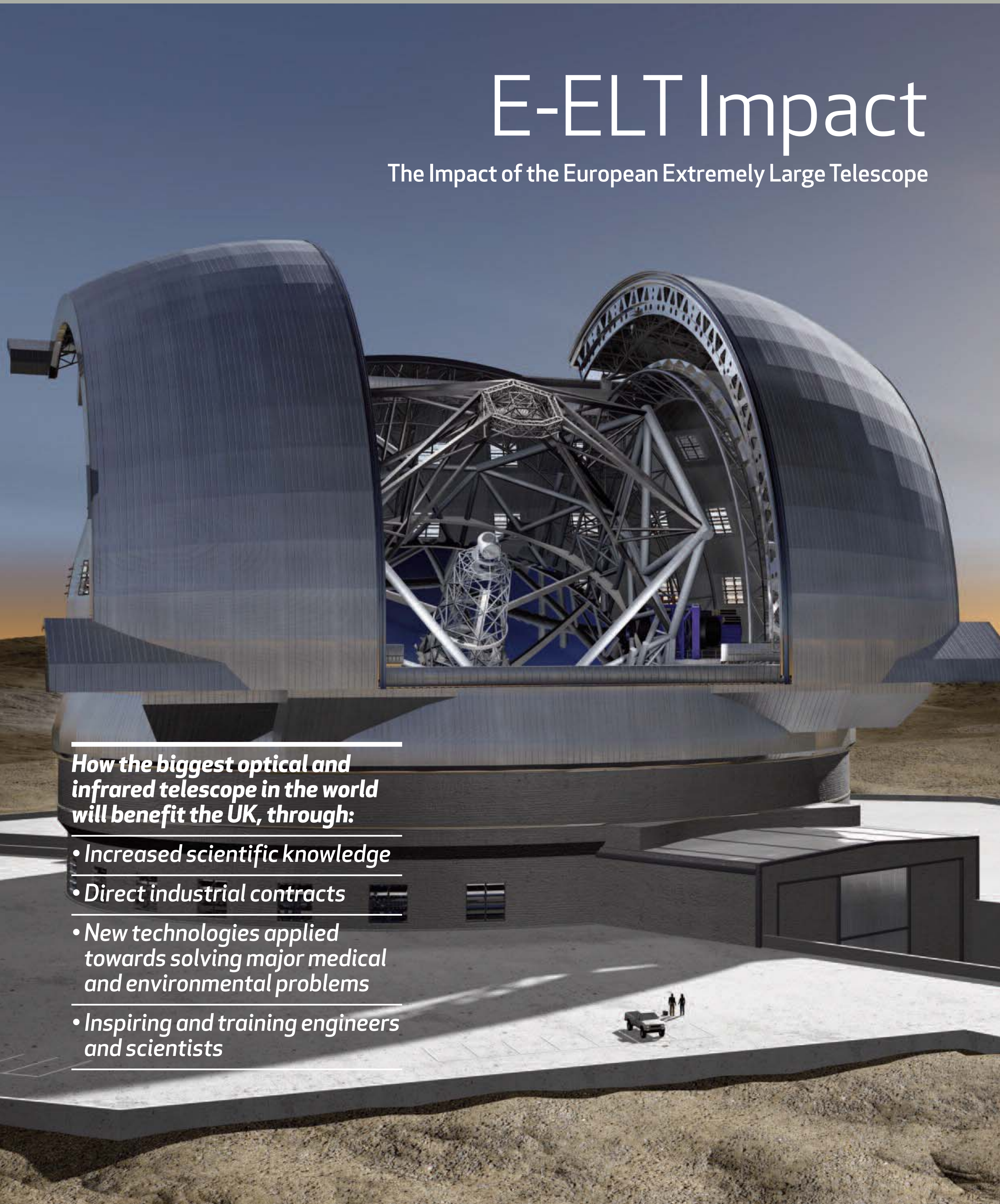
Science & Technology Facilities Council
UK Astronomy Technology Centre

E-ELT Impact

The Impact of the European Extremely Large Telescope



How the biggest optical and infrared telescope in the world will benefit the UK, through:

- *Increased scientific knowledge*
- *Direct industrial contracts*
- *New technologies applied towards solving major medical and environmental problems*
- *Inspiring and training engineers and scientists*

Cover image: European Southern Observatory

The European Extremely Large Telescope will be the biggest optical and infrared telescope in the world. It will have enormous impact in enabling astronomers to probe and understand a whole range of phenomena from planets around nearby stars (perhaps including planets where life may exist) to the most distant faint galaxies at the edge of the observable universe.

