EST NEWS 12

THE EUROPEAN SOLAR TELESCOPE NEWSLETTER

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COORDINATOR'S CORNER

In a meeting held on April 25, the EST Board of Directors approved the creation of the European Solar Telescope – Fundación Canaria (EST-FC). The deed will be signed in Santa Cruz de Tenerife on July 25, 2023, by 10 research institutions from 8 European countries. With this critical step, the Consortium formed by the institutions working for EST will have a legal character and will be able to contract with third parties, hire personnel, and receive funds or grants, among other possibilities. With this step, all partners in the EST-FC will have control on the progress of the project, with a flexible governance scheme that facilitates an easy transition to the future EST-ERIC for construction and operation. An article in this issue is dedicated to the UK community. A UK Universities Consortium (UKUC), represented by the University of Sheffield, has been formed to join the EST-FC. Six universities form part of the UKUC, and others might join in the near future.

The role of EST in the European research landscape has recently been highlighted by the Astronet Roadmap 2022-2035. The scientific goals and milestones in all fields of astronomy have been analysed by dedicated groups formed by renowned European researchers, leading to a prioritisation of future facilities. EST is listed as one of three recommended projects in the field of new ground-based infrastructures, due to its unique capabilities and the strong support from the European solar physics community.

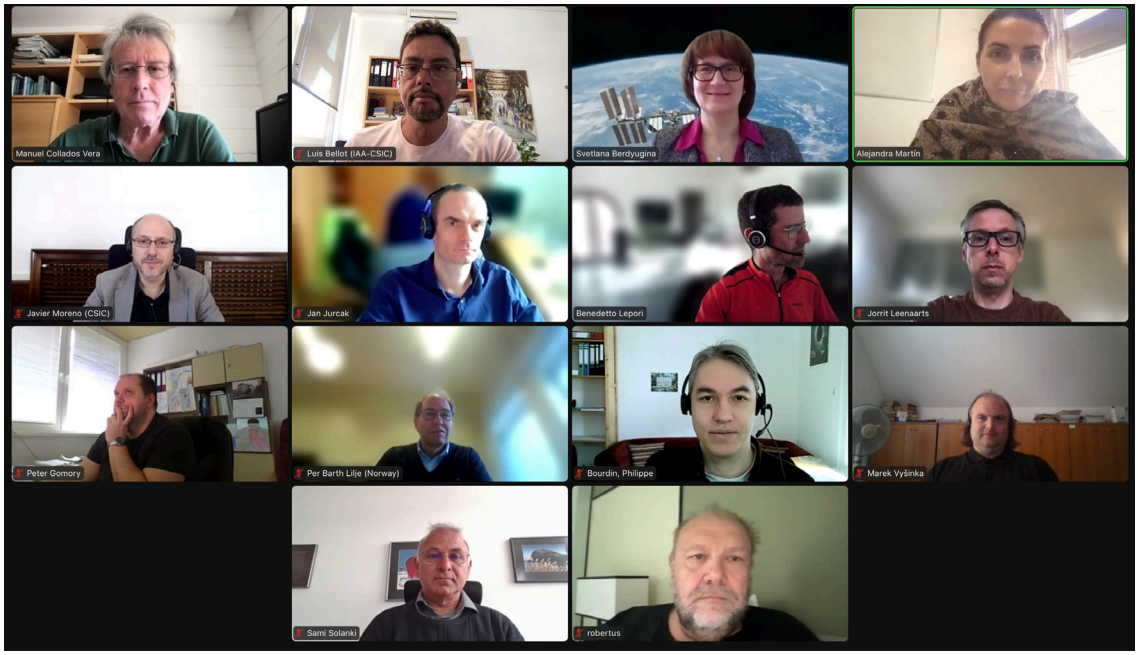
The most recent activities of the Science Advisory Group are also described in this issue, together with the progress achieved in the design of some particular subsystems (Heat Rejecter and Data Centre), focused on the Preliminary Design Review of the telescope to be held soon.

As a relevant communication activity, we highlight the presentation of the TV documentary "Reaching for the Sun" at the Accademia Nazionale dei Lincei (Rome, Italy) on May 26, 2023, where the video series "Here comes the Sun" was also introduced.

M. Collados, EST coordinator

CREATION OF THE EST CANARIAN FOUNDATION

The EST Canarian Foundation deed will be signed on July 25, 2023 in Santa Cruz de Tenerife.



Virtual meeting of the EST Board of Directors on April 25, 2023.

After one year of negotiations, the EST Board of Directors gave its green light to the documentation required for the creation of the European Solar Telescope – Fundación Canaria (EST-FC). The deed will be signed and notarised in Santa Cruz de Tenerife on July 25th, 2023.

The institutions that have confirmed their participation are: Stockholms Universitet (SU, Sweden), Leibniz-Institut für Sonnenphysik (KIS, Germany), Max-Planck-Gesellschaft zur Foerderung der Wissenschaften (MPG, Germany), United Kindgom Universities Consortium (UKUC) represented by the University of Sheffield (UoS, UK), Astronomický Ústav AV ČR, V. V. I. (AIAS-CR, Czech Republic), Astronomical Institute of the Slovak Academy of Sciences (AISAS, Slovakia), Università della Svizzera Italiana (USI, Switzerland), Universität Graz (UG, Austria), Agencia Estatal Consejo Superior de Investigaciones Científicas (CSIC, Spain), and Instituto de Astrofísica de Canarias (IAC, Spain). Other institutions will have the possibility to join the Foundation at a later moment.

The main objectives of the EST-FC are, among others:

- To contribute to the setting up of the EST-ERIC, or the most appropriate alternative entity, as the legal organisation created to implement the construction and operation phases of EST.
- To facilitate the development and consolidation of the European Solar Telescope project, ensuring that the design of EST meets scientific and technical requirements.

To achieve these objectives, the EST-FC shall address the following main activities during the first year of operation, starting in August 2023:

- Establish the steps for the creation of the Board of Governmental Representatives, so that negotiations at the highest level can be started for the construction phase of EST
- Complete the EST preliminary design, so that the design is ready for external evaluation.
- Pass the EST Preliminary Design Review (PDR), in which the design is evaluated by a panel of external experts to assess that it meets the scientific and technical requirements, the correct design options have been selected, interfaces have been identified, and verification methods have been described.

The three governing bodies of the Foundation are the Board of Trustees, the Executive Committee, and the Director.

The Board of Trustees is the governing body that shall represent the Foundation and exercise all the powers needed to achieve the Foundation's aims. All partners institutions entering the Foundation are represented in this body.

The main function of the Executive Committee is the examination of all documentation to verify compliance with the Budget and the Explanatory Report and the adoption of appropriate measures to correct any deviations that may occur.

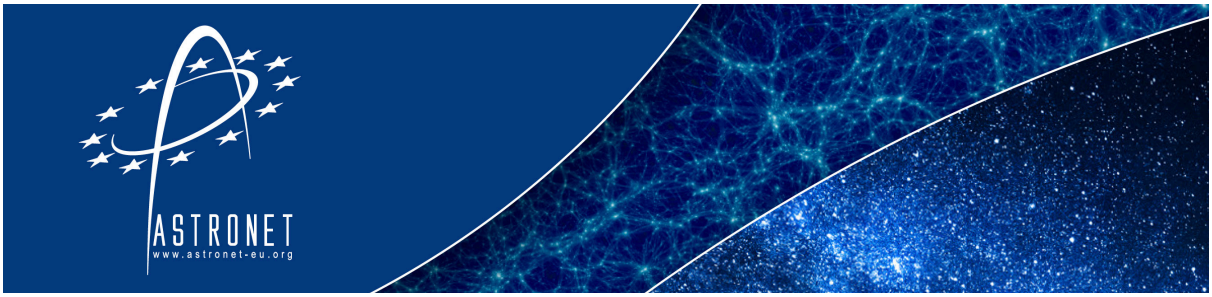
The Director for the Foundation shall be in charge of the affairs and good running of the Foundation. He/she shall be appointed by the Board of Trustees.

The EST-FC will host the Project Office for, among other tasks, completing the EST preliminary design, preparing the PDR, closing the EST Final Detail Design and Construction Specifications after considering all issues raised by the external review panel during the PDR, and preparing the construction procurements documentation.

With the creation of the EST-FC, a key milestone will be achieved, giving a legal character to the Consortium formed by the institutions working jointly for making EST a reality and paving the way to the future construction of the European Solar Telescope.

