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Optical Infrared Coordination Network for Astronomy

Reporting

Project Information

OPTICON

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Coordinated by
THE CHANCELLOR MASTERS AND SCHOLARS OF THE UNIVERSITY OF CAMBRIDGE
United Kingdom

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Research for regions: a coherent research area for Europe

Final Report Summary - OPTICON (Optical Infrared Coordination Network for Astronomy)

Executive Summary:
The OPTICON consortium set out to deliver a simple yet challenging set of strategic objectives:
1. To structure the European astronomical community by ensuring astronomers are able to carry out state of the art research on state of the art facilities.
2. To develop European astronomy by allowing astronomical communities to develop scientific and implementation plans for their own future facilities.
3. To strengthen European astronomy by delivering technology research and development to help ensure extant and future astronomical research facilities are state of the art.

These technological ambitions are met through a complementary set of technology development RTD activities, combining University-based, national agency based, international agency based, and industrial partners. The community strengthening activities are met through a focused set of networking activities, concentrating on developing the community to develop and implement next-generation world-leading facilities and infrastructures. The structuring activities have been met through a unique common-operation peer-review based programme to deliver access to Europe's premier national infrastructures to all scientists irrespective of nationality or local funding support.

Globally OPTICON has made, in conjunction with other national and European astronomical organisations, considerable positive impact in all of the following areas:

i) Maintained European leadership in the key technologies and techniques of Adaptive Optics (WP1, 2);
ii) Developed synergies between European technology players and the astronomical community, making the industrial concerns aware of expertise in the scientific community and vice versa. (WP3, 5, 6, 9.1);
iii) Enhanced co-ordination of the European Interferometry Community (WP4, 11.2);
iv) Opened a range of European observatories to new user communities (WP7) and made significant efforts to engage with these new communities so they can take advantage of these opportunities, by offering a single proposal process (WP12) and training schools (WP11.1);
v) Supported Technology Development for European Solar telescopes (WP1), enabled access to existing solar facilities (WP7) and enabled strategic planning for future new facilities (WP12);

vi) Provided a communications pathway between the general user community and the future European ELT project teams (WP 10);
vii) Published its RTD development results widely for wide benefit, through over 175 published scientific/technical articles.

The beneficiaries of the project include individual research astronomers, astronomers interested in specific subjects or facilities, scientists involved in technical RTD activities, industry, and funding agencies.

Project Context and Objectives:
The OPTICON consortium set out to deliver a simple yet challenging set of strategic objectives:
4. To structure the European astronomical community by ensuring astronomers are able to carry out state of the art research on state of the art facilities.
5. To develop European astronomy by allowing astronomical communities to develop scientific and implementation plans for their own future facilities.
6. To strengthen European astronomy by delivering technology research and development to help ensure extant and future astronomical research facilities are state of the art.

The programme had started to gather pace on all its activities by late 2009 and continued until the end of the contract in 2012. A new grant agreement, approved for the period 2013-2016, will carry forward many of the key achievements of this now completed contract.
WP1: Adaptive Optics Systems
The main objective of this work package was to design and develop Laser Guide Star Adaptive Optics systems for existing large telescopes (e.g. the Large Binocular Telescope (LBT), Very Large Telescope (VLT), the William Herschel Telescope (WHT)), to upgrade extent Adaptive Optics systems for a solar telescope (GREGOR) and to upgrade the Very Large Telescope Planet Finder instrument (SPHERE) to maintain its competitiveness. On-sky tests of prototype systems are a key goal in this, and have been achieved at the William Herschel Telescope as part of the CANARY project.
WP2: Laser Guide Star Adaptive Optics Detectors
The main objective was the development of a scaled-down demonstrator detector CCD for Laser Guide Star wavefront sensing, leading to a version suitable for large scale production and eventual deployment for the European Extremely Large Telescope.
WP3: Astrophotonics
This activity carried out and co-ordinated research in the new field of Astrophotonics to bring to astronomy the benefit of photonic devices developed over many years by the telecommunications industry and to use photonic principles to deal with key challenges in the construction of astronomical instruments required for future generations of observatories.
WP4: High Angular Resolution by Interferometry
The main objective of this activity was to build on the co-ordination of European activities in the demanding area of astronomical interferometry, both to enhance the existing infrastructures and to develop plans for the future.
WP5: Smart Instrument Technologies
This was an effort to develop smart instrument technologies which can be used to meet astronomers' needs for instruments with ever increasing fields of view, higher spectral and spatial resolutions and multi-

object observations within demanding size, mass and engineering limits.

WP6: New Materials and Processes for Astronomical Instrumentation

The main objective was to identify and characterise new types of optically-active materials with possible astronomical applications, moving beyond glass and steel to organic, photosensitive and polymer materials. A specific challenge was the retention of industrial production capability in this technically challenging field following the bankruptcy of the only European based producer of Volume Phase Holographic Gratings (VPHG) substrates.