Astronomy and the wonder of space are particularly appealing to the general public, and as such, the European Extremely Large Telescope (E-ELT) will be a beacon of inspiration for the next generation leading to careers in science, engineering and technology.

The European Extremely Large Telescope will also have direct economic benefit to the UK in terms of contracts to industry, commerce and research institutes which already totals £7.5million, and is expected to reach at least £200million by the end of the project. Less predictable but nonetheless concrete economic benefits will accrue from capability-building in industry, particularly for precision optical surfaces, and from the innovations needed to meet the ambitious technology targets presented by this challenging project.

While hard to quantify, such economic benefits are expected to be many times the value of direct contracts. For example, key technologies being developed for big telescopes are associated with their Adaptive Optics systems. These advancements and innovation in science are being applied to solve a variety of important problems across many sectors, including enhancing the longevity of artificial knee joints, diagnoses of vascular diseases of the eye, improving the performance of industrial lasers and laser fusion research. The increased global economic activity due to these developments could be over £1billion per year within the next ten years.

A final outcome from building this giant telescope will be a cohort of highly accomplished engineers and scientists with skills honed on this great challenge who will be capable of applying their talents in a broad range of areas of great benefit to the UK economy and society.

Colin Cunningham, Claire Dougan and the UK E-ELT Team
March 2009

[1] An Expanded View of the Universe http://www.eso.org/sci/facilities/eelt/docs/E-ELTScienceCase_Lowres.pdf

[2] The 6.5m diameter James Webb Space Telescope is predicted to cost €3.3billion compared with current estimates of €1billion for the 42m diameter E-ELT)

Why we need to build bigger telescopes

There are currently 13 optical/infrared telescopes of between 8 and 10 metres in diameter on the Earth. All are very productive and in great demand, with up to six proposals for every successful observing programme. Among many exciting discoveries in recent years, these telescopes have enabled astronomers to find evidence for the mysterious Dark Energy that is now believed to be causing the expansion of the Universe to accelerate, plot the trajectory of stars around the centre of our galaxy to demonstrate the presence of a black hole, and to make the first direct images of giant self-luminous planets outside our solar system. So why do we need to build bigger telescopes?

There are still many things about the Universe that we do not understand. How did solar systems and earth-like planets form? How did the Universe evolve? When were the first stars born? What is the nature of the first galaxies? What is Dark Energy?

Predicted image quality improvement going from the 2.4m Hubble Space Telescope to the 42m European-Extremely Large Telescope
Roberto Gilmozzi, ESO

Astronomers need to reach further into the Universe in order to answer these key scientific puzzles that cannot be solved using current telescopes. To do this they need to collect more light from the object they are observing – by using a larger aperture telescope, and to see more detail – again by using a bigger telescope.

More information on the exciting science we can predict will be done with a 42 metre diameter Extremely Large Telescope (E-ELT) can be found in the science case document produced by ESO and the Science Working Group (led by Professor Isobel Hook of Oxford University)[1]. It is also axiomatic that opening a new window in sensitivity and spatial resolution will result in stunning new discoveries that we cannot predict.

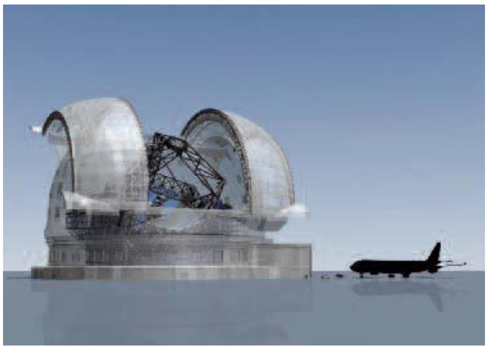
New technology means we can now envisage an affordable E-ELT for the first time, at a similar cost to current large facilities such as the European Southern Observatory's (ESO) Very Large Telescope (VLT), and the Atacama Large Millimetre Array (ALMA). Advances in segmented mirror telescopes have removed two of the major constraints – large mirror manufacturing and their transport. An 8m diameter mirror as used in the VLT is about the largest that can be taken up to a mountain observatory at reasonable cost – so even if we knew how to make bigger mirrors, we could not deploy them. A key innovation in large telescope construction was the successful construction of the W.M.Keck telescope using 36 hexagonal segments to make up the 10m diameter primary mirror. This technology is scalable – we now have detailed designs showing that a 42m diameter telescope is feasible.

