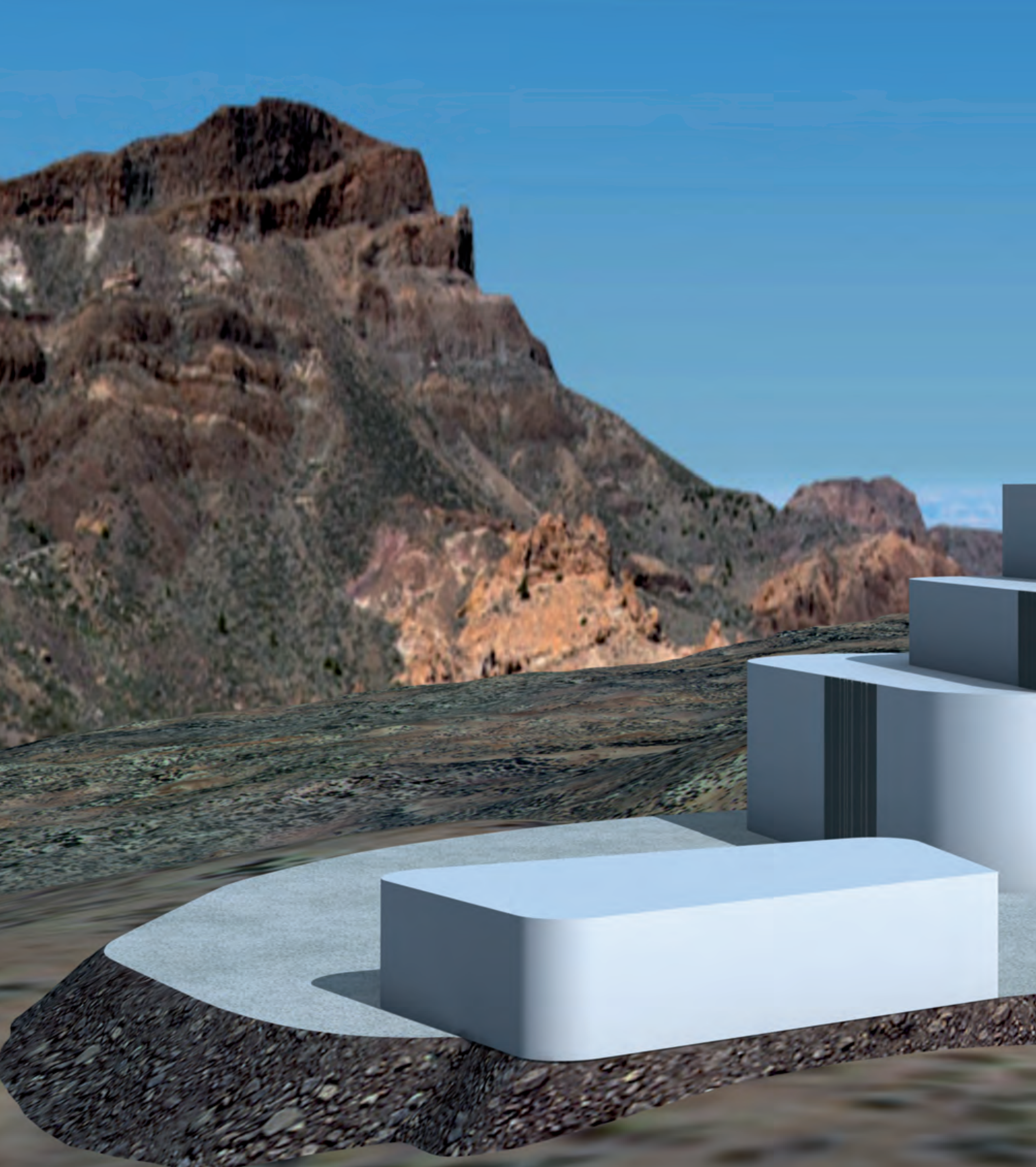
The EIB has set up a new funding mechanism for large infrastructure projects, "*The ESFRI RSFF Capital Facility (ERCF)*", for projects supported by the host country, the ESFRI and the European Commission. This funding stream will become available to the EST if efforts for its inclusion in the next version of the ESFRI "Roadmap" succeed.

User Fees

During the EST's operating phase another funding source, user fees, will become available. The EST could be made available to outside users in return for a contribution towards operating costs proportionate with their use of the telescope. The European Commission, through the RTD Framework Programme, currently allows for operating costs to be met in this way, on condition that the infrastructure is available to the whole European scientific community.

7.

LEGAL ASPECTS OF THE EST AT THE ORM / OT



7.1. LEGAL FRAMEWORK OF THE ORM AND OT TERRITORIES

The grounds comprising the ORM and OT are the legal property of the IAC. However, the observatories were "internationalised" by Spain in 1979, through the above mentioned Agreement for Cooperation in Astrophysics, which was modified in 1983, and this has repercussions for the grounds in question.

Article 7 of the Agreement states that: "The land necessary for the establishment of the observatories and the laboratories at La Laguna shall be made available by the Spanish side to the IAC, while the Spanish entities and bodies which have transferred it for the purposes laid down in this Agreement shall retain full ownership of it". In other words, the land is made available for the use laid down in the Agreement but ownership is not transferred and remains with the Spanish entities that made it available. However, "the use of the land necessary for the telescope installations of the User Institutions shall be guaranteed free of charge for the User Institutions on the conditions which are laid down in this Agreement and during the period which it is in force" (clause 7.4).

Elsewhere the Agreement sets out (arts. 8 and after) the conditions relating to the ownership of instruments supplied by each of the User Institutions (which is separate from the land ownership issue) and Spain's obligation to adequately maintain access routes to the ORM and OT and facilitate access for persons and materials.

As a consequence, and separately from Spain's obligation to make ORM and OT facilities available to any interested Institution, the land on which the observatories stand remains Spanish property.

As none of the entities currently using the ORM or OT have the character of an International Organisation, they enjoy no diplomatic privileges (like diplomatic immunity) and so the land they occupy is fully subject to Spanish sovereignty.

Incorporating the EST at the ORM or OT will bring about a significant juridical change, resulting from the fact that the EST Organisation will be involved, and it is recommendable that it adopts the juridical format recently approved by the European Commission, called ERIC (*and discussed in more detail in the next section*) which may have repercussions not in terms of land ownership but on sovereignty over it.

Indeed, if the EST is managed by an EST Organisation constituted as an ERIC it will be necessary to make land available for the Organisation to install the infrastructure. This could happen with or without transfer of ownership of the land (through sale or an administrative concession). Whatever arrangements are made, if Spain signs a Headquarters Agreement with the EST Organisation, its buildings and annexes will attain immunity and Spain will 'de facto' renounce its sovereignty over the EST site as long as the facility is in operation.

On the other hand, if it is decided to create an entity constituted in accordance with Spanish and autonomic legislation (for example, a Foundation), the privileges and immunity accorded to International Organisations will not apply. In this case Spain would retain sovereignty over the land.

In conclusion, according to that stated above, it can be established that the juridical character of the EST management entity that is finally decided upon could have an influence on sovereignty over the site.

7.2. LEGAL VEHICLES FOR CONSTRUCTION AND OPERATION OF THE EST: ERIC

As stated above, the European Commission has taken the steps needed for member countries to set up new international organisations specifically for the construction and operation of new large scientific infrastructures, which are more dynamic and better suited to the current community situation.

In the past, some countries have opted to set up specific juridical entities to build and run their telescopes, which are subject to Domestic Law and eligible for benefits available in the country or region where the facility is built. This is true, for example, for the "Galileo Galilei – INAF Foundation, Fundación Canaria", a non-profit Spanish entity set up by the INAF within the ambit of Spanish[27] and Canaries[28] law, to operate the Italian Galileo telescope at the ORM.

Foundations have organisational and fiscal advantages that have worked well for the development of non-governmental organisations. They must be imbued with the financial resources to meet its aims as a foundation. Most significant among the available fiscal benefits is exemption from corporation tax on income from partners and benefactors, dividends and profit sharing, interest, levies and rent and from acquisitions or transfer of goods or rights. Non-profit entities also have local tax advantages, being exempt from Property and Urban Land Value Capital Gains taxes.

ERIC (*European Research Infrastructure Consortium*)

Scientific progress and the rising cost of investing in new technologies have intensified cooperation between EU Member States on the creation of large research infrastructures. However, in view of the complexity facing this new generation of large transnational infrastructures *(regulations governing their creation, funding and operation remain*

27 NATIONAL LEGISLATION: LAW 50/2002, of the 26th December, on Foundations. (BOE 27/12/2002) (Errata for BOE 17-04-2003 Modified by Law 47/2003, of 26th November (B.O.E. 27/11/2003).

28 CANARIAN LEGISLATION Law 2.1998 of 6th April, on Foundations in the Canaries (B.O.C 47, 17/04/1998).

fragmented and regional) a specific juridical framework is needed to mitigate the lack of suitable regulations. In response to demands from the Member States and the scientific community, the Commission has developed and adopted a new mechanism, called ERIC[29] to make it easier for member States to work together to create and run large research facilities of pan European interest.

An ERIC is a non-profit entity thus avoiding distorted competition (although clearly, given the nature of the EST, commercial activities are not possible). However, an ERIC can undertake limited economic activities as long as these do not obstruct the research facility's main mission.

If the EST Organisation is to be constituted as an ERIC it must meet the following conditions:

- contribute to the pursuit of European research activities;
- provide added value in the fields of European and international science and technology;
- be open to researchers from the Member States and the countries associated with the EU RTD Framework Programme;
- encourage mobility of researchers and knowledge exchange in the ERA;
- share and make the best use of results from scientific research;

To acquire legal personality an ERIC must have its headquarters in one of its affiliate countries (Member state or country involved in a research framework programme under the auspices of the EU).

At least three Member States must be on the ERIC's affiliate list. Members from third party countries and intergovernmental organisations can affiliate to these.

An ERIC's legal format is considered the same as an international organisation or body for the purposes of Directives on value added tax, special taxes and public contract procurement. It is exempt from VAT and special taxes, and its public contract procurement procedures are outside the ambit of the Directive on public contract procurement.

As the host nation, Spain would have to issue a declaration recognising the proposed ERIC as an international entity for the purposes of VAT and IGIC (Canaries General Indirect Tax) and special taxes.

The affiliates' liability for an ERIC's debts would be limited to the level of their contributions.

The Law applicable is firstly EU Law and then the Law of the State housing the registered office or the State in which technical and safety activities are carried out.

Five years after the adoption of this juridical framework the Commission, with the help of experts, will evaluate it and present a report to the European Parliament and Council.

29 *The European Research Infrastructure Consortium (ERIC)* (Annex A11).

7.3. FISCAL REGIME IN THE CANARIES FOR THE EST

This section sets out the fiscal regime (national taxes, customs charges, etc.) that would apply to the entity managing the EST project if it were located at the ORM or OT. This differs significantly depending on whether the entity is an International Organisation or is constituted under Spanish law, the two most likely models.

Article 12 of the Agreements for Cooperation on Astrophysics provides for tax breaks for entities established at the ORM/OT including:

a) Spain authorises the import and export with exemption from customs and other duties of any apparatus, materials and goods, including accessories, parts and tools, whatever their country of origin, considered necessary for the construction or operation of the Observatories and the telescopes installed at them. These items of equipment, materials and goods would also be exempt from any taxes whilst in Spain.
b) The Agreement also allows temporary import and export of the furniture and personal effects (including a family car) of non-Spanish scientists and their families moving to or from Spanish territory for work covered under the Agreement, with exemption from customs and other applicable taxes and duties on temporary import and export and with no requirement for a deposit or guarantee.
c) The relevant procedures and formalities in Spanish law will be complied with and applied as quickly as possible to put these measures in place.

The specific fiscal rules pertaining to each entity in addition to those already mentioned are as follows:

A. Fiscal regime in the Canaries for the EST if managed by an ERIC

If the EST is managed by an ERIC, this organization would attract the regime applicable to International Organisations (IO) in Spain in line with international practice in this regard and as provided for under Spanish law.

The relevant legislation governing fiscal privileges arrangements for an ERIC-EST if constituted as an IO in the Canaries, is contained in *Royal Decree 3485/2000 of 29th December, on allowances and exemptions of diplomatic, consular and IO* (developed with the *Order of the 24th May 2001 which establishes the limits of allowances and exemptions of diplomatic, consular and IO*), which set out the tax breaks provided for such entities under national law.