EST INCLUDED IN ASTRONET PRIORITY LIST

EST has been highlighted as a first priority infrastructure in the Astronet Roadmap 2022-2035.



ASTRONET Roadmap 2022-2035 report, donwloadable from the ASTRONET website.

On April 27, 2023 the "ASTRONET Science Vision and Infrastructure Roadmap" for the period 2022-2035 was released. ASTRONET is the forum where the European funding organisations and the scientific community work together to provide a coordinated strategic plan for the future of European astronomy. ASTRONET covers all fields of astronomy (from the Solar System to the limits of the observable Universe), observational techniques (from radio-astronomy to gamma-rays), space- and ground-based facilities, theoretical and computational needs, virtual observatory and laboratory astrophysics, as well as outreach and training of human resources.

Eight panels of experts (with the participation of more than 80 European researchers) worked for the generation of the roadmap after analysing the present status of astronomy in Europe and the needs required for a substantial knowledge improvement in these fields.

In the field of new ground-based infrastructure projects, the ASTRONET Roadmap highlights three priorities for the period 2022-2035: the Cerenkov Telescope Array (CTA) and the European Solar Telescope —due to their unique capabilities and strong support from their respective communities–, and a more general wide-field spectroscopic facility for an 8-10 metre class telescope with applications from planetary systems to cosmology. The new ASTRONET Roadmap report states that “EST will significantly increase our understanding of the solar magnetic field and its relations with the heliosphere and the Earth. Its completion and scientific exploitation in synergy with the US-based DKIST is a priority”.

The publication of the ASTRONET roadmap motivated the publication of a short notice in Nature, in which EST was highlighted in the header, together with the Einstein telescope for the detection of gravitational waves.

Step by step, EST is achieving key milestones towards the start of its construction on the island of La Palma, in a site with a well-recognised performance for diurnal observations. The ASTRONET Roadmap release and the creation of the EST Foundation, with the participation of research institutions from eight European countries, put a solid ground to start negotiations with the national funding agencies in the short term.

The project intends to pass the EST Preliminary Design Review in early 2024 to demonstrate the maturity of the adopted technical solutions. With a simple and, at the same time, efficient concept, its innovative approach in terms of adaptive optics and advanced instrumentation leads to technological challenges that will illuminate further projects (not only in the field of solar physics) and put the seed for new scientific discoveries.

UK CONSORTIUM TO JOIN EST FOUNDATION

Represented by a consortium of 6 universities, the UK will join the EST Canarian Foundation.

EST is an ESFRI project that has been designed by a consortium of 27 partners (from academia and industry) in 14 European countries. The UK community has been involved since the project began. EST will be polarimetrically compensated, and the first solar telescope to incorporate multi-conjugate adaptive optics from inception, enabling diffraction-limited observations of an unprecedented 25 km resolution, less than the photon mean free path in the photosphere. EST will provide the most sensitive diagnostics of the thermal, dynamic and magnetic properties of the plasma in the solar atmosphere, at the highest spatial resolution, and over the most scale heights available on any solar telescope, on the ground or in space. The use of Fabry-Pérot spectrometers and Integral Field Unit spectrographs will allow simultaneous high temporal resolution 2-D spectroscopy and spectropolarimetry at multiple heights in the solar atmosphere. This is currently unachievable with any other facility.

EST will also deliver an unprecedented level of data in solar physics, of the order of Pb/day, to be managed by the EST Data Centre (DC). Here, it is foreseen that the UK will have a major role in partnership with a few European institutions in the DC. Addressing the data handling will also enable various opportunities for UK industry.

Following the completion of the H2020 project PRE-EST, all telescope subsystems including the enclosure and the first-generation instruments (Tunable Imaging Spectropolarimeters and Integral Field Spectropolarimeters) are now mature enough to pass the Preliminary Design Review by early 2024. Once the environmental impact assessment is completed and the license issued, a construction start date in 2024 would be feasible.

UK Roadmap for Solar System Research.

At the end of 2022, the EST Board of Directors (on which the UK sits) voted to establish a Canarian Foundation as the interim legal figure for EST, with the goals of bringing on board the ministries to work towards establishing the EST ERIC. Alongside that work the Project Office continued to support the remaining aspects of the telescope and instrumentation design, including managing PDR, as well as the environmental assessment and construction permit applications.

In the UK, the solar community successfully argued and the STFC Solar System Roadmap now includes EST as one of the high-priority future facilities for the UK community.

Led by Sheffield, several groups in the UK including Aberystwyth, Durham, Exeter, Glasgow, and Queen's University Belfast have made a commitment to form a UK Universities Consortium (UKUC) and raised funds to join the EST Canarian Foundation for the next 2 years. University College London has also indicated willingness and is looking into opportunities to contribute. Further, UKUC has successfully applied to STFC who have also supported financially UKUC to join the Foundation.

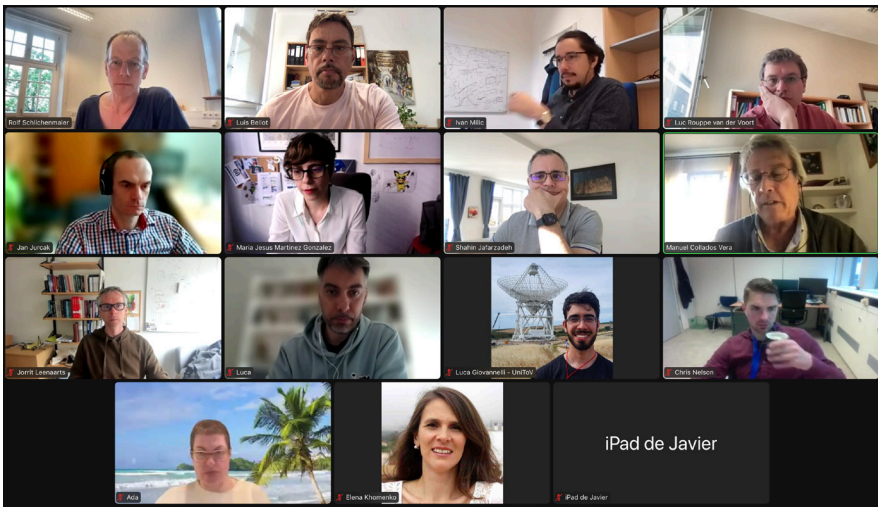
The UK currently supports developments of future benefit to EST, including participation in the TIS design, the Data Centre design, and the development of a solar turbulence profiler and real-time control system which has applications to the adaptive optics implementations for both DKIST and EST.

Membership of the EST Canary Foundation maintains the UK's position in the project enabling the UK solar community to retain the option to join the ERIC and leverage not only previous investments in DKIST, but also the MCAO developments for ELT and UK expertise in big data and data intensive science.

SCIENCE ADVISORY GROUP ACTIVITIES

An update on the SAG activities in the last 6 months is given.

The EST Science Advisory Group (SAG) was formed during the PRE-EST project in November 2017 by the PRE-EST Board and the EAST General Assembly. Twenty two members from eleven European Countries were selected to join the group. Many tasks have been accomplished by the SAG during the first six years of its existence. The first task consisted in revising the EST Science Requirement Document. Apart from defining the main science objectives of EST and specifying the scientific requirements of the telescope, the SAG devised Observing Programmes needed to address the science cases. This work was published in December 2019 on arXiv, a dedicated science server at Cornell University that is commonly used in the field of Astronomy & Astrophysics, under the reference arXiv:1912.08650. Subsequently, these science requirements were translated into technical requirements.



EST SAG meeting held online on April 28, 2023.

SAG renovation

During these years, the project, the scientific and technical state-of-the-art as well as the solar community has evolved significantly. Therefore, time has come to revise the composition of the SAG. This task was presented and discussed at the EST project meeting in September 2022 on La Palma, and later at the EAST General Assembly in January 2023 in Prague. Finally, in a SAG meeting on April 4, 2023, a revised composition of the group was decided. The objectives of the revision were to assure continuity on the one hand and to integrate representatives of the younger generation on the other hand. At this stage of the project, it was considered important to keep the group European as instrument and telescope know-how is well represented and ongoing in European research institutes and companies. For practical reasons of organising online meeting, it is also of advantage to have people who live in a similar time zone. But it is also agreed to profit as much as possible from the experience that is gathered with the US 4m DKIST telescope on the summit of Haleakala (Hawaii). In that respect it will be important to stay in close contact with our colleagues at the headquarters of the National Solar Observatory in Boulder (Colorado, USA).