The other key technology is Adaptive Optics. This technique removes the fluctuations caused by the atmosphere which blur the image and normally limit the angular resolution on the sky, irrespective of the size of the telescope, to about 0.5 arc seconds – equivalent to resolution of about 1km on the Moon as viewed from the Earth at a wavelength of 1μm. We can now produce images that are only limited by diffraction, at near infrared wavelengths. The size of a diffraction limited image of a point source like a star is proportional to the inverse of the telescope aperture, meaning that a 42m diameter telescope could resolve 5 milli-arc seconds, equivalent to less than 10 metres on the moon. Adaptive Optics is now a mature technology in routine use on most major telescopes, so for many aspects of astronomy we don't need to go to space. On top of this, a giant ground-based telescope is much more affordable than a smaller telescope in space[2].

Engineering Challenges

ESO's €57M Phase B study for the E-ELT is based on technology development carried out within an EU-funded Framework Programme 6 Design Study. Industrial and academic teams across Europe have been mobilised to answer the primary design questions on how to build this ambitious telescope within reasonable bounds of cost and risk, at the same time as meeting the demanding requirements generated by the science teams.

The E-ELT and an Airbus 340
ESO



The design of this giant telescope has to address challenges arising from the need to maintain the optical performance in the face of perturbations caused by the fluctuations of refractive index of the atmosphere, variable mechanical loads as the telescope slews round the sky to follow astronomical targets, mechanical disturbance caused by wind forces – and the occasional earthquake.

The light from a distant star reaches the earth's atmosphere as a plane wave. A space telescope has merely to focus this plane wave onto a detector to form an image limited only by diffraction and the aberrations caused by static errors in the optical surfaces. A ground-based telescope needs to correct for the atmospheric disturbances, and maintain the optical surface quality in the face of perturbations. The surface shape of the E-ELT primary mirror needs to be accurate to better than 100nm peak-to-valley across its 42m diameter – equivalent to waves of less than 5mm in height across the Atlantic Ocean. The E-ELT primary mirror will be made from 984 near-hexagonal segments, each 1.4m across.

Each segment will be supported by three actuators, and be instrumented to enable its position to be maintained against gravitational and low-speed wind forces. Two more mirrors in the optical path to the focal plane are deformed or tilted at higher speeds to correct for wind-shake and atmospheric turbulence. The deformable mirror is particularly challenging, being 2.5m in diameter, only 2mm thick and having 8,000 actuators operating at up to 1kHz. This deformable mirror is more than twice the diameter of any similar existing device. Adaptive Optics technologies are critical to the success of the E-ELT, and we will see that pushing the constraints on these technologies has considerable benefit for applications in biomedical imaging, laser optimisation and optical communications.

Impact

As science infrastructure projects become ever-larger we are driven to seek a sharper understanding of the full impact of these investments.It is clear that a project of size and technological challenge of the E-ELT will have significant economic, cultural and scientific impact. Predicting that impact is more difficult. The current state of research into the impact of major science projects is patchy, and of course any sort of quantitative prediction is problematic. Two important contributing factors are the importance of serendipitous discovery and the time taken between fundamental discoveries and exploitation. No one would argue that the discovery of the electron was motivated by the need to develop computers. However, we can make some predictions of the potential impact.

HM Treasury defines economic impact as:

"An action or activity has an economic impact when it affects the welfare of consumers, the profits of firms and/or the revenue of government. Economic impacts range from those that are readily quantifiable, in terms of greater wealth, cheaper prices and more revenue, to those less easily quantifiable, such as effects on the environment, public health and quality of life".[3]

Hence the impact of research can be both tangible and intangible and can be experienced by the general public, industry and the Government in addition to those communities directly associated with the research. Economic impact can happen over varying timescales with some research taking 10 or 20 years to yield tangible returns. Impact can be both direct and indirect, with visibility at regional, national and international levels, the latter being particularly true with multinational large-scale facilities.