Exemptions under RD 3485/2000

Before listing these exemptions it is worth drawing attention to the fact that RD 3485/2000 allows for them to be refined, restricted or expanded as established by any international Agreements or Pacts in force (including the Headquarters Agreements signed by Spain and the IO establishing its headquarters in the country). This means that the following list is not immutable and will not necessarily apply in its entirety but can be adapted on a case-by-case basis.

a) Import Duty Exemptions

As provided for in Article 2 the import of the following goods will be exempt from all classes of duties and taxes (VAT, customs duties and, in the Canaries, the Common Customs Tariff –CCT–, a type of duty applicable to products from both third party countries and countries within the EU):

- Goods needed for the official use of the international organisations recognised by Spain, with limits and conditions as imposed by the international Conventions governing such organisations or by the headquarters Agreements signed by them.
- Goods for communal use by members with Diplomatic Status of international organisations with headquarters or offices in Spain; these benefits also extend to family members forming part of their household and include goods imported to assist with their resettlement. These measures do not take precedence over any other limits or conditions established by the relevant international Agreements, which remain in force.
- Furniture and effects for use by the administrative and technical personnel of the international organisations with headquarters or offices in Spain, as well as their household family members provided that they are neither of Spanish nationality nor reside permanently in Spain, are imported as a result of their relocation to Spain in order to take up work. Goods must be imported within one year from the date on which the worker takes up his or her position.

Exemption from duties and taxes does not extend to storage, transport or similar costs. These provisions do not apply to objects and articles prohibited for import into Spain.

b) VAT exemptions for delivery of goods, services rendered and intracommunity acquisitions

These are covered under Article 3 but, as VAT is not charged in the Autonomous Community of the Canaries due to its special tax regime it is not discussed here, although the provisions are identical to exemption from Canaries General Indirect Tax (IGIC) which is dealt with separately.

c) Exemption from Canaries General Indirect Tax for delivery of goods and services rendered

Article 4 of RD 3485/2000 provides that in their respective territorial areas, arrangements for IGIC will be the same as those for VAT in Article 3.

The following are therefore exempt from IGIC:

- Delivery of goods listed as exempt from duty in section a).
- Handing over or rental of buildings or parts of buildings and any land pertaining to them, purchased or rented by the IO for use as headquarters offices.

The exemption extends to any works required, regardless of any need to procure materials, which are directly arranged between the IO and the contractor, to build, modify, expand or refurbish the said buildings, and for repair or conservation works with a value, for each single task, over €751.26.

- Delivery of office materials for official use when the total amount of goods listed in each invoice exceeds (€300.50).
- Water, gas, electricity and fuel supplies, telephone and telegraph services at the IO's premises.

These exemptions do not take precedence over any other limits or conditions to which the IO is subject through the headquarters agreement, which remain in force.

For the purposes of any international Agreement or Treaty, which only recognise exemption from duties on transactions deemed significant, this will be defined as any transaction with a tax base greater than or equal to (€300.50).

It is important in this context to be aware that Law 19/94 on *Modification of the Economic and Fiscal Regime in the Canaries* contemplates exemption from IGIC for the delivery of investment goods, under certain conditions, it being understood that this benefit derives from the Canaries fiscal regime and is not a diplomatic privilege.

d) Internal exemptions from Special Production Taxes

Manufacturing products whose import was exempt from Special Production Taxes as stated in section a) will be exempt from these taxes.

In the Canaries these taxes are:

- Taxes on the import and delivery of merchandise in the Canaries: levied on the production and import of movables.
- Special duties on alcohol and beer.
- Special Canaries tax on oil-based fuels.

e) Exemptions from Property Transfer Tax (ITP) and Stamp Duty (AJD)

As provided for in Article 1 of RD 3485/2000, exemptions from Property Transfer Tax and Stamp Duty with regard to onerous property transfers for international organisations, will be applied in accordance with the terms of section B.1 of Article 45 of the Revised Text of the Law on Property Transfer Tax and Stamp Duty- ITP/AJD (Royal Legislative Decree 1/1993, of 24th September).

This precept indicates that "transfers and other acts and contracts on which exemption is conferred by International Agreements or Treaties which have become part of internal rules" are exempt from this tax.

On this point, it is important to take into account that Law 19/94 on *Modification of the Economic and Fiscal Regime in the Canaries* allows for exemptions from Property Transfer Tax and Stamp Duty (ITP/AJD) on the constitution or expansion of companies and (regarding this point) on goods or rights acquired in the Canaries which means that this benefit derives from the Canaries fiscal regime and is not a diplomatic privilege.

f) Cars

Article 12 of RD 3485/2000 provides for exemption from all duties and taxes on the import, delivery or acquisition of the following vehicles within the EU:

- Cars imported or acquired by international organisations with headquarters or offices in Spain, within the limits and conditions defined by the relevant international Conventions.
- Cars imported or purchased by staff with diplomatic status working for the international organisations with headquarters or offices in Spain, for their personal use and that of their spouse and children, provided that they are living with and are financially dependent on the same, are not engaged in any economically productive activity in Spain and are duly accredited and documented by the Ministry of Foreign Affairs, except where the headquarters Agreement determines that other conditions shall apply.
- Cars imported or acquired, in quantities determined by the Ministry of Finance, by technical or administrative staff working for the international organisations with headquarters or offices in Spain, provided that they are neither of Spanish nationality nor permanently resident in Spain and are duly accepted and documented by the Ministry of Foreign Affairs in the corresponding categories. However, when the international Conventions governing international organisations or their headquarters Agreements set out other limits or requirements, these will apply to the technical or administrative staff at international organisations.

The definitive registration in Spain of vehicles listed in previous paragraphs will be exempt from Special Transport Tax, provided that the conditions described above are complied with. Acquisition is defined as any act or legal transaction allowing the registration of the said cars in the name of the persons or entities previously mentioned.

Persons or entities benefiting from the exemptions described in this article cannot be holders of cars imported under temporary import regulations.

g) Local taxes

The Headquarters Agreement ultimately signed may render the IO exempt from local direct and indirect taxes.

B. Fiscal regime for the EST in the Canaries if managed by an entity under Spanish law

However, if it is decided to create a specific entity under the ambit of Spanish legislation, whether national or Canaries, for managing the EST (such as a foundation or a company), the fiscal regime applicable will not be as described above for International Organisations as this new entity will have its own legal personality in Spanish law and will therefore have none of the diplomatic privileges of an OI.

Fiscal Regime in the Canaries

It follows that the regime applicable would be the same as for all entities constituted in the Canaries under Spanish law, as determined by Law 19/94 on *Modification of the Economic and Fiscal Regime in the Canaries*, which can broadly be summarised as follows:

a) Canaries General Indirect Tax (IGIC)

IGIC has been levied since the 1st January 1993 and is an indirect tax on the delivery of goods and provision of services by companies and professionals as well as on the import of goods, within the territories of the Canary Islands.

This tax is applied in lieu of VAT and the most significant differences are:

1. Lower rates:
   - 0%: water, medicine, books, teaching materials etc.
   - 2% reduced: fuel extraction, petroleum, oils, textile manufacture, footwear etc.
   - General: 5%
   - Increased: 9% and 13%
   - Special 20% rate (brown tobacco) and 35% (blond tobacco).
2. Transactions subject to the tax whose trading volume is lower than the limit indicated are exempt.
3. The regime for transactions within the EU is not applicable.
4. For the purposes of IGIC imports are defined as the entry of goods into the Canary Islands from mainland Spain, the Balearic Islands, Ceuta, Melilla, any other EU Member State or Third Party Countries, regardless of their intended use or the status of the importer. Import is also defined as permission to consume goods in the Canaries that are subject to temporary import regulations, in transit, active improvement in the sus-

pension system or storage or in duty-free zones and depots.

b) Common Customs Tariff (CCT)

This duty is applied to products from third party countries as well as to products from EU countries.

c) Other Indirect Taxes

- Duty on import and delivery of merchandise in the Canaries: levied on the production and import of movables.
- Special Canaries tax on oil-based fuels.

d) Main tax incentives provided by Law 19/94

- Exemption from Property Transfer Tax and Stamp Duty (ITP/AJD) for the constitution or expansion of companies and the acquisition of goods or rights in the Canaries.
- 50% bonus on Corporation Tax and Personal Income Tax on profits from export to third party countries or the export of tangible goods to the rest of the EU.
- Exemption from IGIC for the delivery of investment assets under certain conditions.
- Up to 90% reduction of the tax base for Corporation Tax of undistributed profit destined for investment reserve.

Fiscal regime for Foundations

If an entity were created within the ambit of Spanish law the most likely legal format would be a Foundation. The fiscal regime that would be applicable in this eventuality is therefore briefly examined below. This is effectively the type of entity already being used to manage some of the installations at the ORM because of the large number of tax benefits pertaining to it. These derive both from national and Canaries legislation and even local regulations.

The main body of the fiscal regime applicable to Foundations is found in *Law 49/2002, of 23rd of December, on the tax regime for non-profit organisations and financial incentives for sponsorship.*

Foundations are therefore subject to Corporation Tax –but not to Property Tax– for profits from non-exempt economic activities (i.e. not included in the closed list in Article 7 of Law 49/2002) but at a rate of 10% as opposed to the 35% paid by companies, although the tax base is not the same.

Article 6 of the Law declares that the following incomes generated by non-profit enterprises are exempt from Corporation Tax:

1. From the following types of income:
   a) Donations and gifts received in support of the aims of the entity, including contributions or donations conceived as asset allocations and economic aids received by virtue of agreements for commercial collaboration provided for in Article 25 and contracts for

sponsored advertising as defined by the General Advertising Law.

b) The quotas met by the associates, collaborators or benefactors, provided that they do not correspond to the right to receive benefits deriving from non-exempt economic activities.
c) The subsidies except those destined to finance non-exempt economic activities.

2. Proceeds from the entity's immovable and movable property, including dividends and company profit shares, interest, fees and rents.
3. Proceeds from acquisitions or transfers, by any title, of goods or rights, including those obtained as a result of the dissolution or liquidation of the entity.
4. Proceeds from exempt economic activities referred to in Article 7 (including section 3 which cites scientific research and technological development).
5. Those, in line with the tax regulations, to be attributed or imputed to non-profit entities and derived from exempt incomes included in some of the sections above.

They may also be exempt from local taxes, like Property Tax, Business Tax and Land Value Capital Gains Tax.

A Foundation shall also be exempt, if exemption is requested and granted, from Property Transfer Tax and Stamp Duty. At any rate, it is not liable for Transfer and Gift Tax and Property Tax.

Except in certain cases there is no special arrangement for IGIC.

Donors do have tax relief on donations to Foundations that comply with the requirements. Without listing every possible eventuality, and in very general terms, it can be said that individual donors benefit of a 25% relief of the donation from Personal Income Tax. Companies can also include 35% of the donation in their Corporate Tax quota. There are also tax incentives available for collaboration agreements with Foundations as the amounts contributed are treated as a deductible expense for the collaborating entity.

Law 2/1998, of the 6th April, on Canaries Foundations, in its Additional Second Regulation, provides that "without prejudice to the exemptions and other fiscal benefits provided for in national legislation, Foundations subject to the current Law may access aid through tax arrangements and favourable access to public subsidies specifically established for the purpose by the Canaries Autonomous Community".

This means that Canaries Foundations can receive all of the benefits established in national legislation and also other benefits allowed for by the Government of the Canary Islands.

8.

ECONOMY AND INDUSTRY IN THE CANARIES

This section provides a brief analysis of the current economic situation in the Canaries and the make-up of its business sector, with the aim of enumerating the services that would be available to the EST during its construction and operation.

8.1. CURRENT ECONOMIC SITUATION IN THE CANARIES[30]

The level of economic development experienced by the Canaries in recent decades has been spectacular; rates commonly seen in developing countries have been replaced by rates frequently seen in the most developed countries. However as a consequence of the combined effects of the international financial crisis since the beginning of 2008 growth in the world in general, and particularly in the Canaries, has depleted considerably. It is now vital for a new economic and financial framework to be established to reinstate sustainable, balanced growth. Experts agree that plans must be made for improving production and increasing employment in the Canary Islands and diversifying their economy.

The predominant economic sector in the Canary Islands, which grew extraordinarily until the crisis struck, is the services sector (Graphic 4) and specifically tourism, which is still the main engine of the Canary Islands' economy. The primary sector has been gradually reduced over the last decades.

Taking each sector in turn, the service sector employs more than three quarters of the total workforce, in line with its contribution to overall production in the Canary Islands (Graphic 5).

The most recent data available for RTD show that there are 622 companies operating in this sector in the Canaries (0.4% of the total) compared to 17,905 nationally (0.5% of the total).

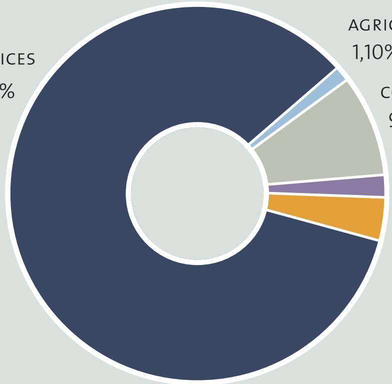
This sector has also grown in recent years although at a slower rate than the national average (spend on RTD in the Canary Islands was at 0.48% of GDP in 1995 and had grown to 0.58% by 2009 compared to an average of 1.38% nationally). A noteworthy feature of RTD in the Canaries is the fact that only 19% of investment in RTD comes from the private sector, whereas in Spain as a whole this figure is 55% and the target for the EU envisaged by the 2020 strategy is 66%.