Finally, the following 22 members of the SAG were approved on April 4, 2023: Rolf Schlichenmaier (Leibniz Institute for Solar Physics, KIS, Germany, chair), Luis Bellot Rubio (Instituto de Astrofísica de Andalucía, IAA-CSIC, Spain), Mats Carlsson (University of Oslo, UiO, Norway), Sanja Danilovic (Stockholm University, SU, Sweden), Robertus Erdelyi (University of Sheffield, USFD, UK), Alex Feller (Max-Planck Institute for Solar System Research, MPS, Germany), Luca Giovannelli (University of Rome Tor Vergata, UniToV, Italy), Peter Gömöry (Astronomical Institute of Slovak Academy of Sciences, AISAS, Slovakia), Shahin Jafarzadeh (Max-Planck Institute for Solar System Research, MPS, Germany), David Jess (Queens University Belfast, QUB, UK), Jan Jurčák (Czech Academy of Sciences, CAS, Czech Republic), Elena Khomenko (Instituto de Astrofísica de Canarias, IAC, Spain), Christoph Kuckein (Instituto de Astrofísica de Canarias, IAC, Spain), Jorrit Leenarts (Institute for Solar Physics, Stockholm University, SU, Sweden), María Jesús Martínez González (Instituto de Astrofísica de Canarias, IAC, Spain), Ivan Milic (Leibniz Institute for Solar Physics, KIS, Germany), Chris Nelson (European Space Research and Technology Centre of ESA, ESTEC, The Netherlands), Ada Ortiz (Expert Analytics AS, Norway), Javier Trujillo Bueno (Instituto de Astrofísica de Canarias, IAC, Spain), Luc Rouppe van der Voort (University of Oslo, UiO, Norway), and Franziska Zeuner (Istituto Ricerche Solari, IRSOL, Switzerland).

Updating the observing programmes

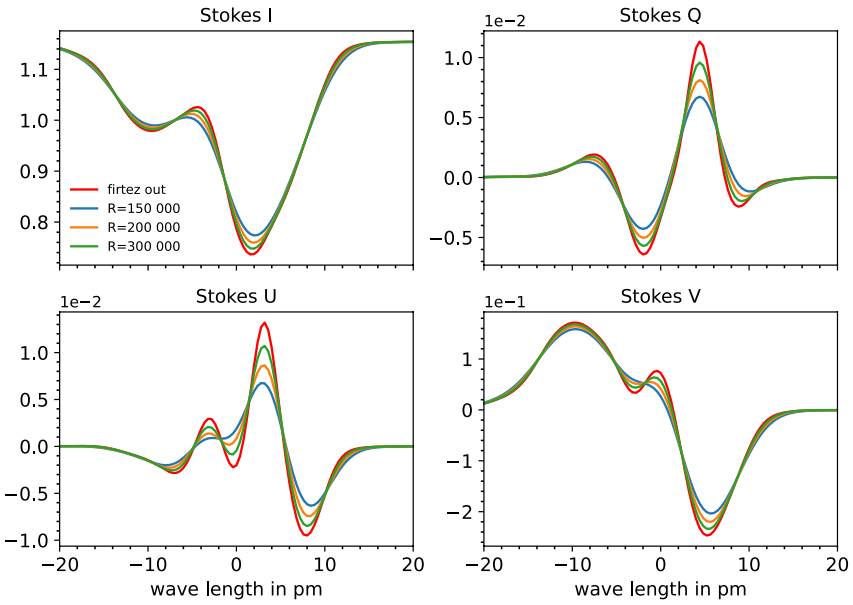
In a joint effort between the EST Project Office, the review panel which consists of instrument and telescope experts, and the SAG, the Coudé room light distribution (CLD) and the Science Instrumentation Suite (SIS) was developed during the last 3 years. The SRD published in December 2019 contained Observing Programmes that were the baseline for developing the CLD and the SIS. However, already four years later the observing programmes of 2019 are in some respects outdated. Science and instrument technologies have evolved making an update necessary. Also, one needs to make sure that the old observing programmes can be adapted to the specific plan for the light distribution (CLD) and the available instrumentation (SIS) such that the corresponding science objectives can be met.

Many science cases request to observe simultaneously different layers of the solar atmosphere. The EST light distribution concept is now planning for three optical arms in the blue, visible, and red/IR. Each of the arms shall be equipped with a Tunable Imaging Spectropolarimeter (TIS), based on Fabry-Pérot interferometers, and an Integral Field Spectropolarimeter (IFS), with the exception of the IR arm. There, two IFS instruments are planned: an image slicer which simultaneously observes the spectral bands at 1 micron (including He I 1083.0 nm) and 1.5 microns (including the iron lines around 1565 nm), respectively, and a micro-lens array for the Ca II IR line at 854 nm.

For each observing programme, characteristic key parameters of the instruments need to be specified. One has to select the list of spectral lines, the central wavelength, choose one of three modes of observation (imaging, spectroscopy, or spectropolarimetry), specify the field of view, the spatial sampling, the spectral resolution, the spectral range, the signal-to-noise ratio, and the cadence time to cover the field of view for repetitions. For TIS instruments, one assumes critical sampling in the spectral dimension, but for specific science cases, an undersampling may be necessary to be able to complete the measurement fast enough to freeze the dynamic solar atmosphere. In such cases, the number of wavelength points can be used to characterise the observing programme. For IFS instruments, the required field of view may not be covered in a single measurement. In these cases, the field of view is measured subsequently with a mosaic scanning device. The integration for an individual tile of the mosaic should then also be specified in order to assure the integrity of the spectra.

One of the challenges of updating the observing programmes consists in choosing which instrument of a given optical arm is used for which spectral line. The TIS instruments will allow to switch between spectral lines during the measurement by changing a prefilter, while this will not be possible for the IFS instruments. IFS instruments can be tuned to observe different spectral lines, but the tuning cannot be done during one measurement.

The update of the observing programmes is ongoing and the SAG plans to finalise this exercise before the summer break, such that the design reviews for the light distribution system and the instrument suite can be completed by the end of 2023.



Spectropolarimetric signals produced by a small-scale photospheric feature in the Fe I 630.25 nm line for different values of the spectral resolving power R.

Study on spectral resolving power

Monitoring all telescope and instrument developments and assuring that the scientific objectives of EST are guaranteed is a major task of the SAG. One SAG subtask is to quantify the spectral resolving power of the IFS instruments.

The TIS instruments cannot afford high spectral resolution, as the scan through wavelength takes time, and time is limited by the short dynamic time scales of the solar atmosphere. The situation is different for the IFS instruments, which record the entire spectral lines in one go. Although their exposure time will also be limited by the dynamic time scales, there is more freedom to choose the spectral resolution that is needed. Therefore, a critical question consists in determining the minimum resolving power required to detect small-scale magnetic properties. Such an investigation is ongoing, but the preliminary results suggest that photospheric small-scale features need a resolving power of at least 200,000 to be studied properly.

JOINT MEETING OF INSTRUMENT TEAMS AND SAG

The status of the EST instrument suite was reviewed in a joint meeting of the instrument teams, the EST SAG and the EST Project Office held in Prague in January 2023.

Instrument design progress meeting held on January 19-20 at the headquarters of the Czech Academy of Sciences in Prague.