A good example is the source of the now all-pervasive laser, which came from fundamental research on microwave oscillators, including natural molecular oscillators in space.

There is a growing body of publications on the potential economic impact of future large scale facilities, reflecting recent focus on this area. These reports include several on the future European Spallation Source (ESS) project[4], the Australian Light Source and the Canadian Light Source. The Science and Technology Facilities Council (STFC) has recently completed a study on the economic impact of the Synchrotron Radiation Source over its lifetime. There has however been very little work done on the impact of astronomy apart from an economic impact study undertaken on radio astronomy in 1981[5].

Categories of impact

The E-ELT will generate impact in the broadest sense of the word in the following categories (using the framework from Salter and Martin[6]):

- **Generating knowledge** – understanding the Universe and our place in it
- **Providing inspiration** – the cultural and symbolic impact of doing inspirational science, essential for attracting the next generation into careers in science, technology and engineering
- **Increasing the skills base** – for scientific and technological problem-solving – especially development of trained graduates
- **Building industrial capacity** – creating new firms, and attracting inward investment
- **Stimulating innovation** – development of technologies which can ultimately lead to new goods and services
- **Improving the quality of life** through new technologies which address the grand challenges of the 21st century

Examples of where the E-ELT will contribute to these impacts include:

Science – the primary motivation to build the biggest optical infrared telescope in the world is to push back the boundaries of our understanding of the universe from the birth of the first galaxies after the Big Bang to planets around nearby stars. *Generating knowledge, providing inspiration and increasing the skills base*

Adaptive Optics – *the success of the E-ELT is dependent on development of new Adaptive Optics technologies and systems against challenging requirements.*

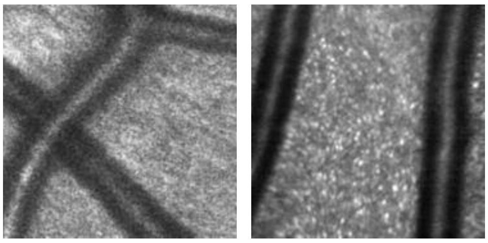
[3] HM Treasury's "The Green book: Appraisal and Evaluation in Central Government" (2003) www.hm-treasury.gov.uk/media/05553/Green_Book_03.pdf

[4] Neutrons and innovations. "What benefits will Denmark obtain for it science, technology and competitiveness by co-hosting an advanced large-scale research facility near Lund?", F. Valentin, M.T. Larsen and N. Heineke, Copenhagen Business School, April 2005.

[5] Spin-off from Basic Science: the Case of Radioastronomy, B.R Martin, and J. Irvine, Phys. Technol, 12, 204-212, (1981)

[6] The economic benefits of publicly funded basic research; a critical review, A.J. Salter and B.R. Martin, Research Policy, 30, 509-532, (2001)

Retinal blood vessels:
left without and right with Adaptive Optics
Applied Vision Research Centre at City University, London

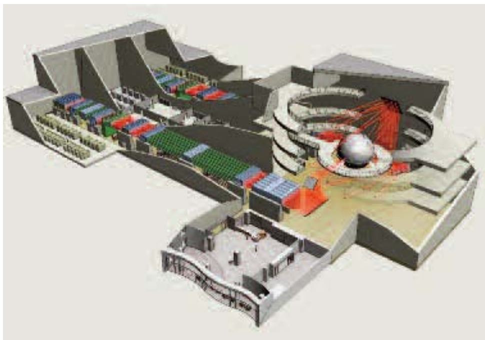


Adaptive Optics is being increasingly applied to biomedical imaging such as diagnosis of vascular disease in the eye, optical communications, security, and laser systems. *Improving the quality of life, increasing the skills base, and stimulating innovation.*

Detectors – again we are pushing the requirements on sensitivity, pixel count and speed. High performance optical and infrared detectors have wide application outside astronomy, especially in biomedical imaging and security scanning. *Improving the quality of life, increasing the skills base, building industrial capacity and stimulating innovation.*

Large precision optics – the E-ELT primary mirror requires over 1200 precision segments (including spares), pushing the development of rapid production and metrology techniques.