WP7: Transnational Access

The Transnational Access programme was a key part of the OTICON I3. It made it possible for European astronomers from any region to access the state of the art telescopes and instruments owned and operated by just a few European countries. This was achieved by opening access to a network of telescopes via single, international peer review process which treated all applications equally, giving priority to the best scientific projects irrespective of their origin.

WP8: Management

The Management Board was responsible for making strategic decisions. Meetings were held roughly annually so that the work package leaders could provide overview presentations of their activities, status, and progress to the whole consortium. An Executive committee oversaw the day-to-day implementation of the OPTICON programme and ensured feedback to the key national funding agencies. Both groups met regularly during the contract.

WP9.1: Key Technology Network

This group focussed on specific areas where value could be added by bringing together scientists and engineers from across Europe and from different industrial sectors to exchange ideas and plans, and to generate impact and value. A key role is publicising the future technology opportunities to industry.

WP9.2: Software Standards

This activity has developed detailed software standards for an open, modular system for processing and analysis of astronomical data by end users.

WP10.1: Science Case for the European ELT

The main objective of this working group was to continue to develop and monitor the scientific case for the building of the European Extremely Large Telescope and to maximise community involvement in, and support for, this critical future infrastructure.

WP10.2: European Network for High Time Resolution Astrophysics (HTRA)

This network developed science cases and concepts for telescope and instrument designs for the E-ELT in this specific area. In particular, it concentrated on the science foundations of HTRA, and included considering the implications of suitable detectors and the data acquisition and handling aspects of HTRA on the E-ELT.

WP11.1: Community Development

The main objective was to organise activities transferring knowledge from experienced astronomers familiar with forefront observatories to new users (young scientists, or scientists from the new member states). This was achieved via training schools and conferences.

WP11.2: The European Interferometry Initiative

This activity set out to maximise community-wide involvement in the world's first common-user large telescope interferometer, ESO's VLTI, strengthening both scientific and technical involvement (see for example http://www.european-inteferometry.eu).

WP12.1: Telescope Directors Forum

The telescope directors forum, which included the managers of all the observatories in the TNA programme, met regularly to develop actions of common interest to medium sized telescopes, both those in the Transnational Access network, and those currently of lesser international competitiveness.
WP12.2: Planning for a Viable Future
This multi-pronged activity was set up to optimise and, where possible, integrate the operation of Europe's main 2-4m night time telescopes and Europe's 4 major solar telescopes.
WP12.3: The European Association for Solar Telescopes (EAST)
The main objective was to establish groups which will address key objectives towards plans for a large solar telescope to be included in the ASTRONET Science Vision Roadmap. This led to the creation of a stand alone I3 called Solarnet which began operations in 2013.

Project Results:
WP1: Adaptive Optics Systems
Adaptive optics systems (AO) are complex opto-mechanical systems using either natural starlight or laser light to correct for atmospheric turbulence and thus allow ground based telescopes to take images of heretofore unachievable sharpness. Already providing greatly enhanced capabilities at ESO's VLT telescope and at other large facilities, this technology will be essential for the European ELT. CANARY, a specially developed AO test bench which is unique in the world as being a dedicated experimental facility, is operated at the William Herschel Telescope in the Canary Islands.
After very successful Phase A for the Natural Guide Star (NGS) element of CANARY which was achieved by the end of 2010 and the successful completion of the Phase B Conceptual Design Review in early 2011, the system was built and laboratory-tested over the following year (with separate on-sky testing of the Laser Guide Star system). The combined Phase A/B system was then tested on-sky in July and August 2012, with high performance NGS and Laser Guide Star data being obtained.

[Please, see picture in attached pdf document]

Laser being fired from the WHT to generate an artificial guide star for AO tests.
SPHERE is an instrument for discovering planets around other stars and will be fitted to the European Very Large Telescope in Chile. The activities performed in this work package allowed optimizing, fully calibrating and mastering the overall stability of the SPHERE system in the laboratory. New concepts for optical aberrations measurements were proposed, fully validated in simulation and experimentally applied to SPHERE data during the Assembly, Integration and Test process. The first results were extremely encouraging and efforts will be invested in the future to push the concepts towards a Technology Readiness Level compatible with their final use in the SPHERE instrument for its first light at the ESO Paranal observatory, now expected in 2014.
Another objective of this workpackage was to design the Laser Guide Star Facility for the international Large Binocular Telescope project in which German and Italian astronomers have a large investment. The project aims at an initial implementation of a Ground Layer Adaptive Optics system, which enables wide field seeing improvement for imaging and spectroscopy at the LBT with the LUCI instrument. All deliverables of this work package were completed. After the final design in spring 2010 the teams went on to build the ARGOS instrument. Currently, the overall project is in the integration phase and is close to shipment to the telescope. The laser system, which was built by MPE, is under intensive testing in Garching, Germany. In October 2012 the Preliminary Acceptance review was held successfully for this