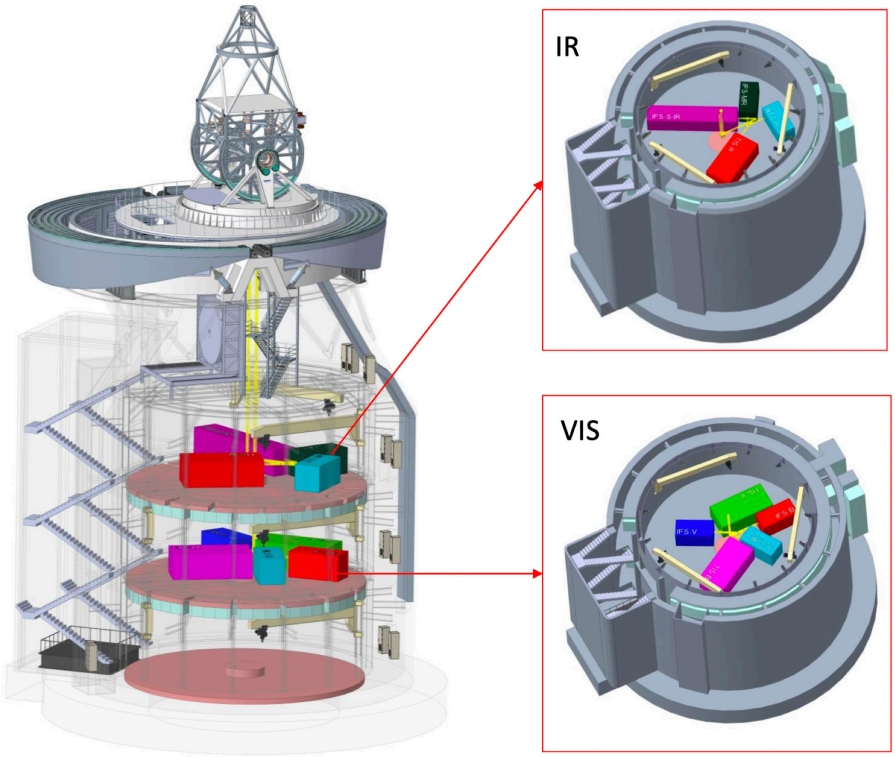
As the EST design evolves and becomes more detailed, continuous monitoring by the Science Advisory Group is mandatory to ensure that the science requirements of EST are met. While the engineers at the EST Project Office work on the completion of the opto-mechanical design, various teams have been formed and have started to draft conceptual designs for the different types of instruments. To keep the loop closed between these groups, a first meeting after the end of PRE-EST was held in Prague on January 19-20, 2023.

The local organisation was done by the solar group at the Astronomical Institute of the Czech Academy of Sciences. The Astronomical Institute is located in Ondřejov, southeast from Prague. As venue for the meeting, the solar group managed to provide the venerable lecture hall in the headquarters building of the Czech Academy of Sciences in downtown Prague.

After years of pandemic, remote meetings became more and more common, but this meeting was held as a hybrid meeting. Many participants were present in person, and those who could not attend for various reasons participated online. The participants profited from the inspiring atmosphere of the venue and took advantage of having personal contacts with each other. During these informal discussions, a lot of brainstorming was possible, and the EST Project Office team, the instrument teams, and the members of the Science Advisory Group exchanged their ideas and discussed their different perspectives on the design of EST.

The meeting started with an introductory presentation of the EST science requirements and the EST unique design advantages from the perspective of the Science Advisory Group. It was acknowledged that the innovative solution of an adaptive secondary mirror makes for an excellent EST baseline design. The first two imaging mirrors are followed by four mirrors that transfer the light beam into the Coudé lab and serve also as conjugate deformable mirrors to integrate the Multi-Conjugated Adapted Optics (MCAO) into the telescope proper without the need for transfer optics. As such, EST needs only six mirrors and a doublet lens to deliver the light beam to the instrument platform in the Coudé lab. As a result, EST will provide the science instruments with an extremely high photon flux and a large field of view of excellent image quality. A comparable low number of mirrors has previously only been realised at the Swedish Solar Telescope (SST) on La Palma. The SST is known for its excellent image quality and high photon flux, demonstrating the concept in a clear way.

The EST Coudé Light Distribution (CLD) and the Science Instrumentation Suite (SIS) was presented and discussed both from the science requirements perspective and from the systems engineering point of view. The CLD foresees three optical arms in two Coudé rooms: the lower room will receive light with wavelengths from 380 up to 680 nm. This beam will be split into a blue arm from 380 to 500 nm and a visible arm from 500 to 680 nm. The upper room will hold the instruments that operate in the red and near infrared, from 680 to 2300 nm.



Two Coudé rooms inside the EST building will host the telescope scientific instruments.

The EST Science Requirement Document had identified key spectral lines for the three optical arms to monitor simultaneously different layers of the solar atmosphere. Following careful assessment of current technologies, two different types of instruments have been selected to be part of the EST SIS. The first is Fabry-Pérot imagers that have large fields of view and scan the spectral line in wavelength. These instruments, called Tunable Imaging Spectropolarimeters (TIS), contain a broad-band channel for image reconstruction that can be used to perform broad-band imaging as well. The other type of EST instruments are integral field units, called Integral Field Spectropolarimeters (IFS). Concepts for these two types of instruments were presented and discussed at the meeting.

Two kinds of IFS based on different technologies are being considered for EST: image slicers (IFS-S) and microlens arrays (IFS-M). A third type of IFS was proposed in Prague: an integral field unit based on a multi-channel design in which the beam passes the grating two times. The concept of this New Generation Multichannel Subtractive Double Pass spectropolarimeter, the MSDP-NG, was presented and its capabilities considered appropriate for EST, so it will be followed up in the future.

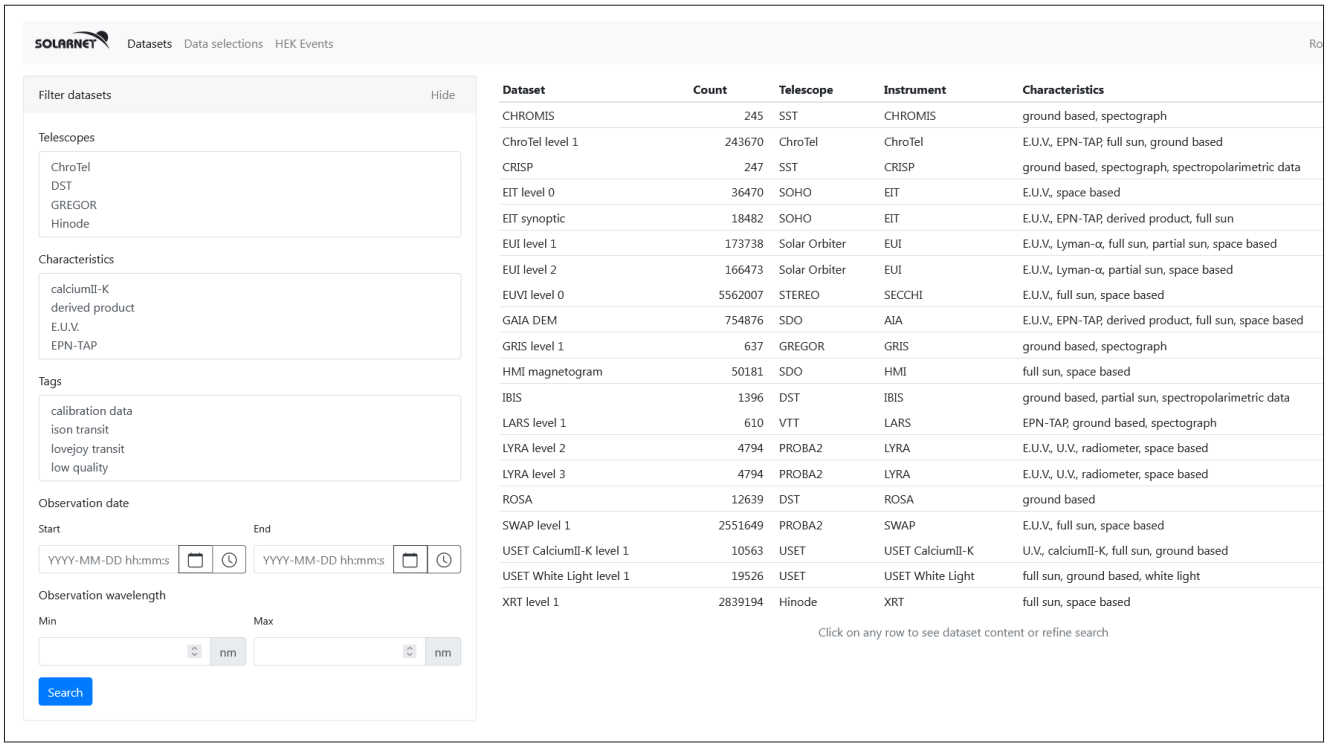
The EST SIS concept which resulted from the scientific requirements is being examined from a systems engineering perspective by the EST Project Office. The interfaces between the telescope and the instruments need to be defined, which will result in the General Design and Interface Requirements (GDIR) document. This document specifies the number, kind, and type of planned instruments. It describes the properties of the light beam that is delivered to the individual instruments, and presents a concept for the physical size, weight, and location of each instrument in the respective Coudé room.