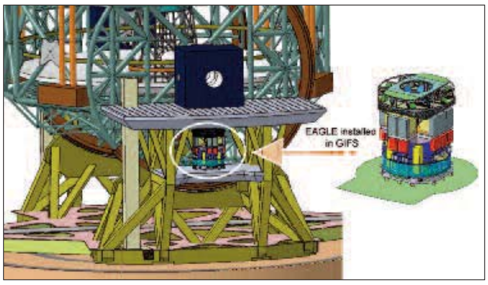
HiPER Laser Fusion Concept
STFC Rutherford Appleton Laboratory



Such large optics have application for laser fusion, semiconductor lithography, earth observation satellites and solar energy. *Improving the quality of life, increasing the skills base, building industrial capacity and stimulating innovation*

Instrumentation – ELTs need large, complex optical and IR instruments involving challenges in materials, mechanisms, cryogenics and optical components.

EAGLE E-ELT Instrument concept
STFC UK Astronomy Technology Centre and EAGLE consortium



These are generic technologies, with application in a wide range of scientific instrumentation, from earth observation satellites to infrared spectroscopy for medical diagnostics. *Improving the quality of life, increasing the skills base, building industrial capacity and stimulating innovation*

Photonics – adoption in future instruments of photonic technologies from the telecommunications industry will cycle innovation back into industrial, environmental and biomedical applications. *Generating knowledge, improving the quality of life, increasing the skills base, building industrial capacity and stimulating innovation.*

Image and data processing – challenging requirements for extraction of information and images from noisy and complex images stimulate development of new techniques, which are being applied to biomedical imaging applications such as histopathology and MRI scanning. *Generating knowledge, improving the quality of life, increasing the skills base, building industrial capacity and stimulating innovation.*

Structural Engineering – the E-ELT is a massive structure with precise alignment requirements. Lessons learned could be applied to large scale laser fusion systems. *Improving the quality of life, increasing the skills base, building industrial capacity.*

Environment and Energy – operating on a remote mountain-top site, with 10MW energy requirements. This can be thought of as an exemplar for low-carbon sustainable systems. *Increasing the skills base, building industrial capacity and stimulating innovation.*

[7] *See ESO webpages: http://www.eso.org/public/astronomy/teles-instr/e-elt.html*

E-ELT Structure
ESO

Looking at some of these impacts in more detail: generating knowledge

The European Extremely Large Telescope is proposed to be built in order to expand our knowledge of the universe, and it will have a major impact all the way from the earliest phases of star and galaxy formation as the first light was generated, to studies of exoplanets around nearby stars. These two key science themes are expanded in the following section.

Are we alone?[7]

The E-ELT has embraced the quest for extrasolar planets — planets orbiting other stars. This will include not only the discovery of planets down to Earth-like masses through indirect measurements of the wobbling motion of stars perturbed by the planets that orbit them, but more excitingly, the direct imaging of larger planets and even the characterisation of their atmospheres.
Furthermore, the E-ELT's suite of instruments will allow astronomers to probe the earliest stages of the formation of planetary systems and to detect water and organic molecules in protoplanetary discs around stars in the making. Thus, the E-ELT will answer fundamental questions regarding planet formation and evolution in a sample of solar systems at different evolutionary stages to our own, and will bring us a huge step closer to answering the question: are we alone? Apart from the obvious scientific interest, this would represent a major breakthrough for humanity.

First light: understanding the first stars and galaxies

While 8m-class telescopes and Hubble Space Telescope have enabled us to begin to probe very distant galaxies, it is clear that we have only reached the tip of the iceberg. We know remarkably little about the first galaxies, stars and black holes that formed, how they formed, how they evolved and their impact on the surrounding medium. Studying galaxies soon after the Big Bang gives us a unique means to investigate the nature of the early Universe, and to study systems like our own Milky Way in their infancy. The power and capability of an E-ELT will enable the measurement of physical properties of these galaxies, which will not be possible with any other facility. In addition, the E-ELT will be a unique tool for making an inventory of the changing content of the various chemical elements in the Universe with time, and to understand the star formation history and evolution of galaxies through cosmic time.
One of the most exciting goals of the E-ELT is the possibility of making a direct measurement of the acceleration of the Universe's expansion. Such a measurement would have a major impact on our understanding of the Universe. The E-ELT will also search for possible variations in the fundamental physical constants with time. An unambiguous detection of such variations would have far-reaching consequences for our comprehension of the general laws of physics.
While we push towards these grand aims, we will also generate significant knowledge of benefit to industry, and other science sectors.