sub-system in Garching. The shipment is scheduled for 2013. The wavefront sensor is built by the Osservatorio Astrofisico di Arcetri and is undergoing assembly in Florence, Italy. Several parts of the instrument are already mounted on the telescope. This includes the laser launch system, the swing arms for the calibration unit and the instrument platform. The goal is to hand over the full commissioned instrument to the community by 2014. This system will be the first multi Rayleigh laser adaptive optics system on any large telescope. The Rayleigh laser technology is commercially available and therefore much cheaper than sodium lasers. This is crucial for future Extremely Large Telescopes, which plan on using large laser facilities.
Another activity was to procure a deformable mirror for high order Adaptive Optics to be fitted to the GREGOR solar telescope in Tenerife. This has been delivered and has enabled the Kiepenheuer-Institut to improve the performance of the GREGOR telescope AO system significantly.
WP2: Laser Guide Star Adaptive Optics Detectors
Adaptive Optics techniques require the availability of a suitably bright 'guide star' to be visible in the sky close to the astronomical object of interest. It is the light from this star which is used to calculate the distortions caused by the atmosphere and then to correct for them many times per second. This in turn requires detectors able to sense faint stars and to be read out with very great speed while producing as little extraneous noise as possible. This is a very challenging requirement, but the better such detectors can be made, the fainter and hence more numerous, are potential guide stars. The E-ELT must have an effective AO system in order to function properly, so high speed low noise detectors are critical for this flagship European facility.
In this workpackage a detailed technical specification was developed and detector fabrication was sub-contracted to e2v technologies, the well known UK visible light detector manufacturer. More than a development chip, this demonstrator will be useable for wavefront sensing on the E-ELT with natural guide stars. The requirements for a final device which can be used with artificially produced laser guide stars are challenging as they combine several properties that to date have never been achieved at such a high specification on a single detector. This work package was completed successfully.

[Please, see picture in attached pdf document]

WP2 Camera Conceptual Design

WP3: Astrophotonics
Photonics is a term derived from Photon and Electronics and includes the generation, emission, transmission, modulation, signal processing, switching, amplification, and detection/sensing of light. It covers all technical applications of light over the whole spectrum from ultraviolet through the visible to the near, mid- and far-infrared. Most applications, however, are in the range of the visible and near infrared light. It is a technology used widely in the telecommunications industry which should have valuable applications in astronomy.
An international collaboration called Astro-Photonica Europa (APE), which is largely industrially-financed, has been established. Several research partners are able to participate in that collaboration through OPTICON support. The success in matching technology to astronomical capability provides a powerful justification for the activities of APE and for EU funding via OPTICON. It is also notable that APE provides a unique forum which allows astronomers working in very different fields (i.e. long-baseline optical/IR

interferometry and highly-multiplexed spectroscopy) to exchange ideas and share technology. Technology research and development was, and continues to be, carried out by the members of APE using funding supplied from national and regional agencies as well as through OPTICON. Thus OPTICON's primary role has been to provide leverage to direct the products of the regional programmes in the most useful direction. Thus the main activities in the workpackage were: (1) Coordination including the activities of the coordinator and the management by the coordinating institute; (2) workpackages with specified deliverables; and (3) training and communication activities to educate and inform the wider community.

The programme is necessarily a bottom-up activity in that it seeks to determine the benefits to astronomy from existing devices and technologies. However this is tempered by a top-down understanding of the direction of current research in astrophysics and the specific needs of new observatories including Extremely Large Telescopes and new interferometric facilities. Ideally the bottom-up and top-down approach should mesh to provide new instrument capabilities. Thus, this work package has been able to direct and coordinate research out of all proportion to its funding. As well as a considerable number of publications in technical journals, a combined workshop and training school on Astrophotonics was held at Schloss Wiesenburg, Brandenburg, Germany, 24-28 September 2012. This was co-sponsored by OPTICON Durham University, InnoFSpec and the Leibniz Institute, Potsdam and the Municipality of Wiesenburg. Thirty students were enrolled, mostly, but not exclusively, young researchers. The scientific programme included 17 lectures each given by a different lecturer drawn from the Astrophotonic Europa partnership or from prominent astronomers or photonicists. The students were encouraged to bring posters which were judged. Prizes were awarded to the winners. Feedback from the students and lecturers was very positive and the local people were very enthusiastic.

[Please, see picture in attached pdf document]

Astrophotonics summer school participants at Schloss Wiesenburg, Brandenburg.

WP4: High Angular Resolution by Interferometry

Interferometry is a technique, first used by radio astronomers, in which the signals from two telescopes separated by a considerable distance are combined to mimic the resolving power of a single telescope equal in diameter to the separation of the two telescopes used. Since all the properties of the two beams have to be conserved before they are combined, expanding this technique to optical telescopes, where the wavelengths concerned are many times smaller than radio waves, requires exquisite precision. This is being achieved by the European Southern Observatory's VLT Interferometer (VLTI) where the light beams from several telescopes are passed via tunnels to an optical laboratory where the various beams can be combined. This technique can be used to create images and map structures on the surface of distant stars, objects which would normally appear only as a point of light in today's large telescopes.