The Islands have unique features that encourage innovation. These include:

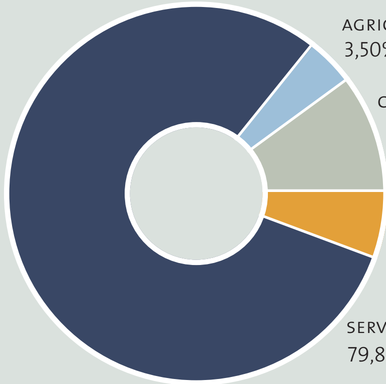
- the geographically strategic position of the Canaries as an Atlantic region with potential for internal development;
- the landscape and climate of the Canary Islands, which have made them a perfect tourist destination;
- their unique financial and fiscal arrangements, which make them very attractive financially;
- the presence of universities;

30 This section is based on the Report of the Economic and Social Council of the Canaries on the economic, social labour and situation of the Canary Islands in 2009. June 2010.

Graphic 4. The Canary Islands' economy by sector. 2009



Graphic 5. Structure of employment in the Canary Islands in 2010. ISTAC



- and the significant concentration of science and technology centres in the Canary Islands, with a range of different specialisms (astrophysics, electronics, information technology, renewable energy, water, geology, biology, agricultural sciences, medicine and aerospace technology).

If the EST is sited on either La Palma or Tenerife it will also generate incentives for a new wave of industrial growth, not just on the island but in the region and the whole country, favoured by the profits to be made from its construction, the demand for parts, electrical and mechanical supplies and the maintenance and operation activities needed for a project of this kind.

8.2. INDUSTRIES IN THE CANARIES FOR THE EST

To review the industrial sector present in the Canaries for a project like the EST, data from ORM institutions is given below (*this information is not available for the OT*). As there is much similarity between the services and materials used by the existing facilities and those which will be needed to build and operate the EST, these statistics provide information on the industrial capacity available for the new installation.

Table 7 gives a breakdown of budget estimates for the ORM for 2010. 62% of the costs are for companies in La Palma, 8% for companies elsewhere in the Canaries, 13% for professionals and/or companies elsewhere in Spain and 17% for international enterprises.

Table 7. Cost of the User Institutions by sector and location of subcontractor

Sector	ORM	Location of Subcontractor La Palma	Rest of the Canaries	Rest of the Spain	International
Scientific Research & Technology Development	4.600.00 €	73%	9%	9%	9%
Chemical Industry	175.00 €	90%	9%	0%	1%
Metallurgy Industry	2.700.00 €	25%	10%	25%	40%
Shop, restaurants, accommodation and repairs	1.000.00 €	100%	0%	0%	0%
Transport and communications	500.00 €	32%	10%	30%	28%
Building rentals	425.00 €	100%	0%	0%	0%
Other services	50.00 €	100%	0%	0%	0%
Energy	200.00 €	100%	0%	0%	0%
Total	9.700.00 €	62%	8%	13%	17%

These figures show that the most important business sectors for ORM activities (and thus the EST) include RTD, the chemical industry, metallurgy and precision mechanics, shops and hotels, transport and communications and real estate and other services.

These sectors include the services shown in the next page.

Research and Development

There are about 25 RTD companies in La Palma. However, given the experience available within other institutions there is not expected to be a strong local demand for this sector as RTD requirements can be met by the telescope staff.

Chemical Industry

There are 50 chemical companies in La Palma. Spending in this sector includes nitrogen supplies, helium, industrial oil, liquid coolants and diesel. 90% of these resources are procured from local companies, with 9% procured from elsewhere in the Canaries (helium comes from Tenerife).

The volume of nitrogen procured is particularly significant and this is currently produced by ING. ING has a nitrogen production plant with its own supply. It produces 2,000 litres of nitrogen per week. Given the increase in demand that will result from the EST, it would be financially feasible for a specialised company to open a branch on La Palma or to set up a service via a local enterprise with the ability to work with the required technology.

Metallurgy industry, Optics and Electronics

Services used by the ORM from this sector include optical design, optical instrument maintenance, optical treatments, hardware, software, electrical installation, electrical materials, electronic materials, precision me-

Chemical Industry

▪ Liquid Nitrogen ▪ Industrial oil ▪ Diesel ▪ Helium ▪ Deionised water ▪ Alcohols ▪ Liquid coolants ▪ Other gases

Transport and Communications

▪ Landline telephone ▪ Internet ▪ Mobile telephone ▪ Parcels service ▪ Post ▪ Staff see and air travel ▪ Vehicle hire ▪ Vehicle purchase

Metallurgy Industry

▪ Optical design ▪ Optical instruments ▪ Optical treatments ▪ Optical instrument maintenance ▪ Hardware and software ▪ Electrical installation ▪ Electrical materials ▪ Electrical instrument calibration ▪ Electronic materials ▪ Electronic equipment ▪ Electronics maintenance ▪ Precision mechanics ▪ Dimensional metrology calibration ▪ Mechanical design ▪ Hydraulics ▪ Climate control ▪ Goods lifts

Shops, restaurants, accommodation and repairs

▪ Hotels ▪ Restaurants ▪ Supermarkets ▪ Small business ▪ Vehicle maintenance

Other Services

▪ Fire prevention system ▪ Safety equipment ▪ Water supply and transport ▪ Congresses ▪ Training courses ▪ Events ▪ Other

Building rental

▪ Headquarters rental ▪ Various rentals (garages, staff apartments etc.)

chanics, dimensional metrology calibration, mechanical design, hydraulics, climate control, goods elevators and locksmiths.

Before the arrival of the GTC most subcontracts were issued to national and international bodies (88%) but the fact that 57% of the same expenditure for the GTC was awarded to companies in La Palma demonstrates that the island's industry is able to supply a proportion of the services needed, particularly parts manufacturing, electrical materials and installation, electrical generators, climate control and maintenance and optical treatments.

Hardware continues to be sourced from national and international enterprises, although it is possible to procure components on La Palma.

Estimates put the spend on La Palma for this sector at 25%.

Shops and hotels

For the ORM this sector covers spending on hotels, restaurants, supermarkets, small businesses and vehicle maintenance. 100% of this budget is spent on La Palma and this is expected to remain the same after the arrival of the EST. These are services that need to be provided in situ and the island's enterprises are perfectly capable of providing them.

Transport and Communications

There are 300 enterprises in La Palma providing transport and communications services. The ORM uses this sector for landline telephones, internet, mobile telephone, parcel delivery, post, staff travel by air and sea and vehicle hire and purchase.

The highest of these costs for the institutions at the ORM is staff travel. Current estimates put the proportion of transport and communications services sourced from local enterprise at 32%.

The existing infrastructure on the island (such as vehicle hire companies, sea and air transport facilities, communications networks, etc.) is believed to be adequate to meet demand from the EST.

Building rental

There are some 200 companies on the island of La Palma providing property services, making this one of the largest business sectors.

Spending in this sector by the ORM includes institutions' head offices at Santa Cruz de la Palma (head office rental) and, in some cases, rental of staff accommodation, garages and stores, etc.

Other Services

For the ORM, this sector includes lift maintenance, fire prevention, security equipments, conferences, events and courses and water transportation (bottled and in bulk containers).

100% of these services are sourced on La Palma and this is not expected to change after the arrival of the EST.

Energy

Electricity in La Palma is generated at the Los Guinchos power station in Santa Cruz de La Palma, and the hydroelectric plants at Salto del Mulato, Argual and San Andrés y Sauces, all of which are currently owned by UNELCO-ENDESA. The capacity of the ORM supply is currently 3 MW and new projects are expected to increase power.

100% of these services are sourced on La Palma and this is not expected to change after the arrival of the EST.

In conclusion, expenditure by ORM user institutions demonstrates that local enterprises in the Canary Islands have the capacity to deliver some 70% of the services, materials and supplies needed for building and operating the EST. Main shortages are found in goods and services provided by specialist sectors including computer hardware, electronics, optical and other components, new technology development and large industrial contracts.

The economy of the Canary Islands is dependent on the services sector and it needs investment and backing from projects like the EST to diversify into the knowledge society, widen its industrial offer and increase investment in RTD.

Industry in the Canaries is currently able to meet 70% of the demand for services needed to operate the EST.

9. INDUSTRIAL AND SOCIO-ECONOMIC IMPACT

9.1. EST CONSTRUCTION AND OPERATING COSTS BY GEOGRAPHIC AREA AND ECONOMIC SECTOR

9.1.1. EST construction phase

The budget for the EST construction phase is approximately 135 million euros. This section describes the major impact that the EST is expected to have on socio-economic development in the host region (Canary Islands) and the financial and industrial opportunities that it will provide for the rest of Europe.

THE CANARY ISLANDS

The industrial return expected for the Canary Islands, related to the installation of the EST in this region, can be estimated with some accuracy based on a set of assumptions.

- Minimum return for the Canaries: 19%, or around €25 million.

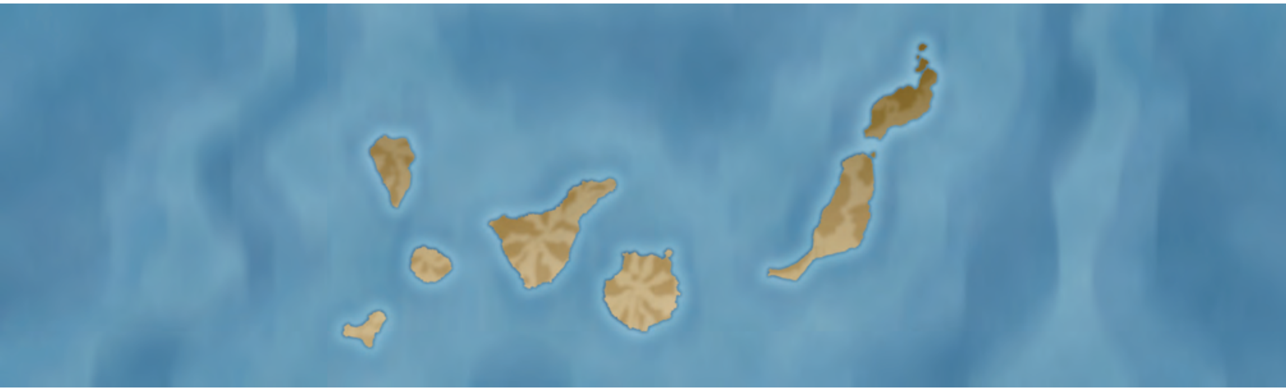
  Civil works, the project office, tests in situ, component transport and a proportion of the contingency funds are all likely to be sourced from local companies and they represent around 19% of the total construction budget.
- Maximum return for the Canaries: 25%, or around €34 million.

  This 6% increase would result from a higher level of local involvement in instrument development, through the establishment of new technology companies, and a slight increase in the proportion of minor items and contingency funds. Although the return from involvement in instrument could theoretically be higher, this is unlikely as the EST will be a highly collaborative project and it is foreseen that all of the EAST institutions will be highly involved.

EUROPE

European industry's capacity for delivering technology for cutting edge telescopes is evidenced by its involvement in large scientific facilities construction projects like those related to the ESO, (VLTs, E-ELT, ALMA, etc.) or those at the Canary Islands' Observatories, telescopes like MAGIC and the GTC. The knowledge gained in the area of technical requirements for solar telescopes (like turbulence, thermal issues, etc.) is worthy of special mention, particularly with regard to telescopes like the VTT, GREGOR, THEMIS, SST and DOT, all of which are at the Canary Islands' Observatories. The part currently being played by European industry in the EST conceptual design is also noteworthy. This augurs well for positive and successful responses to future tender invitations for the EST.

A survey of current European enterprises reveals that they have advanced knowledge, not just for civil works and basic technologies but also in fields like telescope mechanics, dome, optics, primary mirror support system, design and manufacture



of the secondary mirror actuators, and design and manufacture of the edge sensors for the primary mirror. They have also gained wide-ranging experience of next generation telescope instrument design and development.

If the EST is sited in the Canaries it will be possible to chart its impact on the region in detail. However, quantifying the industrial and economic returns from its construction for enterprises across Europe (including the rest of Spain) is a more complex exercise. The high degree of technological capacity that will be called for, together with the absence of a funding vehicle for its construction that could determine the scale of each country's involvement, means that it is impossible to provide realistic estimates of the returns that could accrue to each country.

Nonetheless, as a first attempt and assuming that proportional financial backing is received from the different countries involved in the EST, a minimum return for each country could be envisaged of between 2% and 10% of the construction budget, weighted by factors including the relevance of its solar physics community, the type of contribution made (in-kind or cash), the level of resources currently earmarked for solar physics and its industrial capacity. Countries within the EU with the highest levels of technological capacity could see industrial returns from the EST of somewhere between 20%-30%. Spain, as the host country, could see returns above 30%.