Providing inspiration

Some idea of the level of current public interest in astronomy can be gauged from the following statistics:

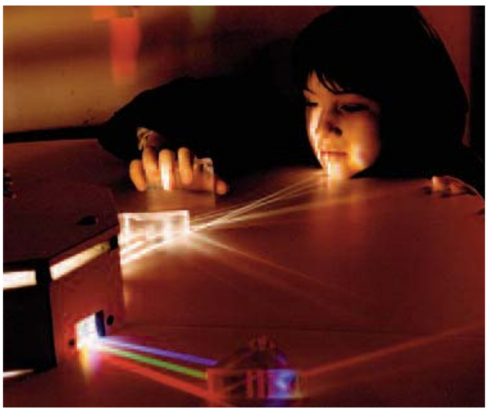
- **Popular astronomy magazines in circulation[8]:**
  - BBC Sky at Night magazine – 4,500
  - Astronomy Now – 7,500
  - Sky & telescope – 120,000
  - Astronomy – 130,000
- **Galaxy zoo – an example of 'citizen science' – 50 million galaxy classifications from 150,000 members of the public in its first year[9]**
- **1.3 million visited the National Maritime Museum in 2008/9, most of whom would have visited the Royal Observatory Greenwich**
- **Leicester Space Centre attracts 220,000 visitors per year**
- **2,800 people attended two open days at the Royal Observatory Edinburgh in September 2009**

A recent study of how to attract young people to careers in engineering, sponsored by the Royal Academy of Engineering (RAE)[10], stated:

"Young people will be impressed if we can demonstrate the crucial role engineers play on big, iconic projects; they add glamour, longevity, respect and fame to engineering."

It also added that, currently, there is little aspiration or allure attached to engineering, but that this could be enhanced. This is certainly an area where the E-ELT can contribute with high impact.

Royal Observatory Edinburgh Visitor Centre



The UK E-ELT programme has a significant public outreach programme designed to take advantage of the public's natural interest in such a readily understood flagship project. The E-ELT will be the world's largest optical-infrared telescope, with the potential to revolutionise our view of the Universe. The project represents the biggest opportunity for publicity and public outreach in ground-based astronomy for the next 15 years.

Royal Observatory Greenwich

There have already been well-publicised outreach activities linked to the UK Dark Sky Discovery programme and the International Year of Astronomy (2009). There has been extensive coverage of the E-ELT in the press[11]. These include articles in The Times, The Telegraph, Science, Nature, BBC On-line and coverage on BBC Radio 4's Today programme. The UK ELT Project Office has been successful in bidding for an exhibit at the Royal Society's celebration of its 350th anniversary at the South Bank in June 2010 – a major opportunity for reaching a large number of members of the public and decision makers.

Working with universities and industry, the UK Project Office is developing a high impact outreach programme that capitalises on all the exciting features of science, engineering, technology development and sheer scale that come with the project.

[8] Worldwide circulation figures

[9] http://www.galaxyzoo.org

[10] Engineering Our Future – Inspiring and attracting tomorrow's engineers, National Grid & Royal Academy of Engineering

[11] http://www.roe.ac.uk/elt/media.html

Building industrial capacity

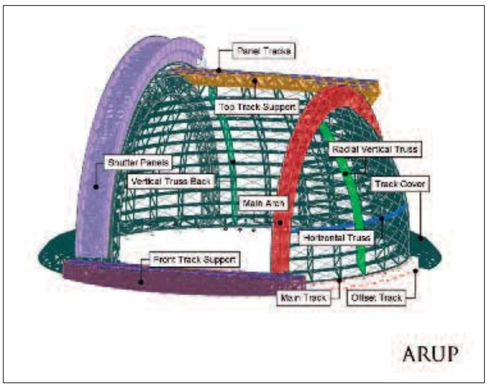
One of the key strategic aims of the E-ELT programme is to ensure that UK industry wins contracts for the construction of the telescopes and its associated systems and instruments. To this end we have an Industry Liaison Manager specifically working with UK industry. Activities have included a series of industry-specific regional events, with visits from ESO project office and procurement staff.