[Please, see picture in attached pdf document]

The principle of Optical Interferometry, combining two beams, in phase, to mimic a huge telescope (Photo ESO)

Members of the OPTICON work package have taken part in the writing of the VLTI Mid-Term

Implementation Plan, which was done under ESO management, but with important contributions from the European interferometric community. Apart from this short- to mid-term analysis, it is worth noting that ESO is still working, in parallel with the E-ELT, on a Long Range Plan for the la Silla-Paranal Observatory that should include the development of the VLTI optical interferometric instrumentation and/or the telescope array. A meeting in ESO/Garching in November 2011 was thus very important to develop ideas about the next 10 years of the VLTI.
An important part of the activities has been to organize the community with respect to the future of interferometry in Europe. Various activities have been developed and it was decided to create a Working Group for the Future of Optical Long Baseline Interferometry in Europe and to undertake a common action for the development of a general-user tool for image reconstruction. These activities were presented at an EII meeting in Amsterdam in July 2012 and form the core of the interferometry workpackage in the future.
At a more technical level, considerable work was done evaluating the parameters of the atmosphere over the ESO observatory at Paranal and how they relate to high precision fringe tracking. After a review of the status of atmospheric turbulence at Paranal, a synthesis of the literature and of the ESO technical reports has been made from the more than 60 articles dealing with that subject. Considerable work was done analyzing the initial results from the VLTI instruments FINITO and PRIMA. A better state machine for FINITO has been developed with good separation and robustness between Group Delay and Phase Tracking. This made it possible to have a better estimation of the performances and limits of FINITO, and helped produce a better calibration of the V^2 measurements of AMBER.

[Please, see picture in attached pdf document]

This image of the VLT at Paranal shows the tunnels which can used when the four 8m telescopes are operated as an Interferometer (Photo ESO)
The conclusions of this work are that new ways of calibrating various components have been identified, that we are now able to perform correct computation of the group delay and the phase delay and finally that we have obtained a correct estimation of the signal to noise ratio and of its threshold. This is very important for the second generation fringe trackers to be built for the VLTI. The following important lessons have been learned:
o The Importance of photometric channels
o No spatial filtering after beam combination
o The computation of sensitivity to hardware imperfections
o The importance of calibration and stability
o That linearity of measurement is essential
o The need for care regarding all possible sources of instrumental polarization
The majority of the other outputs from this activity are highly technical in nature and are described fully in the three periodic reports submitted by OPTICON during the contract.
WP5: Smart Instrument Technologies
Over several generations telescopes have become steadily larger and the instruments required to exploit those telescopes have grown corresponding larger as well. Today instruments for Europe’s flagship VLT telescope may be several metres in size and weight several tonnes; already some of the next general VLT instruments are reaching masses close to the limit than can be supported by the telescope infrastructure. This situation is not sustainable, and instruments for the next generation of telescopes will have to include innovative ways to save space, weight and exploit the large focal planes offered by, for example, the

European ELT.
A particular development, of general applicability but especially of relevance to future instruments on the Extremely Large Telescope, is micro-autonomous robots, by which an instrument can be made much smaller and lighter. These are small, self powered robots which can be driven around inside an instrument to position tiny mirrors that can pick of the light from selected targets in the image. Considerable progress has been made on prototype robots over the last three years. They can in principle replace the movable arms used to position mirrors in existing instruments such as the ESO KMOS instrument. KMOS has 24 robotic arms, but scaling up of this technology is likely to encounter problems as there will simply not be enough room for all the arms to move about without mutual interference.

[Please, see pictures in attached pdf document]

A Microrobot and the power grid over which it roams with very high precision. (Photo UKATC)
Another key technology for future instruments is the production of highly aspheric mirrors. The state-of-the-art in optical fabrication makes it possible to obtain highly aspheric reflective shapes, reaching several millimetres compared to the best fit sphere, but only for small mirrors. OPTICON has studied the potential of an innovative manufacturing process in optical fabrication, free of mechanical tool contact. This method, which is called hydro-forming, is based on the property of metallic materials to plasticize (their ability to be permanently deformed) and is already used to supply aluminium dishes for radio astronomy applications. The manufacturing process we are developing adapts the hydro-forming method for visible and near infrared applications.
Using Finite Element Analysis (FEA) the global geometrical profile of a substrate before deformation can be defined and the preliminary aspects of plastic behaviour of material can be highlighted. These made it possible to finalise the concept of the first ever hydro-forming machine prototype to produce a 100 mm optical diameter component. When completed, which will occur during our future contract, this prototype will allow us to compare the mechanical behaviour and the optical performances obtained by tests and by FEA for different metallic samples. An evaluation of the sensitivity of different working parameters will be established and the FEA models will be adjusted. Then, an optimization process applied on the FEA models will allow us to converge toward the manufacturing of highly aspheric shapes and free form surfaces.
Once this has been done, the formed samples will be characterized optically. The opto-mechanical results will allow a fine tuning of FEA parameters to optimize the residual from errors obtained through this process. Tests will start with axi-symmetric spherical and aspheric shapes and will continue with highly aspheric shapes and freeforms. In the next phase, hydroformed mirror activities will continue with increasing complexity of the shapes and the development of optical characterisation methods. Combining real tests and finite elements analysis, we will be able to highlight performance estimates, sensitivities and tolerances for freeform mirrors manufactured with this innovative process. The main aim will be the integration into one single system of a freeform mirror supplied by LAM with the smart active mechanical structure supplied by ASTRON and UKATC, obtaining the first smart active freeform mirror demonstrator for visible and near infrared astronomy.