Based on scientific and technical requirements, the instrument teams issued the first drafts of their Instrument General Requirement Document (GRD). In an iterative process, the GRD of each instrument will need to match the GDIR. While the Project Office and the instrument consortia iterate on optical interface issues as well as on the detailed physical design of the instruments, the task of the EST Science Advisory Group consists in monitoring the performance parameters of each instrument to assure that the science requirements are met.

Another crucial interface discussed in Prague is the data transfer interface. The planned suite of post-focus instruments will record a vast amount of observations that will need to be transferred to a data storage system. The observations will be calibrated, reduced, and analysed. The final data products will be archived and distributed to science users. Possible architectures for the EST Data Centre were discussed as well as data rates and data volumes. At this point in time, there are still a lot of uncertainties in quantifying such numbers, so various scenarios need to be considered. New developments in the field of machine learning may lead to methods that can be applied to reconstruct the acquired images. If such methods prove to be reliable, data rates and volumes could be reduced significantly. Present ideas about the EST Data Centre are summarised in a separate article in this issue.

THE SOLARNET VIRTUAL OBSERVATORY

The SOLARNET Virtual Observatory (SVO) has been developed into an operational system and multiple solar physics datasets have been made accessible and searchable through it, ready to be used by the solar community at large.



The Solarnet Virtual Observatory web interface, accessible at https://solarnet.oma.be upon registration.

The SOLARNET Virtual Observatory (SVO) was first developed into a prototype version in the FP7 SOLARNET project and further developed into an operational system in the H2020 SOLARNET project.

One of the aims of both projects was to bring together high-resolution solar physics data. These data often come from ground-based solar telescopes that cannot take measurements continuously but do so during observing campaigns, unlike data gathered by instruments onboard satellites which can make observations more or less continuously.

Keeping this in mind, the SVO was designed to work like a discovery machine, where researchers could not only search for the specific data or event that they are interested in but also search across multiple datasets so they can easily "discover" other data that they did not immediately think of but will help them in their research.

At the heart of the SVO is a meta-data database containing the meta-data from solar datasets taken both by space-borne and ground-based instruments. This lets users search across multiple datasets, by observation date, wavelength, tags and telescope, but also make more in depth queries on the meta-data of an individual dataset. The database can be queried through a web interface, an IDL client, and a Python client. Other tools can be interfaced with the database through the RESTful API. In addition, the Heliophysics Event Database (HEK) has also been integrated into the SVO and lets you search for data that overlaps with events from the HEK.

The SVO web interface (shown in the accompanying figure) makes it possible to see quick look images of data searches if the images are available and allows you to download the selected data through one FTP link which can be easily shared with colleagues.

Already quite some solar datasets are fully or partially available through the SVO, some through the EPN-TAB protocol, and work is being done to add more. Please have a look at the SVO website (https://solarnet.oma.be) and share and bookmark it if you like what you see. This work has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 824135.

THE EST PRELIMINARY DESIGN REVIEW

The EST Preliminary Design Review (PDR) will be the main tool to establish the technical readiness of the project to proceed to the construction phase. It is scheduled for early 2024.

According to the International Council on Systems Engineering, a PDR "*is the revision to evaluate the technical adequacy of the design that must fulfil the top level requirements that had been broken down up to low level requirements and allocated on engineering items so that they can be verified reliably by design, by digital models analysis or by testing prototypes. The risk of the design, manufacturing, integration, maintenance and operation must be identified and mitigated to an acceptable level. The interfaces must be defined and frozen. The main design decisions must have been taken.*"

The main EST Construction Plan shall define the Management Plan, the Quality Assurance Plan, the System Engineering Plan, and the Assembly, Integration and Verification Plan. Construction costs and schedule shall be estimated for the next construction and commissioning phases. After the PDR, the design will be updated with the feedback of the PDR reviewers, so that the baseline design approach is technically feasible and within the schedule and financial constraints. The detailed design documentation specifications and the construction permit paperwork shall also be produced.

The EST PDR will be a technical review to help identify weaknesses in the project in order to take correction measures and mitigate risks. An intensive review of the telescope preliminary design by leading solar scientists in the different fields covered by the EST design will be carried out. Different reviewer profiles are expected: experts on solar telescope design, maintenance and operations, experts on particular technologies used by EST, etc.

During the first half of 2023, the preliminary designs of several EST subsystems have been concluded while others are progressing towards completion. Once the design of the various subsystems is finished at the level required for PDR, the EST global PDR will be held, to cover all the engineering aspects of the telescope at preliminary design level.

The EST science instruments and Data Centre will be at a conceptual design level. Their design and integration with the telescope will be verified; therefore, they will be reviewed at the PDR, but at a less advanced level.

The current status of the design work is as follows. The Telescope Structure, Primary Mirror, Secondary Mirror, Pier and Enclosure preliminary design is complete. These subsystems have passed their specific PDR and their performance has been checked by design, analyses and/or tests.

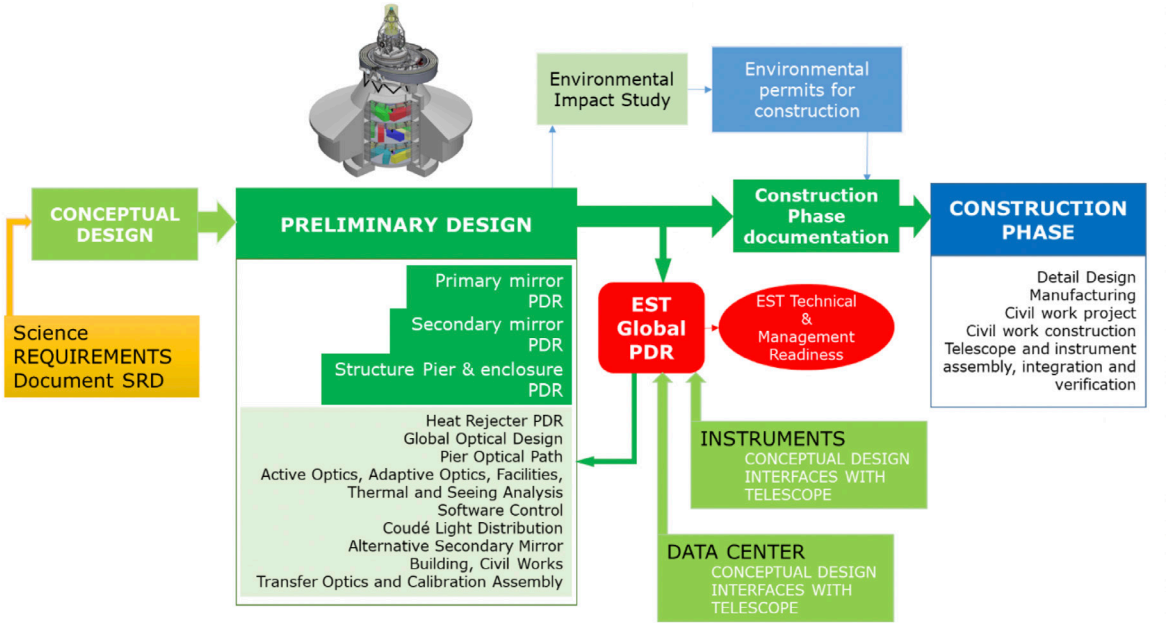
A number of prototypes have been developed for verification purposes: M1 actuators, M1 thermal model, a 19-actuator M2, and an M2 thermal model. Tests at a wind tunnel have been performed with a scaled telescope structure and pier model using the orographic information of the construction site. Some of the tests have been carried out at the IACTEC premises after the conclusion of the design contracts.

Other subsystems are quite advanced:

- The Heat Rejecter (HR) is in the last phase of the preliminary design and the prototype is ready to undergo a test campaign. The specific HR PDR is scheduled for summer 2023.
- For the thermal and seeing analyses, thermal and fluid models have been consolidated with an external reviewer and a series of analyses have begun by the EST-PO to provide design information and seeing inputs for the error budget to be presented at the global PDR.
- The telescope Optical Design, Active Optics, Adaptive Optics, and Coudé Light Distribution are presently under a critical analysis by the EST-PO to improve their performance.
- The Pier Optical Path (POP) baseline developed by the EST-PO is advanced and an external review has been carried out to study an alternative optical design proposal.
- The required accompanying Facilities and Services are in an advanced stage, including the last modifications implemented to meet the design requirements of each telescope subsystem.
- Tests of alternative control software packages are almost finalised using demonstrators of the candidate control systems (from GTC and DKIST). In parallel, the software and control requirements of the different subsystems and the control interfaces between them show a good progress. As a result of these analyses, the software and hardware document that will include the structure of the EST Control System will soon be produced.