The financial returns for the whole of Europe (excluding the Canaries) are significant under all of the scenarios suggested for the Islands, at least 75% and up to 81% of the construction budget for the EST. The high level of involvement of European institutions (through EAST) and industry in the current conceptual design phase, and their commitment to the subsequent preliminary design phase, suggest that economic returns are likely to be shared widely among the different countries involved.

EST CONSTRUCTION AND OPERATING COSTS BY GEOGRAPHIC AREA AND ECONOMIC SECTOR

The construction budget for the EST gives a preliminary breakdown of the different component costs of the telescope (civil works, dome, telescope mechanics, optics etc.). The budget has been broken down into the following areas to facilitate detailed analysis of the economic impact of the project.

Electrical, electronics and optical industries includes the main costs of manufacturing the primary and secondary mirrors, the adaptive optics systems, the transfer optics, the optical and electronic components of the different instruments, the control systems electronics and all of the other elements of the telescope, as well as assembly and testing of all of the different elements. The estimated costs under this heading are in the region of 51 million euros.

Technical consultancy relates to costs for architecture and engineering specialists. During the construction phase these costs will be high, and include the first year of testing and dealing with various contingencies. It is estimated that some €17 million will need to be allocated for this budget heading during the construction phase.

Research and Technology Development includes the cost of EST staff and costs related to the technological advances that will be needed to build a facility like the EST, which is at the limits of current technology. It is estimated that some €8.8 million will be needed during the construction phase for this budget heading.

Machine and mechanical equipment manufacturing industry includes the design, construction and installation of the telescope's mirrors, its mechanical structure and control systems and the scientific instruments, adaptive optics. It is estimated that some €14.3 million will need to be allocated for this budget heading during the construction phase.

Construction includes civil works costs and the cost of building the dome. The ultimate level of investment by geographic area will depend on the results of the international calls, although even when the winner is a foreign company much of the budget will be spent in the local area. It is estimated that some €10 million will need to be allocated for this budget heading.

Metallurgy and manufacturing industries (metal, concrete, etc) includes the manufacture of parts of the dome, the telescope pillar, mount and other materials used during construction.

Computer activities include developing all of the control equipment for the telescope and its buildings and assembling and testing them.

Transport and communications includes the costs of transporting materials and staff for the EST construction project. The cost of

Table 8. Percentage estimates of investment in the EST construction project by geographic area.

Investment percentages for the EST construction phase by geographic area and sector		% range of spend Minimum and maximum limits by geographic area and sector	
	Investment (M€)	The Canaries	Europe (including Spain but excluding the Canaries)
Electric, electronics and optical materials and equipment industries	51	0-3%	97-100%
Architecture and engineering technical Consultancy	17	62-70%	30-38%
Machine and mechanical equipment manufacturing industry	14.3	1 -15%	85-99%
Construction	10	100%	0%
Research and Development	8.8	6 -9%	91-94%
Computer activities	8.4	5-6%	94-95%
Metallurgy and manufacturing industries (metal, concrete, etc.)	18	15-28%	72-85%
Transport and Communications	4.7	9-13%	87-91%
Other sectors	2.8	35- 41%	59-65%
Total	135	19%-25%	75%-81%

these activities during the construction process is estimated at 4.7 million euros.

Other sectors include estimated costs in sectors like chemical industries (nitrogen, helium, industrial oil, coolants and diesel) water supply and treatment, accommodation and other minor costs. €2.8 million is estimated for these costs. This cost will be split across the geographical areas being analysed.

Table 8 shows the breakdown of the total construction budget by the cost headings shown above, together with estimates for the proportion that could be spent in the Canaries as the host region.

In conclusion, at least €25 million could return to the Canaries (as the host region) during the EST construction phase. The best-case scenario for the Canary Islands would be a return increased up to €33 million.

9.1.2. EST operating phase

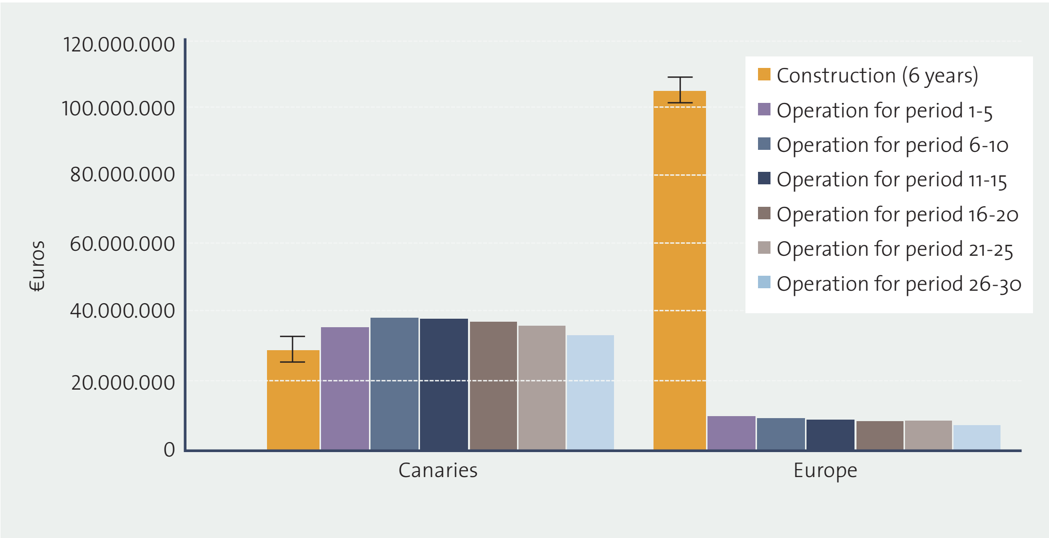
As stated above, the cost of operating the EST will be approximately 7% of the construction budget. A budget of €9 million is therefore estimated. This will cover activities relating to the operation and maintenance of the telescope as well as the potential development of new instruments.

In section 2.1.3 an estimate was given for operating the EST, broken down into different headings (staff, materials, service contracts and direct costs of operating the telescope), with the conclusion that 9 million euros would be needed to operate and maintain the EST at the ORM or OT. The headings are listed again below with an estimate of the proportions that would be spent in the Canaries as host region and which percentages would go to other parts of Europe. It leads to the conclusion that approximately €7 million would be spent annually in the Canaries (operation and maintenance at the site) whilst a further €2 million would be spent in other parts of Europe.

This is based on the following assumptions:

- 100% of the EST operations team will be directly recruited. 70 people are expected to work at the EST.
- Most of the spare parts and mechanical and electrical supplies needed for routine operations and maintenance at the EST (80%) will be procured from within the Canary Islands. Only some very specialist parts, like some of the optical or electronic components, will need to be supplied by companies outside the islands.
- Most of the supplies needed at the telescope, like water, electricity, liquid nitrogen, diesel, etc. will be sourced from within the Islands, as will other services like cleaning, air conditioning maintenance, electrical maintenance etc. Other more specialist services for maintaining and developing optical and electronic equipment will have to be sourced from outside the islands. It is estimated that 70% of services (in addition to the electricity and water supplies and the communal services provided at the Observatories) can be procured from within the Islands.
- It is to be hoped that a significant number of researchers at EAST member institutions will come to the Canaries for short work trips. It is difficult to estimate, at this point in the project, the number of observers and staff from institutions participating in the operation of the telescope that might come to the Canaries each year for this purpose. However, it is possible to foresee some 200 visits per year by such staff, for an average of five days, at a cost of €150 per day for food and accommodation.
- To promote close working relationships between EST staff and staff from the user institutions, a large number of visitors will also come to the Canaries for stays of weeks or months at a time. We estimate that there could be some 30 visits of a month each year, on average, again at a cost of €150 per day.
- There will also certainly be regular meetings and seminars on science and technology related to the EST in the Canaries, as there are for other installations at the ORM and the OT. These events can be technical, focusing on new techniques and instruments; strategic, on the aims and future of the telescope; or purely scientific, on the

Graphic 6. Economic returns from the construction and operation phases of the EST, taking into account the uncertainty of estimates for minimum and maximum returns for the host region (Canary Islands) and other European countries involved in the project (including Spain but excluding the Canary Islands) during the construction phase



results that will be achieved with it. Based on previous experience, there are likely to be around 4 meetings of 50 people, over an average of 4 days, each year. The cost of this per person would be more than double that for individual visits. The estimated cost of each conference (organisation, conference room hire, refreshments etc.) is around €75,000.

Analysis of the operating costs, including maintenance, improvements, supplies and services, confirms that most of these items can be provided at more competitive prices by companies in the archipelago than those elsewhere in Europe. It is assumed that the management organisation for the telescope will also be based in the Canaries for operational reasons

Graphic 6 gives a breakdown of estimated operating costs, grouped in 5-year periods, together with an estimate for the construction costs, by geographic area.

In conclusion, the projected direct returns for entities in the host region during the operating phase are very positive, as a high proportion of the investment for operating the telescope will be spent in-situ. Although initially there is no provision for the development of new instruments, only part of the materials needed, together with some specific subcontracts (computer hardware, optical design and treatments, manufacture of specific components etc) would need to be procured from outside the Canary Islands.

Operating and maintaining the telescope could therefore generate direct economic returns for the region of around ~7.35 million Euros per year (80% of the estimated operation and maintenance budget) during the 30 year period, the anticipated life of this facility. In other words, some €220 million (year zero Euros) of the total €275 million operating budget.

The return for other European regions is estimated at some €55 million, with the final distribution dependent on the type of services to be provided (maintenance, technical support, instrument development, etc.) as well as the terms and conditions set for contributions to the EST project.

Table 9 provides a forecast for economic returns by activity for the Canaries whilst the EST is in operation, with current data from the conceptual design phase.

Table 9. Financial returns for the Canaries from operation and maintenance of the EST

Activity	Economic return/year
Direct employment	~€500 million
Materials and supplies	~€0.75 million
Service contracts	~€1.25 million
Residential stays, visits and meetings	~€0.35 million
TOTAL	≈ €7.35 million

9.2. ECONOMIC IMPACT OF BUILDING AND OPERATING THE EST IN THE CANARIES

As described above, the EST project will require a direct investment of around 135 million euros for the six years of the construction phase and some 275 million for operation and maintenance over the subsequent thirty year period.

This section examines, using estimates given above, the effect on GDP in the region (Canaries) and the number of jobs per year that will be created.

Separate analyses are given for the construction and operating phases. No assessment is made of the dismantling phase at the end of the telescope's useful life, although this will undoubtedly have an economic impact.

The method chosen to produce the estimate of these indirect effects, using the information available, is the Input-Output model. To apply this method, which is described briefly below, we have taken as a basis the latest tables for expenditures and revenues of each branch of economic activity that are available for the Canaries (2005).

This methodology, together with a high level of uncertainty in the estimates for returns for individual EAST countries, does not allow realistic projections for impact on GDP and employment across the EU, either as a whole or country by country. This report therefore focuses on the project's immediate area (the Canary Islands).

This section is a summary of the report "Impact of building and operating the EST on the Canary Islands using input-output tables", which was produced by Dra. E. Valle Valle (UIB, 2010)[31]

9.2.1. Methodology. Input-Output Analysis

The input-output tables give an overall but disaggregated view of a specific economy within in a territory, so that interaction between different sectors contributing to the domestic and external economies can be seen.

These tables are in double entry format, listing the value of flows of goods and services in the economy of a particular area. They also contain three sub tables: Intermediate Consumption, Final Uses and Primary Inputs and Resources.

The rows in these tables correspond to the different uses of products in each sector, and whether they are intermediate or final. The first shows the demand for production of a defined good in each of the other production sectors. Final use (final demand) shows final consumption for the good, as well as its contribution in the form of gross capital formation and exports. The ends of each row give the total demand for each production sector, in other words the sum of intermediate and final demand.

On the other hand, columns show the resources used for effective production in each of the sectors. Two classifications are used. The first refers to intermediate consumption, in other words resources procured at each branch of production. The second, primary inputs, shows the different elements of gross added value (GAV) for each branch and for imports.

The columns show how available resources are acquired for each production sector in the region being examined. In summary, these tables give the account balance expressed in table 10.

Table 10. Resources and Uses

Resources (columns)	Uses (rows)
1. Intermediate Resources	1. Intermediate Products
2. Added Value	2. Final Consumption
3. Effective Production (1+2)	3. Gross Capital Formation
4. Imports	4. Exports 5. Final Demand (2+3+4)
5. Total Resources (3+4)	6. Total Uses (1+5)

31 "Impact of building and operating the EST on the Canaries and Spain using input-output tables" (Annex A12).

These tables therefore show defined interactions in the production system. Specifically, to calculate the effect of an investment, technical coefficients, and particularly its inverse matrix, are used.