[Please, see pictures in attached pdf document]

Prototype design: left, a global view and right, a zoom inside the cavity
To improve the optical modelling capability of highly aspheric optical components a new analytical definition was developed. This model is being implemented as a plug-in model in the ZEMAX ray tracing package and will then provide optical designers with ray-tracing capabilities to allow them to analyse optical designs containing highly aspheric optical components.

One unforeseen, but very satisfactory, outcome of the activity was a L’Oreal award for PhD student Zalpha Challita’s work on this project. This award is presented by the L’Oreal cosmetics company as part of its national and international programme "For Women in Science". Through it, the L’Oreal foundation and UNESCO reward women for their scientific career. Since 2007, the French programme named L'Oreal France - UNESCO "Pour les femmes et la science", in partnership with the French Academy of Sciences, has rewarded women PhD students for their scientific work by giving them a grant of 15 000€. This grant is dedicated to prepare their professional career post-PhD by presenting their works in conferences, in international laboratories, etc. The project congratulates Zalpha on her award.

WP6: New Materials and Processes for Astronomical Instrumentation

Volume Phase Holographic Gratings (VPHG) are now being used extensively in astronomy because of their high diffraction efficiencies. VPH gratings are generally used in transmission with diffraction being caused by a near-sinusoidal variation in the refractive index perpendicular to the fringes (300-6000 lines/mm). For astronomy gratings, the active layer is typically 3-10 microns thick and is sandwiched between glass substrates a few millimeters in thickness. A common active layer is DCG (a Gelatin material) but chemical post-processing is extremely difficult and requires skilled and experienced technicians if it is to be carried out properly. This, together with the limited number of customers and consequent low annual revenues, limits the number of players in the market and also the possible areas of application.

Until recently the main European supplier of substrates on which these gratings can be written was ATHOL in Belgium, but after a few years of successful deliveries the company lost a key person and with him the capability to deliver quality products to the community. Since the option to attempt to set-up another spin-off company to recover European VPHG production capability appeared to be very risky it was decided to concentrate on DCG alternatives, especially in the area of handling and post-processing that needed to be more repeatable and easy. We continued to follow the work of the few DCG-based VPHGs producers (all from outside Europe).

As an alternative we were able to obtain another species of tailored polymer from Polygrama (Sao Paulo, Brazil), a small lab developing photopolymers to customer specifications who agreed to produce some following a POLIMI designed recipe. After a number of iterations, high-grade gratings were made in INAF laboratories. Some of these samples are shown here.

[Please, see pictures in attached pdf document]

In late 2011 the company BAYER contacted the workpackage team offering the baseline version of their photopolymer films and an agreement to customize them to our needs (with some non-disclosure agreements etc.). The company's interest is linked to the solar energy business where large size holographic gratings are of potential use in co-generation solar farms. Astronomy is however a niche of "high visibility" and a possible interesting business. An 8x8 cm sample manufactured in INAF labs with a BAYER polymeric substrate and the related efficiency plots are shown here

[Please, see pictures in attached pdf document]

One of the VPHGs fabricated with the new polymer techniques has been tested in the AFOSC instrument at the Italian Asiago observatory where is currently installed and offered to astronomers.
In 2010 the OPTICON team established contacts with Elche University (Spain), who were manufacturing DCG-based gratings for laser applications. These devices are tuned to a specific application so they come only in one size and with a single grating spatial frequency, but they have excellent appearance and efficiency. A sample obtained was fully tested and characterized at cryogenic temperatures at IAC (Tenerife, Spain). The sample, the setup and an interferometric map are shown below.

[Please, see pictures in attached pdf document]

Testing of DCG-based gratings developed for Laser Applications.
Finally, as part of a search for new materials and processes for reflective and refractive optics it seems that the application of photochromic rewriteable polymers for the production of HOE (Holographic Optical Elements) is extremely promising. Many tests have been done in the context of the OPTICON programme both for the qualification of the writing process and for the evaluation of performance. The early tests performed in the INAF laboratories evolved during the project to professional quality CGH written in collaboration with Institut fuer Technische Optik - UNI-Stuttgart. Both are shown here

[Please, see pictures in attached pdf document]