Industrial contracts account for over 80% of the costs of the E-ELT. During the construction phase UK industry will be able to compete for all of this work and can reasonably be expected to win contracts of total value up to €200M. As well as the major structural and mirror systems, these contracts will include instrumentation incorporating optical elements, Adaptive Optics, detectors, cryostats and software. Companies who may benefit from these contracts include ARUP, SciSys, SEA, Qinetiq, Selex, e2v and a consortium based in North Wales at OpTIC Technium.

There has been considerable success already, with several of the above companies having been awarded contracts – currently to a total value of €8.5M:

- Enclosure study – undertaken by ARUP. This involves the design of the enclosure systems, structure and mechanisms for the 100m rotating dome and retractable doors that will house the telescope.

Telescope dome concept
ARUP



- Software and control systems – undertaken by Observatory Sciences Ltd and SciSys Ltd. These projects involve investigation of software and control architecture options for the E-ELT.
- Fast low-noise detector arrays for wavefront sensing. New detectors developed for the E-ELT Adaptive Optics systems by E2V.

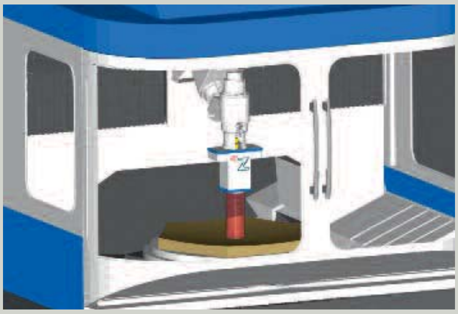
Polishing a prototype mirror segment
Optic Glyndŵr

- Prototyping of primary mirror segments – undertaken by the consortium based at the OpTIC Technium. This contract alone could pave the way for industrial contracts for the E-ELT worth up to €200M, as well as facilitating future contracts for other sectors, such as laser fusion, ultra-precision optics for lithography in semiconductor manufacture and earth observation systems. It could therefore be instrumental in generating a multi-billion pound revival of the large optics industry in the UK, centred on the OpTIC Technium and giving excellent leverage on RCUK Basic Technology programme, EPSRC and Welsh Assembly Government funds.

The UK E-ELT programme is also driving several technology development projects, for example detectors and deformable mirrors. The deformable mirror project, called Large Adaptive Carbon Fibre Reinforced Plastic (CFRP) Mirrors for Extremely Large Telescopes[12], is funded by the STFC to design, build and test a 1m diameter nickel coated CFRP mirror of flat optical form as a technology demonstrator for the next generation of large deformable mirrors. University College London, the University of Birmingham and BAE Systems together provide academic and industrial participation. Other work on novel materials and actuators for large deformable mirrors involves the University of the West of Scotland, the UK Astronomy Technology Centre, Durham University and industrial partners.

Spin-out company example:

ZEEKO



Zeeko is a spin-out from University College London. It specialises in precision polishing machines and metrology for devices up to 2.5m in size. Zeeko have sold 53 polishing machines to world-wide markets including China, Japan, Taiwan, Hong Kong, Singapore and India, most European countries, as well as a number of installations in the US. Most of their machines are used for non-astronomy markets, including four machines in the UK that are used for the precision forming of artificial hip and knee-joints. Zeeko are growing rapidly, and now employ 43 people worldwide of which the majority are based in Coalville near Leicester. Annual turnover in 2009 will be over £3.0m growing to over £4.0m or higher in 2010.

http://www.zeeko.co.uk/

The UK is currently participating in the design studies of 5 out of 8 potential first generation instruments for the telescope. The aim for the instrument studies is to develop industrial involvement as the requirements and designs progress; this is especially relevant for instruments that have significant modularity and consequently opportunities for industrial manufacture.

The UK E-ELT programme is also pursuing commercialisation and spin-out opportunities. For example, there are potential spin-out opportunities in the fields of medical imaging and turbulence monitoring. There have already been several spin-outs from astronomy technology – two examples are described in the highlight boxes (Zeeko and Blackford Analysis).

The emergence of new companies both in response to the procurement requirements of the facility and from technology spin-offs, are expected to be a key impact of the E-ELT. The value of these new industries and companies to the UK economy cannot be predicted accurately, but it is possible to place some boundaries on potential economic return.