Technical coefficients are basically the percentages of each input that are directly consumed to produce the sector's outputs. The technical coefficient matrix can thus be used to calculate the inputs that each industry has absorbed for any given amount of final demand.

Technical coefficient between sectors *i* and *j*,

$$a_{ij} = \frac{x_{ij}}{X_j}$$

Where x_{ij} is the number of units that sector *j* needs from sector *i* and X_j is the production output of sector *j*.

Technical coefficients can therefore be used to determine the direct quantity of inputs needed per unit of output. The index of interaction between sectors is shown as indirect needs. The inverted technical coefficient matrix therefore provides the indirect coefficients. This matrix is known as the Leontief Inverse Matrix. It shows production as a function of final demand.

In summary, the technical coefficients represent the proportion of intermediary purchases and sales relative to total production and demand. The inverse matrix coefficients also take in all of the indirect transactions arising from changes in demand.

Mathematically, the formula for the Leontief model is as follows:

$$X = A * X + D \quad [1]$$

where *X* is a vector column of total inputs of the *n* productive sectors, *A* is the technical coefficient matrix and *D* is the vector column of final demand.

Applying expression [1] gives us:

$$X - A * X = D$$
$$(1 - A) * X = D$$
$$(1 - A)^{-1} * (1 - A) * X = (1 - A)^{-1} * D$$

and finally,

$$X = (1 - A)^{-1} * D \quad [2]$$

with $(1 - A)^{-1}$ being the above-mentioned Leontief inverse matrix.

Using a vector column containing the inversions resulting from a particular project in the relevant sector, application of the Leontief inverse matrix will give all of the direct and indirect effects that these investments have had on the economy of the area under examination. If the investments vector column is labelled Y and the column containing the direct and indirect effects R, then the formula is as follows:

$$R = (1 - A)^{-1} * Y$$

In addition to impact on the local economy, the structure of these tables allows estimates to be made for the indirect effects on the external economy and in the case of investment in the Canary Islands, this means that the effect on the economy of the rest of Spain can be calculated (the

The INPUT-OUTPUT MODEL as a method to quantify the economic impact of the EST on the Canaries

Wassilly Leontief, winner of the Nobel Prize in Economic Sciences in 1973, is credited with creating the first input-output table for the American economy. Since then an infinite number of tables have been produced for many different countries and purposes. SNA-93[32] and SEC-95[33] view these tables as an essential tool for producing National Accounts[34].

Regional IO tables first appeared half a century ago in the pioneering work of Walter Isard (1951 and 1960) and his collaborators. In Spain, the first regional tables appeared during consolidation of the political and administrative decentralisation process initiated in 1978.

The main aim of input-output analysis is to look at the productive interrelations between different branches and sectors of an economy, with a much higher degree of disaggregation than is normally used in applied economic studies. This means that they are expensive to produce.

Input-output analysis is a label covering a range of very different applications (for a more detailed description see Pulido and Fontela, 1993). The common hypothesis of the majority of these applications is that the structure of production in each sector can be represented by fixed technical coefficients and constant scale returns. This is also known as the Leontief's production function. This hypothesis and the idea that producers minimise production costs makes it possible to specify the fixed coefficients for each sector using the information provided by input-output tables for flows between sectors and payments for primary factors. There are many limitations, which have been widely documented in the literature: they do not allow for the range of factors to be limited, nor for the reassignment of factors between sectors; there is no interaction between markets, no price flexibility and the behaviour of economic agents is not taken into account. However, in spite of these limitations, this method is a basic ingredient for understanding the structure of an economy and helping its regulators to make decisions.

This methodology is frequently used to quantify the economic effects for the rest of the economy of certain public investments and the performance of some infrastructures. It is a useful method for quantifying the effect that a specific economic factor has on the rest of the economy. Some concrete examples of its application to the Canary Islands' economy are the economic impact assessments for the airports in Gran Canaria (De Rus, et al. 1997) and Tenerife. It has also been used for impact assessments on tourism in the Canaries (Hernández, 2004). At the national level it has been used in many different studies, one of the most noteworthy of which is the "Socioeconomic impact assessment of Spanish science and technology parks" recently published by the Spanish Association of Science and Technology Parks (APTE), and funded by the Ministry of Education and Science (MEC).

32 The *System of National Accounts* manuals (SNA) set out the general structure and classification and accounting criteria for the production of national accounts. The last revision in 1993 (SNA-93) presented the results of a working group comprising experts from the world's principal international statistical organisations (EUROSTAT, OECD, IMF, World Bank and UN)

33 In 1996 EUROSTAT published the manual *Système européen des comptes. SEC95*, which aimed to harmonise the national accounts of EU countries with the guidelines set down in SNA-93. During the 1980s and the first half of the 1990s the accounting practices of EU and other countries was adjusted to the criteria contained in the European System of Integrated Economic Accounts.

34 See SNA-93, pg. 343, Cañada (1997), pgs. 57-8 and Carrasco (1999), pg. 278

2005 IO tables for Spain were used for this calculation).

As well as the product, the number of jobs created by an investment can also be calculated. Impact on employment is estimated as follows: *L* is defined as the vector column obtained by dividing the number of people employed by the total amount of production for each sector. This formula gives the number of people employed in each sector for each million Euros of production. It can be used to obtain the number of jobs created in each sector after a particular investment has been made.

The vector *L* can then be multiplied by the total impact vector *R*, to give the number of jobs created in a year as a result of the investment. In this method, a job created is defined as a job that lasts for one year.

Economic impact assessments carried out using the input-output model and other relevant articles

Burgos Martín, J., Martínez Roger, C. Barcons, X., Del Cerro Gordo, A. B., Herrero Davó, A., Lecuona Ribot, A., Martínez Benítez, A., Mas Hesse, M., Muñoz Tuñón, C., Ruiz López de la Torre Ayllón, L.E., Serrano Ariza, M., Torra Roca, J., Varela Conde, M., Valle Valle, E. (2009). *Scientific, technical, industrial and socio-economic aspects of the European Extremely Large Telescope E-ELT at the Roque de los Muchachos Observatory, La Palma*.

APTE (Asociación de Parques científicos y Tecnológicos de España). *Study of the socio-economic impact of Spain's science and technology parks*. Málaga. España.

Cañada Martínez, Agustín, 1997, *Practical introduction to national accounting and the input-output framework: a computer assisted manual*. Madrid: INE.

Carrasco Canals, Fernando, 1999, *Fundamentals of the European system of national and regional accounting (SEC 1995)*. Madrid: Ediciones Pirámide, S.A.

De Rus, G., L. Trujillo, C. Roman y P. Alonso, (1997): *Economic impact of the airport in Gran Canaria*. Civitas Ediciones, S.L. (ISBN 13:9788447007202)

Gutiérrez, P., L.J. López y M. Navarro. *Economic impact of the airports in Tenerife on the surrounding area: analysis of passengers using the airports on the island of Tenerife*.

Hernández Martín, Raúl (2004). *Economic impact of tourism. The role of imports as outputs of the model*. ICE Sector exterior español.

Isard, W., 1951, "Interregional and regional input-output analysis: A model of space economy", *The Review of Economics and Statistics, 33*, págs. 318-328.

Isard, W. et al., 1960, *Methods of regional analysis: An introduction to regional science*. Cambridge, Mass.: MIT Press.

Pulido, Antonio y Emilio Fontela, 1993, *Input-Output Analysis. Models, data and applications.* Madrid: Ediciones Pirámide.

9.2.2. Direct, indirect and induced effects on employment and GDP

The input-output table method described above has been applied to the EST construction and operating phases.

EST construction phase

To produce estimates of the proportion of the construction spend that would remain in the Canary Islands and Europe-15, other similar projects were used as a reference by examining each sector of their budgets.

Table 11 gives a breakdown of the different budget headings for the EST construction project in the Input-Output sectors on which the investment would impact.

If we focus on the relevant features within the Canary Islands (like the telescope site, entities with technological capacity, providers, specialised human resources, etc.) two extremes scenarios emerge for direct returns (tables 12 and 13) anticipated in the Canary Islands, which will serve as entry values for the corresponding Input-Output analysis.

Preliminary results for the construction phase

Effect on GDP

On the basis of the hypotheses produced, and that returns are most likely to be between the limits described, the first results from the application of the input-output table method are given below.

These first results indicate that building the telescope in the Canaries, at a cost of between €25 and €33 million in the region, will require an investment of between 0.062% and 0.077% of gross added value for the Canaries in 2005. To meet this, direct and indirect investments of between 0.07% and 1.23% of the Canaries' total resources (between 56 and 98 million euros) will be needed. If induced effects are included this figure rises to 0.13% and to 0.20% of the Canaries' total resources in 2005 (105 to 160 million euros). With regard to added value, 0.065% and 0.077% (€20.3 and €25.54 million) will be needed directly and indirectly and 0.13% and 16% of gross added value (€43 to €54 million) if induced effects are included.

Effect on employment

Regarding job creation, the construction of the EST will create between 434 and 564 jobs (between 349 and 564 salaried positions and 85 to 107 non-salaried), where a job is defined as lasting one year. If other induced effects on gross added value are taken into account, this figure rises to between 1003 and 1279 jobs (between 824 and 1054 salaried positions).

EST operating phase

The operating costs for the EST in the geographic areas studied are significant not only for the gross added value and employment that will be directly created, but also because of the effect that it will have on the rest of the economy. Supply companies and production of the elements needed to build the telescope are also an essential part of the impact of this project on the economies analysed. Impact on the Canary Islands is particularly relevant as they are the physical location where this large telescope will operate.

Estimates for the economic impact of operating the EST on the Canaries are based on the following assumptions:

Table 11. EST budget headings, by Input-Output sector

EST BUDGET ESTIMATE OCTOBER 2010	PERCENTAGE INVESTMENT PER YEAR BY SECTOR							
CANARIES INPUT OUTPUT 2005 SECTORS IDENTIFIED IN THE EST CONSTRUCTION PROJECT	Budget (€uros)	1	2	3	4	5	6	Total % investment /sector
Electric, electronics and optical materials and equipment industries	50.808.000	3,78%	7,56%	9,12%	11,35%	5,67%	0,05%	37,82%
Architecture and engineering technical consultancy	17.183.000	1,92%	1,92%	2,56%	2,56%	1,92%	1,92%	12,79%
Machine and mechanical equipment manufacturing industry	14.281.100	1,59%	1,59%	2,13%	2,13%	1,59%	1,59%	10,63%
Construction	9.846.920	0,50%	1,10%	2,17%	2,47%	1,10%	0,00%	7,33%
Research and Development	8.770.920	1,63%	1,31%	1,31%	1,31%	0,98%	0,00%	6,53%
Computer activities	8.424.240	0,94%	0,94%	1,25%	1,25%	0,94%	0,94%	6,27%
Metallurgy and other metal products	7.183.160	0,80%	0,80%	2,35%	1,07%	0,80%	0,00%	5,35%
Fabrication of metal products for construction	6.197.237	0,69%	1,89%	2,12%	0,92%	0,00%	0,00%	4,61%
Fabrication of concrete, gypsum and cement elements and stone industry	41.00.960	0,46%	0,46%	0,61%	0,61%	0,46%	0,46%	3,05%
Post and telecommunications	3.022.856	0,34%	0,34%	0,45%	0,45%	0,34%	0,34%	2,25%
Maritime transport	1.213.075	0,14%	0,14%	0,18%	0,18%	0,14%	0,14%	0,90%
Hotel and other accommodation services	1.143.896	0,13%	0,13%	0,17%	0,17%	0,13%	0,13%	0,85%
Fabrication of other non-metallic mineral products	913.000	0,10%	0,10%	0,14%	0,14%	0,10%	0,10%	0,68%
Water storage, purification and distribution	559.740	0,06%	0,06%	0,08%	0,08%	0,06%	0,06%	0,42%
Land transport	465.600	0,05%	0,05%	0,07%	0,07%	0,05%	0,05%	0,35%
Chemical Industry	223.896	0,03%	0,03%	0,03%	0,03%	0,03%	0,03%	0,17%
TOTAL	134.337.600	13,16%	18,42%	24,74%	24,78%	14,31%	5,80%	100,00%

Table 12. EST budget headings, by Input-Output sector for the Canaries - Lower limit