WP7: Transnational Access
As a first step towards a more European approach the solar telescope time funded under the EC Trans-National Access scheme began to be awarded by a single panel drawn from members of the EAST consortium (WP 12.3). This panel also accepted the responsibility of allocating solar time to be awarded on the four solar telescopes in the Canary Islands as part of the international agreements connected with the La Palma and Tenerife observatories (The 'CCI International Time Programme'). In semester 2010B we launched the new OPTICON Common Time Allocation Process for night time telescopes. Proposals were entered via the NORTHSTAR system, developed jointly by FP6 and FP7 contracts to Radionet and OPTICON, and were reviewed by an international panel.
This panel (the CTAC) comprises 7 independent scientists drawn from 7 different national communities and normally linked to their own national time allocation process as either current or recent members of national panels. This ensures both a valuable mix of skills and provides essential feedback between the OPTICON and the various national processes. The panel ranks the proposals by scientific merit and the ranked list is then submitted to the telescope director's forum (part of WP12) for approval. Once this approval is received (and to date the CTAC rankings have always been accepted without modification) the highest ranking proposals are then scheduled on the various telescopes until either no time is available on

the requested facilities or the funds available for the TNA programme for that semester are exhausted. This resource cut-off has always occurred at a higher, often very much higher, ranking than the lowest scientifically acceptable proposal, confirming the high standards of the proposals submitted.
This programme continued until the end of the contract and remains popular in our new contract. The steady rise in the number of proposals submitted seen in the first few semesters levelled out but the proposals received remain of a high standard. Most of the facilities in the TNA programme are requested and while the AAT and the NOT telescopes continue to be popular due to their specific capabilities; allocations have been made across a wide range of telescopes each semester. The oversubscription factor of about 3 is typical for telescopes in this class.

[Please, see picture in attached pdf document]

To summarise, in the 5 semesters since the CTAC scheme was introduced we have received 216 proposals involving 969 team members from 35 countries. The nationality breakdown of these teams is shown above. We have investigated the large over-representation of UK astronomers applying to the TNA programme and concluded that this is mainly a function of UK astronomers having a wide range of scientific interests, having a few projects (notably extra-solar planets) which require access to specialised instruments not available on UK telescopes and to having a long tradition of applying to international facilities.
The topics covered by these projects included studies of solar system objects, extra-solar planets, young stars, variable stars and a small number of projects on external galaxies.
Regular articles about the Trans-National Access programme appear in the newsletter of the European Astronomical Society.

WP8: Management
The Management Board is responsible for making strategic decisions. Meetings are held roughly annually so that the work package leaders can provide overview presentations of their activities, status, and progress to the whole consortium. The Executive oversee the day-to-day implementation of the OPTICON programme. Both groups met regularly during the contract. The project scientist maintains close links with the various work packages, and reports regularly to the co-ordinator so that, should it be required, appropriate intervention can be organised in a timely fashion.
WP9.1: Key Technology Network
Technology and astronomy have always been closely linked, even since the time of Galileo and Newton it was new technologies of the day that allowed telescopes to be developed and improved. This process continues today, but on a much more far reaching scale as new technologies spring up across Europe and in many disciplines. To try and bring these two communities, which are diverse but at the same time following similar paths, together OPTICON set up an activity especially to do this. The network chair, Colin Cunningham, made strong connections from the OPTICON activities with a technology foresight activity for space science (TECHBREAK), run by the ESF for ESA. Two recent workshops covered the following topics:
1: Polarimetry with Extremely Large Telescopes (Utrecht, November 2011)
Polarimetric observations would enable some of the most exciting science cases of the near future: direct detection and characterization of Earth-like exo-planets, revealing the structure of active galaxies in the early Universe, measurements of stellar magnetic fields, and mapping of structures around young stars

and in supernovae. The light-collecting power of the Extremely Large Telescopes will offer unprecedented opportunities for astronomical polarimetry, but the technical challenges of such giant facilities do not easily lead to a design that facilitates polarimetry with commensurate precision. This workshop included presentations on state-of-the-art astronomy research and instrumentation, panel discussions, posters, and demonstrations of experimental set-ups and industry technology, from a range of specialists (scientists, instrumentalists, engineers). One of the conclusions from the workshop was that it was crucial that the polarimetry community team up and develop the 'highlight' science cases for the E-ELT, as well as exploring future options for current 4-10m class telescopes

Workshop 2: Disruptive Technologies for Astronomy (Marseille, April 2012)

Advances in astronomy are often enabled by adoption of new technology. In some instances this is where the technology has been invented specifically for astronomy, but more usually it is adopted from another scientific or industrial area of application. The adoption of new technology typically occurs via one of two processes. The more usual is incremental progress by a series of small improvements, but occasionally this process is disruptive, where a new technology completely replaces an older one, for example the replacement of music discs (on Vinyl or CD) with direct music downloading changed the music retail landscape entirely. This workshop brought scientists and instrumentalists to identify the science challenges and drivers of the future, the features needed to achieve these (of telescopes, instrumentation, and analysis), and the technological components/solutions needed to enable them. These discussions were captured in detail in a paper presented at the 2013 SPIE Astronomical Instrumentation conference: 'Innovative Technology for Optical & Infrared Astronomy' by Cunningham et al. (Proc. SPIE, 8450, 31). This paper was also used to seed the discussion of a session on 'revolutionary technologies' in one of the SPIE sessions of the 2012 Amsterdam conference.

WP9.2: Software Standards

The main objective to develop detailed software standards for an open, modular system for processing and analysis of astronomical data by end users was completed in 2011. Most of its outputs can be downloaded free of charge for use as required.