A recent market study suggests that the world market for Adaptive Optics in biomedical and communications applications could potentially grow to over £500M per year within ten years[13]. Detector developments currently funded to provide better optical and infrared detectors for ELT instruments and Adaptive Optics systems could also expand this market by several hundred million pounds per year, but the largest potential market would be opened up if Laser Fusion is successful as a new energy generation technology. Even the development systems like HiPER and its successors could provide market opportunities in the hundreds of billion of pounds range.

[12] http://zuserver2.star.ucl.ac.uk/~osl/projects/cfc2/home.html

[13] UK Adaptive Optics Market And Supply Chain Study, Photonics KTN 2009

[14] *The study surveyed 277 PhD students and 58 MSc students who were trained at Jodrell Bank and Cambridge University between 1945 and 1978.*

Increasing the skills base

Developing and using the E-ELT is a major endeavour in science, technology and engineering. We have already started to build teams and partnerships between institutes, university groups and industry to build and exploit this telescope, its systems and instruments. A major impact of this will be to develop a cohort of trained scientists and engineers, with skills and know-how honed by the challenges of this huge and complex machine. We expect that, at its peak, 100 scientists and engineers will be employed on the project in the UK. Of these, some 40% will be new graduates and post-docs who will transfer these skills to future challenges across a range of disciplines. These skills are applicable to many of the grand challenges facing us in the 21st century.

Spin out company example:

Blackford Analysis is a spin-out from the University of Edinburgh, using image processing techniques developed for galactic survey astronomy. Its patented real-time technology allows 3D image volumes to be fully registered faster than they can be acquired - this enables, for example, MRI scans to be taken on patients who cannot sit still for the duration of a scan.

http://www.blackfordanalysis.com

Intimate knowledge of the instruments on the telescope will allow UK scientists to exploit early scientific breakthroughs. Specific skills in data analysis and interpretation of data will be developed by the optical-infrared UK astronomy community.

Therefore, the process of designing, constructing, operating and exploiting the facility will create large numbers of highly trained people. A cohort survey carried out on radio astronomy students[14] (PhDs and MSc) to investigate their professional destinations found that 40% of PhD students had entered into industry or Government for their first job and 49% were currently employed by industry or Government. The same study showed similar results for MSc students with 39% of students having their first job in these sectors and 51% of MSc graduates currently employed in those sectors. The study also found that these post graduates felt that the skills that they had acquired during their astronomy training were of direct use to industry, particularly high technology R&D. Hence significant benefits are brought to the UK economy through the provision of highly skilled scientists and technologists into industry.

Improving the quality of life

Many of the most direct impacts on quality of life derived from astronomy and its enabling technology have been mentioned in other contexts above. Technologies from optical and infrared astronomy are already being applied to medicine and the life sciences, and the new technology we are developing for the E-ELT is likely to have even more impact. For instance, retinal imaging to help diagnose macular degeneration, wavefront sensing to enable design of more accurate inter-ocular lens implants, medical data analysis for interpretation of brain scans. Lightweight and controllable optical surfaces can be applied to several areas which could have impact on the environment and our carbon footprint, from understanding climate change through earth observation systems to reducing carbon emissions through use of solar power and ultimately laser fusion systems.

One of the intangible ways that astronomy, and the future E-ELT, improve our quality of life is by instilling a sense of our place in the universe, how science helps us to understand it, and that the scientific method can help solve big and complex problems – literally 'the big picture'.

Conclusion

The E-ELT will undoubtedly make a huge impact in terms of its core science because it will be opening up new parameter space in both sensitivity and spatial resolution – providing 20 times more detail than the Hubble Space Telescope at the same time as observing objects at least 100 times fainter and hence more distant than can be observed with current 8m telescopes like ESO's VLT. On top of these science gains, and the consequent excitement generated with the public and inspiration for the next generation of scientists and engineers, the project will have direct economic benefit through development of new technology which will be applied in as yet unknown fields, training of skilled engineers and scientists, and direct benefit to industry by way of contracts of hundreds of millions of Euros.

Further reading

ESO Website:
http://www.eso.org/sci/facilities/eelt/

UK ELT Programme Website:
http://www.roe.ac.uk/elt/index.html

An Expanded View of the Universe
http://www.eso.org/sci/facilities/eelt/docs/E-ELTScienceCase_Lowres.pdf

Future Optical Technologies for Telescopes and Instruments,
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The European Extremely Large Telescope,
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Physics enhancing our lives,
The Institute of Physics and EPSRC, 2009

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