A few work packages are progressing with some delay:

- The development of an alternative secondary mirror prototype based on voice coils by the company Adoptica has started in May 2023.



Block diagram showing the EST path to construction, including main works performed in each of the different phases.

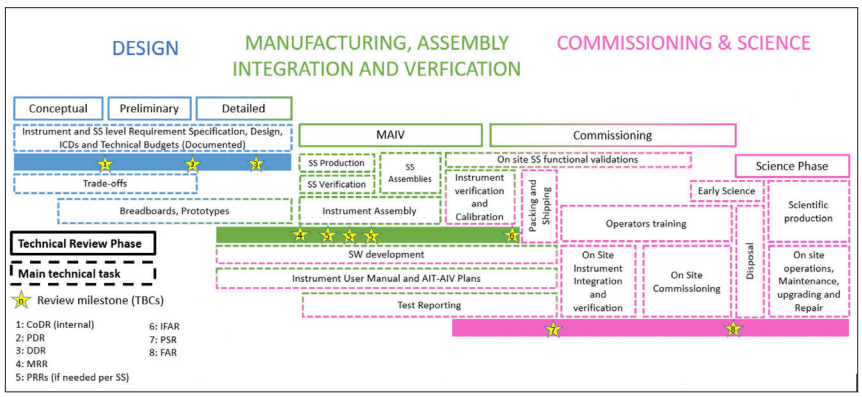
The results obtained with this technology for an adaptive secondary mirror will be presented at the PDR.

- The Transfer Optics Calibration Assembly conceptual design has been completed and the development of the preliminary design has begun. Input from other subsystems and feedback from some manufacturers are still pending. The preliminary design is expected to be ready in the coming months.
- The Building and Civil Works package has been delayed due to problems in announcing the corresponding call for tenders. The kick-off meeting for the Preliminary Construction Project is expected to take place by the end of 2023. It will include a geotechnical study at the EST site and the Environmental Impact Study to initiate the administrative procedures for the construction. The status of this package will be shown at the PDR.

The EST Science Instrumentation Suite (SIS) is currently in the conceptual design phase in order to fulfil the needs of the telescope PDR. This phase shall confirm that the system level requirements are sufficiently well understood by the SIS developers team to establish an initial system-level functional baseline with alternative instrument designs to be further traded or analysed.

The different instrument concepts are being tuned to accurately fulfil the top-level system requirements that translate the needs from the different science cases described in the EST Science Requirements Document. Also, the instrument level external interfaces are being identified and analysed, particularly in terms of design, development, production and operating constraints. This work is being done with the collaboration of the SIS consortia, the EST SAG and the EST-PO. It is encompassed by the SIS Systems Engineering Plan and the SIS General Design and Interface Requirements that drive the overall SIS development according to the EST needs.

The elaboration of the PDR documentation is currently in progress. The original intention was to held this revision in mid 2023 but, due to unexpected issues and in order to achieve a high quality revision, it shall be shifted to the beginning of 2024. This milestone will pave the road towards the detailed design and construction of EST.



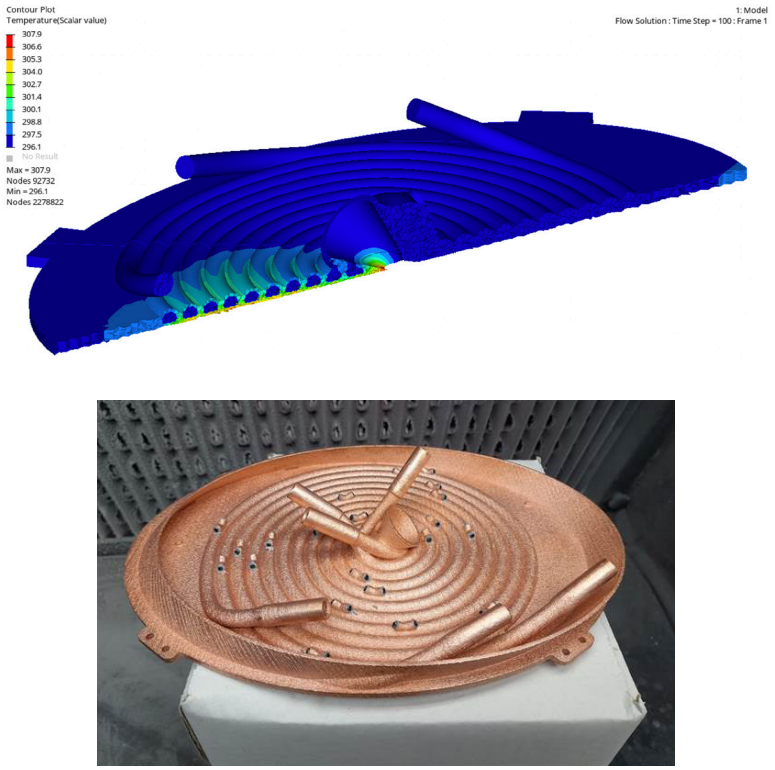
Plan for the Design, Manufacturing, AIV and Commissioning of the EST instruments.

HEAT REJECTER DESIGN STATUS

The status of the preliminary design of the heat rejecter, being performed by CITD, is presented.

The preliminary design of the EST Heat Rejecter (HR, the cooled mirror with a central hole that lies at the prime focus of the telescope) is divided in 3 phases. The Phase 2 review was closed in January 2023. The main goal of Phase 2 was the design and optimisation of the solution selected in Phase 1, based on the jet impingement technology. Another goal of Phase 2 was the design and definition of a thermal prototype to validate the key requirements for the successful operation of the Heat Rejecter.

The cooling system of the Heat Rejecter at the end of Phase 1 was a non-sectored jet impingement, a promising technology in the astronomy field that has been used in many other applications. A prototype of jet impingement as a demonstrator for EST was developed and manufactured by the Italian company SRS in the framework of the SOLARNET-FP7 project, so that its performanece can be verified by tests.



Top: HR thermal analysis. Sun is up, ambient temperature is 25º and coolant 2º below ambient temperature. Bottom: HR prototype in additive manufacturing.

One of the key parts of a preliminary design is to evaluate the most valid solution among the different alternatives. According to the analyses, the jet impingement technology shows benefits but also potential risks. Consequently, it has been decided to investigate its main alternative: the cooling coil.

At the end of the Preliminary Design, exhaustive analyses and prototypes will be available for both technologies, giving EST the necessary information to choose the best concept for the detailed design. The EST-PO also plans to perform parallel test campaigns to compare the performance of the cooling coil prototype (preliminary design) and the jet impingement prototype (conceptual design).

A sectored cooling coil was investigated in the first place. This design would allow using lower coolant temperatures without risk of condensation. A controlled HR would lead to lower thermal gradients on the mirror surface, reducing thermal plumes and their effect on local seeing. Different strategies with different numbers of sectors were tested. It was concluded that the trade-off between performance and the added complexity in manufacturing and control was not sufficient to choose this concept. Consequently, the design evolved into a more robust non-sectored three-channel cooling coil. This new design is enhanced by the use of additive manufacturing. The coil channels are shaped to maximise the heat transfer at the acute angles formed by the tilted surface of the HR (see images).

During Phase 3, several analyses will be carried out in more detail and the manufacturing of the HR prototype based on cooling coils will be finalised for testing. The testing will include variables such as the temperature of the mirror and other external surfaces, the sensor locations, the operational ranges, the settling time of the system, the control system monitoring, the cabling and equipment dimensions, and safety.

The HR mirror prototype will be manufactured in additive manufacturing by the AIDIMME Institute of Technology (Valencia, Spain). Also, the prototype integration and tests will be carried out by ARQUIMEA (Madrid, Spain).

Finally, after checking whether the key requirements are fulfilled by one or both prototypes and updating the design with the feedback from the prototype conclusions, the design shall pass the HR Preliminary Design Review.

THOUGHTS ON THE EST DATA CENTRE AND DATA HANDLING

Challenges and critical guidelines for the design of the EST Data Centre are discussed.

EST's yearly data rate estimates vary between a few 100 PB and up to about 3 EB. Even the lower limit poses a challenge for data calibration distribution and processing. Raw data from the instruments need to be calibrated and previews produced on time, not to mention their distribution to partners on the European continent and the production of compute-intensive higher-level data products. With this amount of data, any strictly unnecessary transport of data needs to be avoided—computations must go where the data resides rather than vice-versa, as it is common today.