WP10.1: Science Case for the European ELT

The main activity of this WP was to organise meetings and talks to engage the scientific community with the E-ELT project. In 2011 the activity organised a major meeting: "Feeding the Giants: ELTs in the era of Surveys", on the island of Ischia, Italy from 29 August to 2nd September. The focus of the meeting was to explore science cases that exploit the synergy between large survey facilities and future extremely large telescopes. The meeting attended by about 75 people and was very successful. The programme included reviews of current and future survey facilities, and future extremely large telescopes (focussed on the E-ELT, but other projects such as the American led TMT and GMT were also represented). Further presentations addressed the developments that these facilities will bring to a wide range of science areas, including extra-solar planets, star formation, stellar populations, galaxy formation/evolution and cosmology. A discussion was held in a "World Café" format, allowing several small groups to discuss a series of specific questions. There was also a public event held one evening during the conference, where the E-ELT Programme scientist (Roberto Gilmozzi) gave a public talk and small telescopes were set up for public viewing of the night sky.

[Please, see picture in attached pdf document]

Impression of the 40m class European Extremely Large Telescope. (Photo ESO)

In addition we organised a smaller meeting during the EWASS (European Week of Astronomy and Space Science) in Rome, July 2012. The “Special Session” on E-ELT was held on 5 July. 70 people registered, and around 40 attended at any time. Presentations were given on E-ELT science cases, operations and instruments. There was plenty of lively discussion, especially on science policy for large observing campaigns, and instrumentation plans (especially on the expected performance of AO systems and relative priorities of mid-infrared and multi-object spectrographs). The programme and links to presentations can be found on the meeting web site, http://www.mporzio.astro.it/ewass_elt/

Along with organising meetings we have presented the E-ELT project and the science it can achieve in talks at several scientific institutions around Europe and in talks and/or posters at major international conferences (including the IAU General assembly in Beijing, China, August 2012). The above meetings and talks satisfy the WP objective of informing and engaging the scientific community, in particular future E-ELT users

Another important aspect of this WP was to inform the general public about the project. This has been achieved with a series of public talks (including the public event in Ischia already described above), either as individual events or as part of larger public events. For example A. Calamida gave a public talk on the E-ELT at Researchers Night 2011, which was part of a major public science event coordinated across 320 European cities.

WP10.2: European Network for High Time Resolution Astrophysics (HTRA)

High Time Resolution Astrophysics is one of the few remaining domains of astronomical space which has not been fully explored. Observations with time resolutions of milliseconds can shed light on the physics of extreme objects, for example flows of material falling into black holes and emitting flickering pulses of light as it does so. A few dedicated instruments exist for these kinds of studies but they are often small and privately owned so not available for the wider community. With its huge light gathering power the E-ELT will provide plenty of photons for HTRA projects, but only if the instruments and systems are designed with sufficient flexibility to accommodate the rather special needs of the HTRA community.

[Please, see picture in attached pdf document]

Astronomers at the University of Warwick and the University of Sheffield using an instrument especially developed for HTRA observations helped discover an unusual star system which looks like, and may even once have behaved like, a game of snooker. (see University of Warwick press release at http://www2.warwick.ac.uk/newsandevents/pressreleases/uk_astronomers_help/)

To bring together members of this small and diverse community OPTICON set up a network the members of which met face to face on several occasions. They created a single working group to promote and develop the different areas of HTRA, deciding to concentrate upon educating the community for developing HTRA on existing 8-10m class telescopes and on the E-ELT. A week long school on “Principles of Multi-wavelength High Time Resolution Astrophysics” was held in Sardinia from October 10th-15th 2011 to bring together the next generation of HTRA scientists, i.e. those just starting PhDs, to enable networking as well as developing skills in HTRA science and analysis tools.

WP11.1: Community Development

Young people are the future of astronomy; it is they who will inherit the E-ELT and future large facilities. However as observatories become more complicated, and more remote, the opportunity to gain ‘hands on’ experience of the observing process is becoming more and more rare. While it can be argued that this is

how future astronomy will be done and there is no need for the next generation of scientists to 'get their hands dirty' , there is certainly a case that understanding the basic principles of observing and data reduction is a key skill in understanding and interpreting any observations delivered by large facilities.
To address this problem OPTICON embraced the NEON observing schools which were previously funded under another EU instrument. These schools bring together groups of new astronomers and immerse them in a condensed programme of actual observing, data reduction and the presentation of results. This is combined with advice on proposal writing and job hunting.
A series of NEON observing schools were held through the contract, each engaging 16-24 early stage researchers. For example one was held at the Moletai Observatory (Lituania) in July 2011, taking advantage of the small telescopes there for imaging and the friendly surroundings of the observatory. This was complemented by the remote use of the Nordic Optical Telescope in La Palma for spectroscopy. Another school was held at in 2012 at the Asiago Observatory in Italy. In 2011, an instrumentation school was organised jointly with the AIP in Potsdam, Germany on "Opto-Mechanical design in Astronomy". A meeting was also organised with SREAC (Sub-Regional European Astronomical Community) South-Eastern Europe members in Sofia, Romania to discuss their specific needs for the future and see how we could raise the participation from eastern EU-members in OPTICON activities overall.