INVESTMENT FOR CONSTRUCTION OF THE EST BY SECTOR IN THE CANARIES	PERCENTAGE INVESTMENT PER YEAR AND PER SECTOR IN THE CANARIES							
INPUT OUTPUT SECTORS IDENTIFIED IN THE EST CONSTRUCTION PROJECT	Budget (€uros)	1	2	3	4	5	6	Total % investment /sector
Electric, electronics and optical materials and equipment industries	100.000	0,01%	0,01%	1,57%	0,02%	0,01%	0,05%	0,07%
Architecture and engineering technical consultancy	10.600.000	1,18%	1,18%	1,58%	1,58%	1,18%	1,18%	7,89%
Machine and mechanical equipment manufacturing industry	100.000	0,01%	0,01%	0,01%	0,01%	0,01%	0,01%	0,07%
Construction	9.846.920	0,50%	1,10%	2,17%	2,47%	1,10%	0,00%	7,33%
Research and Development	500.000	0,71%	0,39%	0,07%	0,07%	0,06%	0,00%	0,37%
Computer activities	425.000	0,05%	0,05%	0,06%	0,06%	0,05%	0,05%	0,32%
Fabrication of metal products for construction	510.000	0,06%	1,26%	1,28%	0,08%	0,00%	0,00%	0,38%
Fabrication of concrete, gypsum and cement elements and stone industry	2.050.500	0,23%	0,23%	0,31%	0,31%	0,23%	0,23%	1,53%
Post and telecommunications	320.000	0,04%	0,04%	0,05%	0,05%	0,04%	0,04%	0,24%
Maritime transport	60.700	0,01%	0,01%	0,01%	0,01%	0,01%	0,01%	0,05%
Hotel and other accommodation services	572.000	0,06%	0,06%	0,09%	0,09%	0,06%	0,06%	0,43%
Fabrication of other non-metallic mineral products	92.000	0,01%	0,01%	0,01%	0,01%	0,01%	0,01%	0,07%
Water storage, purification and distribution	56.000	0,01%	0,01%	0,01%	0,01%	0,01%	0,01%	0,04%
Land transport	47.000	0,01%	0,01%	0,01%	0,01%	0,01%	0,01%	0,03%
Chemical Industry	50.000	0,01%	0,01%	0,01%	0,01%	0,01%	0,01%	0,04%
TOTAL	25.330.120	2,88%	4,36%	7,23%	4,78%	2,77%	1,65%	18,86%

SCENARIO 1.1. DIRECT RETURNS FOR THE CANARY ISLANDS EQUIVALENT TO ~19% OF THE TOTAL CONSTRUCTION BUDGET (LOWER LIMIT).

Table 13. EST budget headings, by Input-Output sector for the Canary Islands – Upper limit

INVESTMENT FOR CONSTRUCTION OF THE EST BY SECTOR IN THE CANARIES	PERCENTAGE INVESTMENT PER YEAR AND PER SECTOR IN THE CANARIES							
INPUT OUTPUT SECTORS IDENTIFIED IN THE EST CONSTRUCTION PROJECT	Budget (€uros)	1	2	3	4	5	6	Total % investment /sector
Electric, electronics and optical materials and equipment industries	1.500.000	0,11%	0,22%	1,78%	0,33%	0,17%	0,05%	1,12%
Architecture and engineering technical consultancy	12.000.000	1,34%	1,34%	1,79%	1,79%	1,34%	1,34%	8,93%
Machine and mechanical equipment manufacturing industry	2.142.000	0,24%	0,24%	0,32%	0,32%	0,24%	0,24%	1,59%
Construction	9.846.920	0,50%	1,10%	2,17%	2,47%	1,10%	0,00%	7,33%
Research and Development	800.000	0,74%	0,42%	0,12%	0,12%	0,09%	0,00%	0,60%
Computer activities	500.000	0,06%	0,06%	0,07%	0,07%	0,06%	0,06%	0,37%
Fabrication of metal products for construction	1.900.000	0,21%	1,41%	1,48%	0,28%	0,00%	0,00%	1,41%
Fabrication of concrete, gypsum and cement elements and stone industry	3.000.000	0,33%	0,33%	0,45%	0,45%	0,33%	0,33%	2,23%
Post and telecommunications	60.700	0,01%	0,01%	0,01%	0,01%	0,01%	0,01%	0,05%
Maritime transport	687.000	0,08%	0,08%	0,10%	0,10%	0,08%	0,08%	0,51%
Hotel and other accommodation services	92.000	0,01%	0,01%	0,01%	0,01%	0,01%	0,01%	0,07%
Fabrication of other non-metallic mineral products	92.000	0,01%	0,01%	0,01%	0,01%	0,01%	0,01%	0,07%
Water storage, purification and distribution	56.000	0,01%	0,01%	0,01%	0,01%	0,01%	0,01%	0,04%
Land transport	47.000	0,01%	0,01%	0,01%	0,01%	0,01%	0,01%	0,03%
Chemical Industry	50.000	0,01%	0,01%	0,01%	0,01%	0,01%	0,01%	0,04%
TOTAL	33.181.620	3,70%	5,29%	8,40%	6,05%	3,49%	2,19%	24,70%

SCENARIO 1.2. DIRECT RETURNS FOR THE CANARY ISLANDS EQUIVALENT TO ~25% OF THE TOTAL CONSTRUCTION BUDGET (UPPER LIMIT)

- The cost of operating the EST for 30 years or longer will be around 7% of construction costs. This percentage includes both activities related to operations and maintenance of the telescope and new instrument development.
- The amount of this budget that will remain in the Canaries is around €7.35 million (table 14). As stated above, this sum includes the costs of operating and maintaining the telescope in the Canaries and the proportion of the budget allocated for new instrument development that would return to the Canaries.

Preliminary results for the operating phase

Effect on GDP

On the basis of this hypothesis, the first results from the application of the input-output table method indicate that operating the telescope in the Canary Islands, with a spend of €220 million within this region, would require an investment equivalent to 0.517% of gross added value for the Canaries in 2005. To meet this, direct and indirect investments of 0.725% of the Canary Islands' total resources (€580 million) would be needed. When induced effects are included this figure rises to 1.246% of the Canaries' total resources in 2005 (€997 million) and the figure in terms of added value is 1.101% (€363.7 million).

Effect on employment

Regarding job creation, defined by this input-output model as the number of new one-year positions, the operation of the EST would create around 4,499 one-year jobs, (3,892 salaried positions). Taking into account the effects on gross added value, this figure rises to 1,858 jobs, 28.58% or 2,564 of which would be in the "Research and Development" sector.

Multiplier Effect Estimate

As a result of the direct investment anticipated for the EST, real production will rise in the various geographical locations examined. In addition to this increase there will also be a multiplier effect on the economy, generating increased profits for companies in other sectors within the economy; part of this will go towards consumption, leading to cascade increases and giving rise to a "multiplication" of the investment. This Multiplier is estimated to be 2.89 (including induced effects) for the Canaries.

Table 14 is a summary of the points above in relation to gross added value and job creation for the two project phases indicated.

Table 14. Breakdown of EST operating budget spent in the Canaries by Input-Output sector

ESTIMATED COST OF OPERATING THE EST IN THE CANARIES FOR A THIRTY YEAR PERIOD

SHOWN AS A % OF CONSTRUCTION COSTS

5 YEAR PERIODS -►	YEAR 1 TO 5		YEAR 6 TO 10		
IOT Sectors	% investment ANNUAL	Budget (kEuro)	% investment ANNUAL	Budget (kEuro)	% investment ANNUAL
Electric, electronics and optical materials and equipment industries	0,30%	403,01	0,30%	403,01	0,27%
Architecture and engineering technical advice	0,12%	161,21	0,14%	188,07	0,15%
Machine and mechanical equipment manufacturing industry	0,20%	268,68	0,25%	335,84	0,27%
Research and Development	3,20%	4298,80	3,60%	4836,15	3,80%
Computer activities	0,50%	671,69	0,50%	671,69	0,40%
Metallurgy and other metal products	0,10%	134,34	0,08%	107,47	0,05%
Fabrication of metal products for construction	0,10%	134,34	0,12%	161,21	0,12%
Post and telecommunications	0,25%	335,84	0,22%	295,54	0,20%
Maritime transport	0,05%	67,17	0,05%	67,17	0,03%
Hotel and other accommodation services	0,15%	201,51	0,15%	201,51	0,15%
Catering services	0,05%	67,17	0,05%	67,17	0,05%
Production and distribution of electrical, gas and steam energy	0,19%	255,24	0,19%	255,24	0,20%
Water storage, purification and distribution	0,02%	26,87	0,02%	26,87	0,02%
Land transport	0,05%	67,17	0,05%	67,17	0,05%
Chemical Industry	0,03%	40,30	0,03%	40,30	0,03%
TOTAL COSTS OF OPERATIONS IN THE CANARIES	5,31%	7133,33	5,75%	7724,41	5,79%
TOTAL COSTS OF OPERATING THE EST	6,80%	9134,96	7,10%	9537,97	7,15%
WITHIN THE CANARIES	78,09%		80,99%		80,98%

YEAR 11 TO 15	YEAR 16 TO 20		YEAR 21 TO 25		YEAR 26 TO 30		INVESTMENT TOTAL	
Budget (kEuro)	% investment ANNUAL	Budget (kEuro)	% investment ANNUAL	Budget (kEuro)	% investment ANNUAL	Budget (kEuro)	% TOTAL investment	Budget (kEuro)
362,71	0,25%	335,84	0,20%	268,68	0,10%	134,34	7,10%	9537,97
201,51	0,10%	134,34	0,10%	134,34	0,05%	67,17	3,30%	4433,14
362,71	0,20%	268,68	0,20%	268,68	0,20%	268,68	6,60%	8866,28
5104,83	3,70%	4970,49	3,70%	4970,49	3,50%	4701,82	107,50%	144.412,92
537,35	0,50%	671,69	0,50%	671,69	0,50%	671,69	14,50%	19.478,95
67,17	0,05%	67,17	0,05%	67,17	0,00%	0,00	1,65%	2216,57
161,21	0,05%	67,17	0,00%	0,00	0,00%	0,00	1,95%	2619,58
268,68	0,20%	268,68	0,20%	268,68	0,20%	268,68	6,35%	8530,44
40,30	0,01%	13,43	0,05%	67,17	0,05%	67,17	1,20%	1612,05
201,51	0,15%	201,51	0,12%	161,21	0,10%	134,34	4,10%	5507,84
67,17	0,05%	67,17	0,04%	53,74	0,02%	26,87	1,30%	1746,39
268,68	0,20%	268,68	0,20%	268,68	0,20%	268,68	5,90%	7925,92
26,87	0,02%	26,87	0,02%	26,87	0,02%	26,87	0,60%	806,03
67,17	0,04%	53,74	0,04%	53,74	0,04%	53,74	1,35%	1813,56
40,30	0,03%	40,30	0,03%	40,30	0,03%	40,30	0,90%	1209,04
7778,15	5,55%	7455,74	5,45%	7321,40	5,01%	6730,31	164,30%	220.716,68
9605,14	6,80%	9134,96	6,80%	9134,96	6,20%	8328,93	204,25%	274.384,55
	81,62%		80,15%		80,81%		80,44%	

Table 15. GDP, multiplier and jobs created in the Canaries as a result of building and operating the EST

Geographic area and phase (Millions of euros)	Direct inves-tment	Production (Direct and indirect effect)	Gross added value (Direct and indirect effect)	Jobs crea-ted (Direct and indirect effect)	Production (including consequen-tial effects)	Gross added value (including conse-quential effects)	Jobs created (including consequen-tial effects)
CANARIES							
Construction	25-33	40-51	20-26	434-564	80-101	43-54	1003-1279
Operation (30 years)	221	297	171	4 499	633	364	9 286
TOTAL	246-254	337-348	191-197	4933-5063	713-734	407-418	10.289-10.565
Multiplier		1,37			2,89		

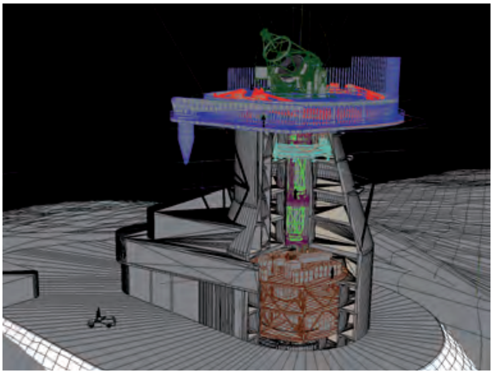
Table 16. Full-time-equivalent jobs created in the Canary Islands during the construction and operation of the EST

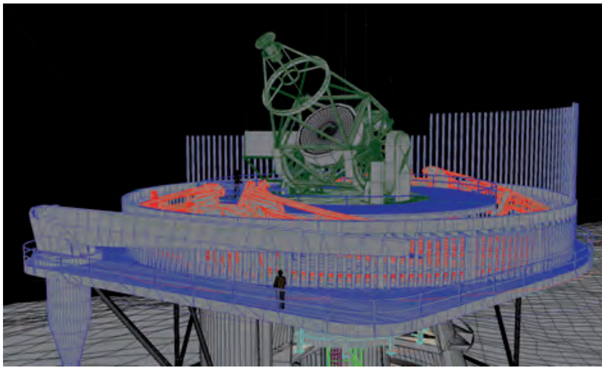
Geographic area and phase	Number of full-time-equivalent jobs created during the project phase indicated. Direct and indirect effect	Number of full-time-equivalent jobs created during the project phase indicated, also including induced effects
The Canary Islands		
Construction (6 years)	72-94	167-213
Operation (30 years)	150	309

If the number of one-year positions is properly adjusted to give the total number of full-time-equivalent jobs created during the telescope's construction (6 years) and operating (30 years) phases, the figure is as follows in table 16.