The long-term storage of all data will be a non-negligible cost factor. It might be impossible to store raw data extensively after observations, and reprocessing by improved pipelines and algorithms, which is common nowadays, might prove to be too costly. Therefore, all standard data processing and calibration routines must comply with hitherto unseen standards of robustness and quality. Hence, science with EST might be forced to rely on novel fast data-processing algorithms based on machine learning and artificial intelligence. At the same time, it is important that data products are kept longer than the 11-year solar cycle for confirming or detecting unforeseen physical effects in the EST's precious high-resolution data.

Sustainability is to be considered from the start. Data handling, FAIR (Findable, Accessible, Interoperable, and Reusable) data policy, and, after some limited embargo time, free access to data beyond the solar physics community in the context of related national and European data clouds (e.g., EOSC), are mandatory.

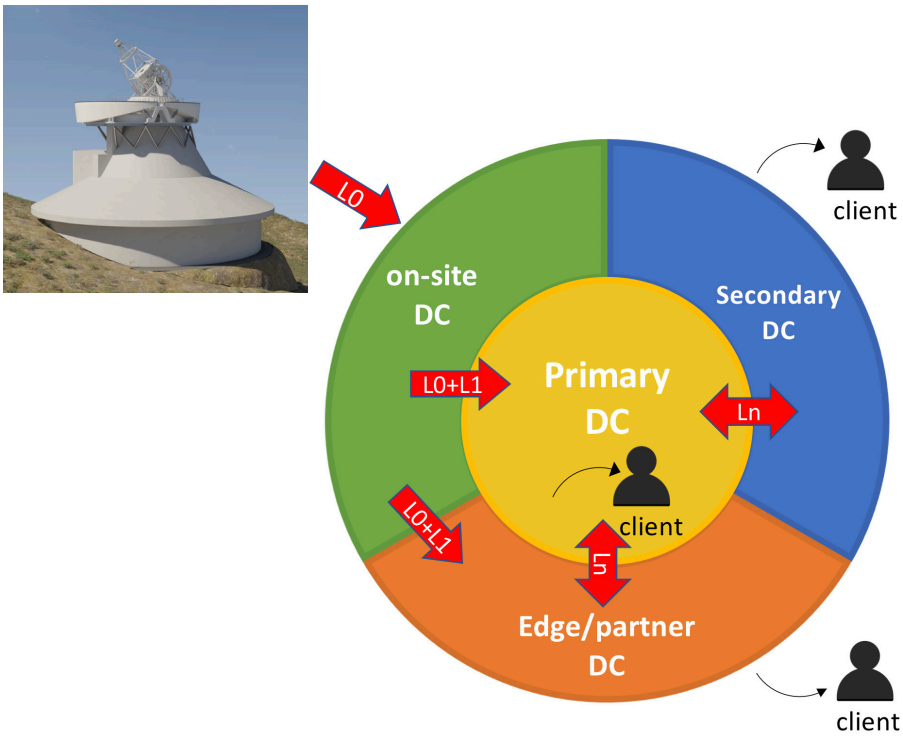
EST will be located in the Canary Islands. Initial data processing, like timely data calibration and producing previews, naturally needs to be done close to the telescope to allow observers to judge and influence ongoing observations. However, most of the subsequent scientific exploitation of EST's data will be done in institutions on the European continent and worldwide (always, as mentioned above, keeping in mind that minimising data transport is prime). That said, the EST Data Centre (EST DC) will at least span two geographically distinct sites, one in the Canary Islands and one or more in mainland Europe. Moreover, because EST scientific instrumentation will be developed by different consortia, expertise in the data of the various instruments will be distributed among several institutions.

As outlined, the EST DC design will have to account and allow for data distributed among various sites throughout Europe and worldwide, yet still forming one homogeneous well-structured data lake from a user's perspective. Ideally, a user should not be bothered where a particular dataset resides. Instead, scientists will submit their analysis to the system, which relocates the job to the EST DC site, where a copy of the particular data set to be processed is already stored, and computing resources are available. This shows that computation in EST cannot be separated from storing data, but analysis must be data-location-aware yet easy to use. Recent scientific efforts producing data of similar size have evolved their computing and data-storage paradigm over time accordingly. EST will have to do so right from the start. Rather than merely being responsible for storing data, the EST DC will also be responsible for developing, evolving and maintaining a scientific computing environment for all participating sites while allowing other data and computing centres and instrument-developing consortia to bring in and leverage their expertise on certain kinds of data and analysis techniques.

Hence, one can foresee, in addition to the aforementioned two data centre sites, a more complex topology of networking and cooperating data centres. Will it consist of one big data centre in mainland Europe concentrating all storage (and computing resources) in one place? Will there be two data centres to provide backup and share the computing load? Will it comprise several small ones with data from one instrument physically located close to the respective instrument-development consortia? From today's perspective, it is important not to exclude any of these possibilities.

Together with a standard data policy (encompassing a consortium-wide embargo policy, copyright, and questions on which data- and software license to use within EST and its DC), the decision for the final topology of the data centre will need to be one of the first to be made in close cooperation with the telescope- and instrument-developing consortia as well as experts in scientific data and computational facilities by the ongoing design of the EST DC.

Several well-maintained open-source solutions originating from particle physics exist for the life-cycle management of data in the multi-petabyte



Conceptual view of the EST Data Centre. In addition to the on-site data centre close to the telescope (green), possible EST data centre topologies range from a single primary data centre node (yellow) on the European mainland or two of those (by adding a "secondary" data centre of similar size, yellow, at some other European location) to several smaller "edge" data centre (orange) with specific tasks located at various partner sites. The data centre could also only consist of the latter, with the "primary data centre" developing, coordinating and maintaining the overall framework for storage and computing.

range that increasingly gain inertia in other communities like astroparticle physics, biology, and chemistry. They nowadays form the basis for most European (ESOC) and national (e.g., Punch4NFDI in Germany) efforts to store and process data from different scientific fields. The goal is that ideally data from other scientific realms can be found, correlated, accessed and processed online (even in the public cloud). Products like Rucio (http://rucio.cern.ch) for data management, as well as dCache (http://dcache.org) and XRootD (https://xrootd.slac.stanford.edu) for reliably storing petabytes of data, come to mind. They all share that data processing is inherently location-aware and can be triggered when data arrives at a particular location. If EST operated today, its data centre would likely be based on these products. It is, however, expected that other products and technologies will be available by the time EST enters operations.

Also common to all those products and frameworks is their ability to interface with various protocols used elsewhere for exchanging and processing scientific data. Data can be stored on almost any medium, including the (public) cloud and tape. The latter, as of today, is still the most energy-efficient way to hold exabytes of data—an aspect that is of uttermost importance for solar physics, with its need to retain data for several decades.

Authentication is typically based on protocols used in the grid computing environment. A shared authentication and authorisation infrastructure spanning different fields of science is needed to grant access to computing resources and data not (yet) publicly accessible. Community-spanning efforts accompanying all the data efforts mentioned above are also well underway.

Designing the EST DC as a distributed facility, including storage and computation, is an effort comparable in size and complexity to the telescope's design. Also, building and operating the DC, allowing EST's data exploitation, will pose a non-negligible cost factor. Considering ever-evolving storage technologies and computing algorithms, neither costs nor technological implications can be predicted reliably over the decade until EST will finally be built.

Therefore, EST and the European solar community are advised to involve existing computing and storage infrastructures built for similarly data-hungry endeavours (e.g., the LHC) during this early design phase. From today's perspective, the most crucial aspect of the data centre design is not to exclude any technology and to stay compatible with European and national data efforts and policies while allowing it to face the computing and data-handling challenges described above.

REACHING FOR THE SUN PREMIERE IN ROME

The EST documentary was premiered in an event held at Accademia Nazionale dei Lincei, where the first observations of sunspots by Galileo are stored.

Presentation of the documentary "Reaching for the Sun" in Rome (Italy). Credit: Giorgio Giannetta / Zeo Studios.

The EST TV documentary "Reaching for the Sun" was presented at Accademia Nazionale dei Lincei in Palazzo Corsini (Rome, Italy) on May 26, 2023.