[Please, see picture in attached pdf document]

Participants of the OPTICON/Neon summer school at the Moletai Observatory, Lithuania, 2011.
A new initiative was to begin to prepare other OPTICON "Enhancement" activities and to consult with partners about their needs and wishes. Some synergies were searched for, for instance by inviting participation of UK PhD students to training sessions organised for French students. An exploratory visit was made to Romania in order to prepare the organisation of a future "Awareness conference" there, which took place under the new OPTICON contract after a delay due to some administrative difficulties.
WP11.2: The European Interferometry Initiative (EII)
The EII is a umbrella group which brings together specialists in this subject from across Europe to exchange ideas and develop plans (see https://sites.google.com/a/european-interferometry.eu/home/).
This group worked closely with workpackage 4 through the period of the contract and it held a major meeting in Amsterdam in 2012 in conjunction with the much larger SPIE technical meeting.
The work package continued to arrange short technical visits for the exchange of ideas and good practice under the Fizeau exchange programme. Calls were issued at 6 month intervals throughout the contract and many dozens of visits were supported. The procedure is very rigorous, involving peer review of the proposed visits and is highly thought of with the community it serves.

[Please, see picture in attached pdf document]

This poster advertising the exchange programme was widely distributed. (Photo P Garcia and the EII)
Two working groups on "Circumstellar disks and planets" and "AGNs and the galactic centre" met and published their conclusions and recommendations.
WP12.1: Telescope Directors Forum and Common TAC
The directors of all the telescopes which participate in the TNA programme (WP7) met approximately annually to review developments, exchange information and monitor the progress of the TNA programme. In particular they approved the ranked lists of proposals prepared by the OPTICON Time Allocation

Committee and provided oversight of the TNA programme generally. They also contributed technical information to the European Telescope Strategy Review Committee.
WP12.2: Planning for a Viable Future
This multi-pronged activity aimed at optimising and, where possible, integrating the operation of Europe's 2-4m night time telescopes and Europe's 4 major solar telescopes. OPTICON and ASTRONET collaborated in this process, and established a joint review which has published its conclusions on the ASTRONET website http://www.astronet-eu.org. The OPTICON project scientist prepared a paper for ASTRONET on how the panel's recommendation of a single integrated telescope time allocation process based on the OPTICON experience might be implemented.
WP12.3: The European Association for Solar Telescopes (EAST)
European astronomers operate a number of solar telescopes, the most significant being a suite of telescopes in the Canary Islands (on Tenerife and La Palma). These offer world class facilities to European solar astronomers, a capability which will be enhanced by the new 1.5m GREGOR telescope. GREGOR is a project of a consortium of the Kiepenheuer-Institut für Sonnenphysik, the Leibniz Institute for Astrophysics Potsdam, the Institut für Astrophysik Göttingen, the Max-Planck-Institut für Sonnensystemforschung and other international partners. The telescope is designed for high-precision measurements of the sun's magnetic field and the gas motion in the solar photosphere and chromosphere with a resolution of 70 km on the Sun. It can also be used for high resolution stellar spectroscopy.

[Please, see picture in attached pdf document]

The new GREGOR solar telescope (Photo KIS)
The EAST network has addressed key objectives towards plans for the next step after GREGOR, a large solar telescope to be included in the ASTRONET Science Vision Roadmap. The project is known as the European Solar Telescope (EST) and is comparable and competitive with its US equivalent, the Advanced Technology Solar Telescope (ATST). The network organised participation in joint ATST-EAST workshops in Solar Physics, the most recent of which was entitled "Magnetic Fields from the Photosphere to the Corona" and was held in November 2011 in Washington D.C as well as supporting various solar astronomy meetings across Europe.
Finally, the group oversaw the solar astronomy element of the OPTICON Transnational Access programme setting up a special time allocation process for EC supported solar astronomy observing which ran in parallel with the night time CTAC described above..
A measure of the success of this activity is that the solar astronomy community was able to secure a contract of its own (SOLARNET) in the final FP7 infrastructure call.

Potential Impact:
The majority of the key individual impacts and their outreach activities are give in the text describing each workpackage and the list of event and papers given in the Appendices. These will not be repeated in details here. Globally OPTICON has made, often in conjunction with other players, considerable impact in the following areas.

Maintained European leadership in the technologies and techniques of Adaptive Optics (WP1, 2)

Developed synergies between European technology players and the astronomical community, making the industrial concerns aware of expertise in the scientific community and vice versa. (WP3, 5, 6, 9.1)

Considerable co-ordination of the European Interferometry Community (WP4, 11.2)

Opened a range of European observatories to new user communities (WP7) and made significant efforts to engage with thee new communities so they can take advantage of these opportunities, for example by offering a single proposal process (WP12) and training schools (WP11.1).

Supported Technology Development for European Solar telescopes (WP1), enabled access to existing facilities (WP7) and enabled strategic planning for future facilities (WP12)

Provided a communications pathway between the general user community and the future European ELT project teams (WP 10)

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Related documents

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