Building and operating the EST could deliver a gross added value for the Canary Islands, taking into account induced effects, of up to €418 million.

The effect on employment, again including induced effects, would be up to 213 new full-time-equivalent jobs during the construction phase, and a further 309, also full time, during the 30-year operating period.





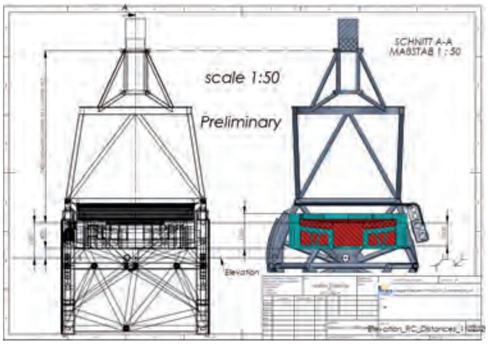


Figure 24. Different perspectives of the conceptual design for the telescope and part of the main building.

9.2.3. Technological and industrial impact of building and operating the EST

The technological and industrial impact is quantified by the return for production activity, either as tangible benefits or opportunities for trade or innovation, from investments in cutting edge technological developments.

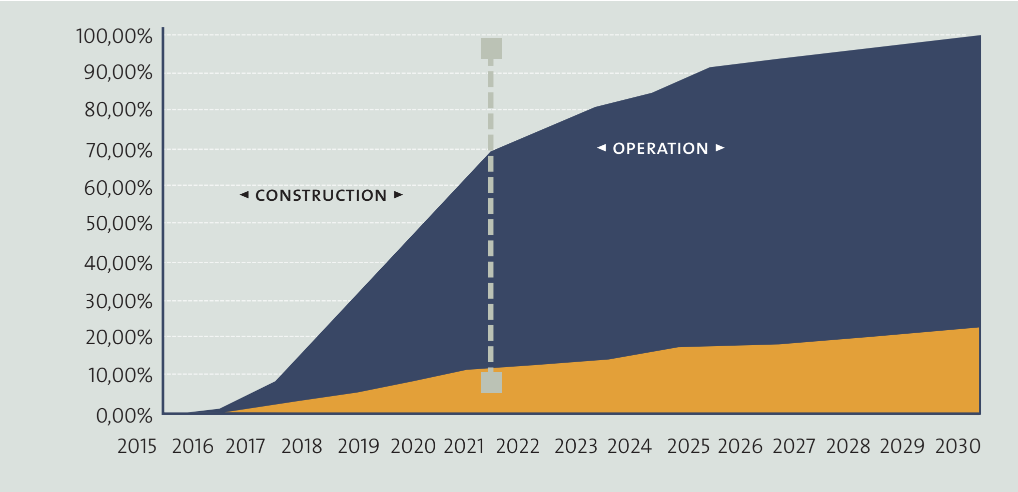
The technologies needed to build the EST will largely be developed during the telescope's construction phase and will come from across the whole of Europe. It is hoped that the construction of the telescope will create new applications for technology and creation of highly skilled jobs and related industry.

Today, the science of solar physics is very dependent on high technology and robust partnerships with industry are needed to confront the large-scale engineering challenges of the next generation telescopes. This means that there are benefits for both sides (science and economy).

The EST, viewed worldwide as one of the most important projects for ground-based solar physics, is a highly technological project. It will give rise to many new technologies with potential applications for industry and will provide opportunities for companies to work on contracts with unprecedented technological challenges.

Innovations of technological and industrial interest from a telescope of this kind, include, during the construction phase, the production of the mirrors, actuators and sensors, large mechanical structures, adaptive optics and post-focal instruments, active support systems and high precision large mass pointing and guiding mechanisms. The critical technologies for the telescope's instruments will include precision mechanics, highly dimensionally stable materials, mechanical integration and thermal

Graphic 7. Profile of cumulative technological and industrial returns by geographical region estimated during the EST construction and operating phases



regulation and multi-conjugate optics. These innovative technologies are all profiled in the conceptual design phase (figure 24).

The level of technological returns for each country from involvement in the project will depend on a range of factors including:

- The strategic technologies needed for construction and operation of the EST.
- The largest companies with the capacity to be involved.
- Financial support for the project from the applicable country.
- New business opportunities arising from involvement in the project.
- Strategic alliances cemented during the project.

It is anticipated that most of the technological returns from the EST will come during the construction phase, both for the host region and for the rest of Europe (Graphic 7).

It is expected that the first technological returns will come from the development and testing of the first technical components for the telescope (heat trap, sensors, control systems, mirrors etc.). Instrument development will take more time, but it promises to bring technological breakthroughs for the companies involved. During the construction phase it is estimated that a technological return of some 10% could accrue to the Canary Islands by the end of the construction phase, with 60% accruing to the rest of Europe. The remaining 30% of technological and industrial returns would be split, with approximately 10% for the Canary Islands and 20% to the rest of Europe.

A large part of the technological impact of the EST will take the form of new highly skilled jobs, during both construction and operating phases. The latter will be especially relevant for the Canaries.

The operating phase will deliver additional technological returns in the form of "technology services" and associated industrial returns in the form of "specific supplies". As mentioned previously, it is anticipated that the Canaries could successfully compete for much of the maintenance and improvement work on the telescope. As no new instruments are during the operation phase, no technological returns are anticipated from this source.

9.3. SOCIO-CULTURAL IMPACT AND POTENTIAL FOR SCIENCE TOURISM

The management and operating model of the Canary Islands' astrophysics Observatories is based on the belief that scientific knowledge must form part of the culture of the Islands' citizens. Installations are therefore open to the general public by means of organised tours. The Observatories receive an average of 12,000 visitors each year including groups of school and university students, conference delegates, tourists, etc. Experience shows that visiting the facilities, hearing about the work that goes on in them and understanding how they contribute to scientific progress, is the best way to build interest in and enthusiasm for astrophysics.

The Canary Islands are visited by over nine million tourists each year, most of them from European countries with telescopes and instruments on the peaks of Tenerife and La Palma. Many of these visitors show an interest in visiting the facilities their home countries take part in. (Figure 25).

It is therefore planned to add to the existing information facilities, which are at the Teide Observatory (Visitors Centre), a Cultural Park at the Roque de los Muchachos in La Palma, with installations designed to demonstrate, in a very user-friendly way, the most interesting aspects of the Observatory and the science it produces. The main goals are as follows:

- Providing first class tourist facilities on Tenerife and La Palma, designed to complement the installations and landscape that they will service.
- Promote the ORM and OT and their natural environment as tourist attractions.
- Develop astronomy and natural science experiences for the public, at facilities designed to complement scientific activities at the Canary Island's Astrophysics Observatories and their National Parks (the natural environment in which they stand).
- Attract the general public basically through astronomic activities in the islands being also an interpreting centre of the natural and ethnographical environment.
- Create an Astronomy Package Holiday, with stays near the Observatories and

a range of observation opportunities, for different types of international group (amateur astronomers, students and those with a general interest).

- Provide the Observatories with a Reception Area, to channel and take care of their needs and a system for controlling visits and guarantee the area is protected for astronomical observation.
- Channel what amateur associations would like from the Observatories.

In pursuit of these goals the Teide Observatory is offering a range of public outreach activities (guided tours, open doors days, star observations), making MONS (a 50 cm reflecting telescope) available to amateurs and students and has opened its Visitor Centre, a converted dome which has been equipped to provide the public with insights into science. With capacity to hold forty people, the centre is used to tell visitors about the observatory and its telescopes and about the vital role that astronomy plays for humankind.

The Cultural Park at the ORM will have general use facilities like a car park, cafeteria, toilets and a retail area, with themed areas and exhibitions making up the visitor centre proper. There will be a range of themed content, which could include some or all of the list below:

- "The Canary Islands, a window on the universe" (145 m² hall holding up to 75 people, for lectures, presentations and press conferences).
- "Eyes on the sky" (Exhibition area, approx 200 m²).
- "Around the observatories" (Exhibition area, approx 125 m²).

This facility is key not only for managing tourism at the Roque de los Muchachos Observatory but also for inspiring quality tourism in La Palma as a whole.

The arrival of the EST will generate a huge amount of economic activity both in itself and through the birth of small companies with interests in its maintenance and operation; it will also be a new attraction for the island, increasing its international profile and visitor appeal. As has been demonstrated elsewhere in the world, large science infrastructure projects are an enormous lure, bringing a constant flow of tourists and with them very significant benefits for the local economy. In other words, large scientific installations are not just advanced science instruments or public education tools; they are the engine that drives the creation of quality tourism.

9.4. SOCIAL PERCEPTION AND ADDED VALUE

The population of the Canaries is imbued with a sense of the importance of the Observatories and their telescopes present and future. They see the Observatories and the quality of the sky as an opportunity for creating quality tourism in Tenerife and La Palma, by targeting visitors who are interested in observation.

Figure 25. Left, a group of visitors to the OT observing the Sun during an open doors day (2009). Right, ORM open doors day in 2008, with the SST and DOT solar telescopes in the background.

The rolling out of the Sky Law has raised awareness, particularly amongst the inhabitants of La Palma, who understand and value the quality of their sky and feel a sense of responsibility for its protection. The IAC's head office in La Laguna has also worked to raise the awareness of residents and visitors on Tenerife, publicising the observatories' work and reinforcing the importance of looking after the sky to minimise negative effects. The inhabitants of the Canary Islands are certainly conscious that they live in a unique site; islands rivalled by just a few places worldwide for the quality of astrophysical observation. As well as the astrophysics enclaves the Canary Islands are home to a multitude of mountain viewpoints where spectacular sunsets, totally clean skies and expansive, beautiful views of the stars can be enjoyed.

Tenerife, which is partially protected by the Sky Law, houses at its Teide Observatory some of the best European solar telescopes, some of which have clocked up over 25 years of uninterrupted observation. The sky quality of this site is backed by decades of atmospheric characterisation data. The OT is also the chosen site for the Gregor telescope, which will be the largest solar telescope in the world when it enters service shortly. This observatory has already been visited by thousands of residents and tourists and is a science and technology resource for the inhabitants of the island.

La Palma, which is entirely protected by the Sky Law, is an Astronomical Reserve and a Biosphere Reserve. It is no surprise that La Palma was the platform for the launch of the Starlight world initiative, which seeks to protect the night sky and the right to observe the stars. Starlight has financial support from UNESCO, the International Astronomical Union (IAU) and other international organisations. A training course for guides, with certification by *Starlight*, has recently been launched.

9.4.1. Cultural enrichment (promotion of science)

There can be no doubt that of all the experimental sciences, astrophysics enjoys the highest level of public interest. There is a range of reasons for this, including:

Canary Islands sky promotional campaign. Tenerife 2008.

- Many of the questions that human beings ask about nature and where they came from are addressed by this science (like cosmology, exobiology, planetary climate studies, black holes, dark matter, astroparticles, etc.)
- Recent technological and experimental developments (like space and giant telescopes, infrared and X-ray observation satellites, new detectors, radio and visible range interferometry, super computers, etc.) are bringing us closer, or will bring us closer in the near future, to answering these fundamental questions, and
- This science is markedly interdisciplinary, with relationships to physics and mathematics as well as chemistry, biology, engineering and computing.

The EST, which will examine fundamental processes in the Sun at their smallest scales, will provide vital information to advance our understanding:

- Sun-Earth Connection (particle and very high energy radiation emission can affect the environment on Earth).
- Basic physics laboratory (detailed information about plasma and magnetic field interaction can only be obtained in Sun's extreme physical conditions).
- A fundamental platform for understanding the rest of the Universe (all stars are suns).

The EAST institutions are aware of the level of public interest in solar physics and the importance of maintaining it. The EAST countries have therefore put together and staged a range of activities to promote public interest in science, both individually in their own geographical areas and jointly in the region of the IAC Canary Islands' Observatories. They include a range of audiovisual material on the astrophysics facilities and their achievements for science, websites promoting astronomy, talks and guided tours at the observatories and educational material and themed exhibitions.

These activities were a valuable experience for students and the general public. They created a sense of familiarity with Astrophysics, encouraged participants to follow and champion the telescopes' achievements, fostered a sense of pride in them and stimulated interest in winning and housing large projects like the EST.

Building and operating the EST will provide tremendous opportunities for solar physics education (student competitions, tele-astronomy workshops, educational material, exhibitions, documentaries, children's theatre, digital newspapers...) by specialist publishers, schools, science museums and planetariums.