Organised by the Solar Physics Group of Università di Roma "Tor Vergata", the event was attended by EST representatives from Università di Catania, INAF-Osservatorio Astronomico di Roma, INAF-Osservatorio Astronomico di Capodimonte, and Instituto de Astrofísica de Andalucía (IAA-CSIC), as well as numerous interested people, Italian students who had participated in the international EST school competition "The Sun at a Glance" in 2022, members of the Accademia, and several media representatives.

The program included welcome words by Prof. Maurizio Brunori, Emeritus President of the Science Division of the Accademia dei Lincei, and Dr. Carlos Tercero, Cultural and Scientific Attaché of the Spanish Embassy in Rome. Then, Luca Giovanelli (Università di Roma Tor Vergata) gave a presentation about the Sun as a star and the EST project, followed by Francesca Zuccarello (Università di Catania) who presented the Italian participation in the EST project, highlighting the contribution of Italian scientists and technological companies over the years.

The EST documentary was screened after these presentations. The event continued with a description of the EST school competition by Mariarita Murabito (INAF-Osservatorio Astronomico di Capodimonte), followed by a student presentation of one of the infographics submitted

EST representatives interviewed by the media. Credit: L. Bellot / IAA-CSIC.

Screening of the EST documentary "Reaching for the Sun" in Rome (Italy). Credit: L. Bellot /IAA-CSIC.

to the competition. Next, Francesco Berrilli (Università di Roma Tor Vergata) introduced the fiction video series "Here comes the Sun", produced by Università di Roma Tor Vergata and Zeo Studios within the framework of the Preparatory Phase of the European Solar Telescope, and its five episodes were screened.

Finally, a round table took place in which the audience and students could ask questions to the EST scientists attending the event.

The presentation made it to several online news channels and TV programs through the ANSA agency and Teleambiente, among others.

The program can be downloaded at https://www.lincei.it/en/node/10237.

"HERE COMES THE SUN" MINISERIES RELEASED

What would happen to our technological society if a superflare would occur on the Sun? The miniseries "Here comes the Sun" addresses this question and highlights the importance of EST.

"Here Comes the Sun" (HCTS) is an innovative video product meant to catch the attention of the general public, and the youngest in particular. The goal of the project is to underline the impact of Space Weather in our daily life and how the European Solar Telescope can help in understanding the source mechanisms of such extreme events.

HCTS was developed by the University of Rome Tor Vergata under the PRE-EST H2020 project, following the goals of WP5 to reinforce the EST visibility and trans-national engagement. It is a miniseries of five episodes, with a duration of about four minutes each. This format has been chosen to match the typical engagement time on YouTube, where it has been distributed. HCTS has been written in order to complement, without overlapping too much, the other video products created under PRE-EST. In this sense, HCTS has a different format with respect to the EST documentary "Reaching for the Sun". The duration of each episode is more similar to the "QuEST" cartoon video series. However, the language is completely different with respect to the animated series. A narrative language set in a hypothetical near future has been chosen, using a writing style in between science and science fiction.

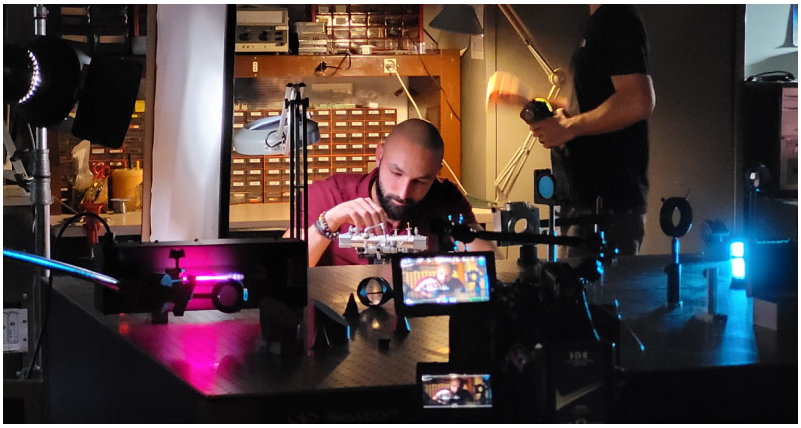
HCTS narrates what would happen to our technological civilisation if a superflare of incredible intensity occurred on the Sun. In the five episodes miniseries we follow Letizia, a science journalist who is the protagonist of this story. Overwhelmed by an event never seen

before, we watch her attempt to understand what happened on the Sun and what repercussions there could be. Space weather researchers and experts explain to Letizia how the Sun works and what are the instruments and techniques used on a daily basis. By doing so the audience is also going to understand the importance of studying the Sun and how challenging it is.

The emergence setup has been chosen to maintain a high level of engagement, always ending the episodes with a cliffhanger to link the viewer attention to the next episode. Letizia herself will have to start a journey to understand what is happening, while the researchers help herself first-hand. An unconventional outreach miniseries that will lead us to discover the Sun and the European Solar Telescope!

HCTS has been developed at national level in Italy and therefore, in order to stay in a medium budget video production, the sets have been chosen to show some of the historical and big science laboratories that contribute to study the Sun in Italy. In order to enhance the pan-european nature of the EST project the miniseries has English subtitles and has been distributed via all the official EST social media. HCTS locations include the THEMIS telescope in the Canary Islands, the APE supercomputer at the INF Rome Tor Vergata, the Borexino experiment for solar neutrinos at the INFN Gran Sasso National Laboratory, and the Telespazio Fucino Space Centre, which with its 170 antennas is the largest teleport in the world for civilian uses, including the control of artificial satellites, telecommunications and hosting, television, and network services multimedia.

The production lasted for over one and half years. The preliminary writing lasted 8 months and included the Zeo Studios company, also involved in the production and the filming, and the outreach association "Space is Cool IT". Filming lasted 10 days, distributed over several months, including 5 people from the technical crew, the actress Alessandra Della Guardia and six researchers and students from Tor Vergata University. HCTS was directed by Giorgio Giannetta of Zeo Studios. Professional cinema equipment was used, including an Ursa mini camera.



Top: Cover picture of the video miniseries. Bottom: pictures of the recording.

In the first episode, "The Superflare", the daily routine of a satellite control center is disrupted by an alarm. Andrea observes something strange on the Sun: will the two events be connected? Letizia has to find out by talking to the satellite connection manager and to Francesco, a professor of Space Weather at the University.

All five episodes can be watched on the YouTube channel of the University of Rome Tor Vergata Physics Department at https://www.youtube.com/playlist?list=PLpV3pIRybyiTFz-yT-y93E-Mc2rIqs3s4R.

EVENTS

EST INVITED TALKS

A list of EST invited talks in national and international meetings is available on the EST website at http://est-east.eu/est-invited-talks

THE EUROPEAN SOLAR TELESCOPE: SCIENCE AND INSTRUMENTS
Rolf Schlichenmaier, in The Many Scales of the Magnetic Sun, Potsdam (Germany), 9 May 2023

EST: THE MOST ADVANCED TELESCOPE FOR ACCURATE HIGH-RESOLUTION SPECTROPOLARIMETRY
Luis Bellot and Manuel Collados, in Solar Polarization Workshop 10, Kyoto (Japan) 7 November 2022

THE EUROPEAN SOLAR TELESCOPE
Manuel Collados, in IAA-CSIC Severo Ochoa Meeting: Addressing Key Astrophysical Questions from Granada, Granada (Spain) 21 October 2022

APPLICATION OF MACHINE LEARNING AND NEURAL NETWORKS TO DATA PROCESSING IN SOLAR PHYSICS
Carlos Díaz Baso, in Hinode 15/IRIS 12 meeting, Prague (Czech Republic), 19 September 2022

OTHER EVENTS

RAS NATIONAL ASTRONOMY MEETING
Cardiff (UK), 3-7 July 2023

VIII SPANISH MEETING OF SOLAR AND HELIOSPHERIC PHYSICS
Granada (Spain), 11-13 July 2023

NLTE WORKSHOP II
Porto (Portugal), 4-6 September 2023

SOLARNET CONFERENCE: SUN IN SCIENCE AND SOCIETY
Venice (Italy), 11-15 September 2023

HINODE-16/IRIS-13 MEETING
Niigata (Japan), 25-29 September 2023

DATA, ANALYSIS AND SOFTWARE IN HELIOPHYSICS
Laurel (USA), 9-11 October 2023

HELIOPHYSICS IN EUROPE
Noordwijk (The Netherlands), 30 Oct-3 Nov 2023

19TH EUROPEAN SPACE WEATHER WEEK 2023
Toulouse (France), 20-24 November 2023

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