CONCLUSIONS

This report, produced in the context of the EST Conceptual Design Study, analyses the principal technical, financial and socio-economic implications of building and operating this large research infrastructure, with the aim of providing a reference framework to be used in the decision-making process for the forthcoming phases of this European initiative in transnational scientific collaboration. Like EAST, the ASTRONET network and other transnational organisations, this report concludes that the EST is an unprecedented opportunity for the European solar physics community to unite behind a technological challenge that will greatly expand the horizons of solar physics. In fact, the EST is the greatest European effort in ground-based solar physics.

It is especially important to underline that the Canary Islands' Astrophysics Observatories have excellent credentials as the site for the EST, meeting all of the scientific, technical and logistical criteria established by the consortium promoting the project. Of all of the projects backed by ASTRONET and ESFRI, the EST is the one large European infrastructure project which the scientists involved unanimously agree can only conceivably be built in the Canary Islands[35]. In addition to the Observatories themselves, sea level support facilities (CALP and the IAC Headquarters) already have the basic and advanced infrastructures needed to build and operate the EST. Infrastructure and supply upgrades, many already underway and others planned for the future, fully meet the support and services needs of the EST. These infrastructures therefore have a significant strategic and economic value for the EST project. Building and operating the EST in the Canary Islands will keep their Observatories at the forefront of solar science and build on their long, successful record of attracting latest generation telescopes and instruments.

The Observatories also offer a number of strategic advantages:

- The proximity of the ORM and the OT to inhabited areas (population centres) is an advantage in terms of comfort, economy and logistics and will make operating and maintenance plans and budgets for the EST more efficient.
- Movement of research and technical personnel from Europe to the EST in the Canary Islands has been well established for decades. These Observatories, because they are within EU te-

35 Other similar projects that could be sited in the Canary Islands, which are highlighted by ASTRONET and ESFRI, like the CTA (Cherenkov Telescope Array), have also considered other potential sites.

rritory, also provide the highest level of legal assurance and protection for research and technical personnel.

- A recent seismic and volcanic risk assessment for the Observatories on La Palma, Tenerife and Hawaii concluded that the level of risk in the Canary Islands is minimal. This is corroborated by data collected over the last thirty-five years and projections created using them. Compared to sites with a higher level of geological risk, construction costs in the Canary Islands would be lower.

Regarding financial feasibility, EAST, an association of European scientific institutions, needs commitment and contributions from their respective funding agencies for R&D in order to build EST. Contributions from the interested countries may be topped up by EU funds although, as with other large research infrastructure projects, the financial impetus will need to come from the corresponding funding agencies. For Spain this project could represent an unprecedented opportunity to oversee the construction of a large European research infrastructure, meaning that decisive support (political and financial) from the country's regional and national authorities is vitally important in order to steer the project through its subsequent phases with the other European partners involved.

The estimated construction budget is around €135 million, most of which is expected to come from funding agencies in the participating countries. Financial commitment must be solid and lasting in order to meet the costs of the subsequent operating phase. These costs are estimated at 7% of the construction costs, a total of €275 million over the anticipated operating period of some 30 years. These large investments will provide an attractive scenario of technological opportunity including, in addition to the ordinary operation expenses, production of mirrors, actuators and sensors, large mechanical structures, adaptive optics and post-focal instruments, active support systems and high precision large mass pointing and guiding mechanisms, precision mechanics, highly dimensional stable materials, mechanical integration and thermal regulation and multi-conjugate adaptive optics, among others. European industry has the technological capacity to meet 100% of the project's needs, whether as a main contractor or on systems and subsystems. Proof of the high level of interest in the project from the manufacturing sector is the dozen European enterprises that were involved in the EST Conceptual Design phase.

There is no doubt that building and operating the EST will create a large number of new highly skilled jobs, especially in areas near the facility. Experience at international organisations like the ESO, ESA and other institutions, indicates that over 60% of the total jobs created often go to personnel from the host region or country. This is particularly important for highly skilled jobs. The Canary Islands are very dependent on the services sector, particularly tourism, and would therefore benefit from the diversified economy, impact on GDP and quality jobs creation that a project like the EST would bring. This report puts the estimated returns from the construction and operation of the EST for the Canary Islands at €54 to €364 million of gross added value respectively, including induced effects. Operating the EST in the Canary Islands will produce direct financial returns for the region of around €220 million over 30 years, the telescope's anticipated lifespan.

The impact on employment, taking into account induced effects, would be some 213 new full time jobs created during the construction phase and a further 309 during the 30 year operating phase, also full time, most of them in the Canary Islands.

However, given the high degree of uncertainty about on which regions tenders and service providers related to this project will be located, apart from those anticipated for the host region, attempting to provide individual information on the industrial return, GDP increase and job creation for the different countries involved (including Spain as a whole) would be a complex and unconvincing enterprise.

From a social and educational perspective the EST will be a permanent resource for the whole of Europe for training young researchers and technologists, and a reference for scientific outreach in the coming decades.

As this report explains, the opportunity that building the EST represents for Europe as a whole goes hand in hand with the particular benefits that would accrue to the Canary Islands from housing this unique infrastructure. The Canaries are involved in the production of the 2014-2020 development strategy for the Outermost Regions, providing them with an unprecedented opportunity to include large research infrastructure projects on the list of priorities for the principal structural funds (ERDF and the European Social Fund), which means a favourable scenario regarding financial support of the EST could be envisaged.

For the governance and management of the EST, the legal framework put in place by the European Commission for the creation and operation of transnational research infrastructure (ERIC) provides a functional model with sufficient guarantees for the project to go ahead without significant difficulty in this regard. The adoption of an ERIC is therefore suggested as the ideal legal format for subsequent phases of the project.

Finally, this report underlines the importance of including this project not just in initiatives like the ESFRI Roadmap but also in the corresponding EU work plans and those of the countries involved in order to grasp the current opportunity to assure the project's continuity and economic feasibility. The countries involved now need to combine and redouble their efforts, continuing on to the following phase of the preliminary design in 2012 and moving forward with the international agreement so that progress can be assured for the subsequent construction and design phases.

ACRONYMS

AO	Adaptive Optics
APTE	Spanish Association of Science and Technology Parks
ATC	Automatic Transit Circle
ATST	Advanced Technology Solar Telescope
BBSO	Big Bear Solar Observatory
BL	Bound Layer
BRT	Bradford Robotic Telescope
BSC-CNS	Barcelona Supercomputing Center-Centro Nacional de Supercomputación
CALP	Centro de Astrofísica de La Palma
CCI	Comité Científico Internacional
CCT	Common Customs Tariff
CERN	European Organization for Nuclear Research
CeSViMa	Centro de Supercomputación y Visualización de Madrid
CDTI	Centro para el Desarrollo Tecnológico e Industrial
CRA	Consiglio per le Ricerche Astronomiche
CSIC	Consejo Superior de Investigaciones Científicas
CTA	Cherenkov Telescope Array
DOT	Dutch Open Telescope
EAST	European Association for Solar Telescopes
EC	European Commission
E-ELT	European Extremely Large Telescope
EIB	European Investment Bank
EIF	European Investment Fund
ERA	European Research Area
ERCF	ESFRI RSFF Capital Facility
ERDF	European Regional Development Fund
ERIC	European Research Infrastructure Consortium
ESA	European Space Agency
ESFRI	European Strategy Forum on Research Infrastructures
ESO	European Southern Observatory
EST	European Solar Telescope
EU	European Union
FA	Free Atmosphere
FP6	Sixth Framework Programme
FP7	Seventh Framework Programme
GAV	Gross Added Value
GDP	Gross Domestic Product
GMT	Giant Magellan Telescope
GSC	Guide Star Catalogue
GSHAP	Global Seismic Hazard Assessment Program
GTC	Gran Telescopio CANARIAS
IA-UNAM	Instituto de Astronomía - Universidad Nacional Autónoma de México
IAC	Instituto de Astrofísica de Canarias
IAU	International Astronomical Union
ICSTM	Imperial College of Science, Technology and Medicine
ICTS	Instalaciones Científico-Técnicas Singulares
IGIC	Canaries General Indirect Tax
INAF	Istituto Nazionale di Astrofisica
INAOE	Instituto Nacional de Astrofísica, Óptica y Electrónica

ING	Isaac Newton Group of Telescopes
INT	Isaac Newton Telescope
IO	International Organizations
JOSO	Joint Organization for Solar Observations
LEST	Large European Solar Telescope
LT	Liverpool Telescope
MAGIC	Major Atmospheric Gamma ray Imaging Cherenkov
MCAO	Multi-conjugate Adaptive Optics system
MEC	Ministry of Education and Science
MSO	Mees Solar Observatory
NOT	Nordic Optical Telescope
OGS	Optical Ground Station
ORM	Roque de Los Muchachos Observatory
OT	Teide Observatory
OTA	Optical Telescope Array
OTPC	Sky Quality Protection Technical Office
PGA	Peak Ground Acceleration
PRACE	Partnership for Advanced Computing in Europe
QUIJOTE	Q-U-I Joint Tenerife CMB Experiment
RIC	Canary Islands Investment Reserve
RSAS	Royal Swedish Academy of Sciences
RTD	Scientific Research, Technological Development and Innovation
REF	Fiscal and Financial Regime
RES	Spanish Supercomputer Network
RIC	Canary Islands Investment Reserve
SHABAR	Shadow Band Ranger
SL	Superficial Layer
SME	Small and Medium sized Enterprise
SOHO	Solar & Heliopheric Observatory
SST	Swedish Solar Telescope
ST	Society of the Telescope
STScI	Space Telescope Science Institute
SUCOSIP	Subcommittee for Site Protection and Characterization
TAC	Time Allocation Committee
TCS	Carlos Sánchez Telescope
THEMIS	Heliographic Telescope for the Study of the Magnetism and Instabilities on the Sun
TMT	Thirty Meter Telescope
TNG	Telescopio Nazionale Galileo
UIB	University of the Balearic Islands
ULL	University of La Laguna (Tenerife)
UNESCO	United Nations Educational, Scientific and Cultural Organization
USGS	United States Geological Survey
VAT	Value Added Tax
VEI	Volcanic Explosity Index
VSA	Very Small Array
VTT	Vacuum Tower Telescope
WHT	William Herschel Telescope
ZEC	Canary Islands Special Zone

LIST OF ANNEXES

A1 *Terms of Reference for the European Association for Solar Telescopes (EAST). February 2007.*
Document produced by EAST on the structure, goals and activities agreed for this European Association.

A2 *"A Science Vision for European Astronomy". ASTRONET 2007.*
Document produced by ASTRONET examining the key science questions of the future and the observational facilities and equipment that will be needed for work on them in the coming years.

A3 *ENO. A priviledged site for astronomical observations. January 2001.*
A leaflet describing the quality of the sky over the Canary Islands' Observatories.

A4 *Spanish Science Vision of EST: Magnetic Coupling of the Solar Atmosphere. February 2007.*
This document describes the current state of existing Solar Physics infrastructures, outlines why the EST is needed and lists the principal scientific projects that this next generation telescope could tackle.

A5 *EST Science Requirements Document. November 2009.*
This document lists requirements for the principal science projects put forward for the EST and other scientific priorities for consideration in terms of its design.

A6 *Agreement for cooperation in Astrophysics. May 1979.*
Cooperation agreement signed by Spain, Denmark, the United Kingdom, Ireland and Sweden governing the use of the Canary Islands' Observatories.

A7 *Law 31/1988 of 31st October, for Protection of the Astronomical Quality of the Observatories of the Instituto de Astrofísica de Canarias.*
This law set out a package of measures designed to assure protection of the astronomical quality of the Canary Islands' sky.

A8 *Royal Decree 243/1992, of the 13th March, giving approval to the Regulations of Law 31/1988, of 31st October, on protection of the astronomical Observatories of the Instituto de Astrofísica de Canarias.*
Royal decree governing the application of law 31/1988 of the 31st October on Protection of the Astronomical Quality of the IAC Observatories.

A9 *Protecting the sky over the Canaries. Sky Quality Protection Technical Office.*
Information leaflet by the OTPC listing obligatory requirements for protecting the Canary Islands' sky.

A10 *Impact of geological activity on astronomical sites of the Canary Islands. December 2010.*
Detailed seismological and volcanic risk assessment for the Canary Islands' Astrophysics Observatories

A11 *The European Research Infrastructure Consortium (ERIC). June 2009.*
Document describing the legal framework for a new juridical format designed for the creation and operation of large European transnational scientific infrastructures

A12 *Impact of building and operating the EST on the Canaries and Spain using input-output tables. February 2011.*
A detailed the study carried out by Dra. Elisabeth Valle Valle, from University of the Balearic Islands, looked at the impact of building and operating the EST on the economy of the Canary Islands and produced estimates for its impact on the Spanish national economy using the most recent available Input-Output tables for the Canary Islands' and Spanish economies in 2005.

For further information please contact the Institutional Projects and Technology Transfer Office (OTRI) of the Instituto de Astrofísica de Canarias.