

# Technology Management Plan

November 2007



# **NERC technology management plan**

## ***Developing the tools needed for innovative environmental science***

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## Summary

Using and developing technology is an essential component of NERC science. In recognition of its growing importance, and pace of development, NERC has established a Technology Management Plan to guide its investments.

The technology management plan outlines a number of key principles. By working with partners, NERC will ensure leverage of funding, efficient use of resources and transfer of knowledge, information and technology. We (NERC) will identify strategic technology requirements and priorities for investment through effective and flexible portfolio planning and management. We will provide training and skill development to maintain and increase our capabilities. We will make available, a range of funding streams and mechanisms to provide flexible and agile support for technology development and other activities.

Three strategic technology 'clusters' will bring together key researchers and other stakeholders. Initially these are:

- Remote sensing
- Intelligent field sensors
- Novel laboratory instrumentation.

Two additional 'underpinning' technology clusters will support them:

- Informatics
- Enabling infrastructure

A technology theme leader drive the implementation of this plan and will facilitate NERC's engagement with the community.

## Introduction

1. Technologies and technology development are an integral part of scientific research, providing us with the national capability to carry out NERC science. They also support the specific science objectives and challenges identified in NERC's new strategy for 2007-2012, *Next generation science for planet Earth*, and lead to innovative applications in environmental sciences. There is a rapid increase in technological innovation. Many science projects depend on advanced technologies but there are often long lead times, high risks and high costs involved. In view of this, NERC recognises the need for a more strategic direction and coordination of its technology investments, and has produced a technology management plan. This is to ensure a coherent and cost-effective approach, and to allow the UK to use its leading position in environmental science to spur on development of world-leading environmental technology.
2. How the technology management plan was developed, and its connection to the technologies theme report, is described in annex A.
3. The technologies theme within *Next generation science for planet Earth*, outlines some key deliverables in a section called 'Meeting the challenges'. These are provided in annex B4. Technology activities form part of many of our current and future science programmes, and are also linked to knowledge exchange and science infrastructure. The technology management plan will support and strengthen links between research and collaborative centres (who provide much of NERC's technology capability) and higher educational institutes.
5. NERC invests at least 20% (~£60 million) of its annual budget in technology and technology activities, in many science areas and using a range of delivery mechanisms. This investment is predicted to increase. The boxed case studies in this document demonstrate the breadth of our technology activities. The technology management plan will help identify areas where the UK's environmental technology development can be world-class, and will help technology developments benefit environmental science. It complements NERC strategy statements, such as on Earth Observation and on information management.

## NERC's role in technology

6. For this technology management plan, we define technology as any instrument, platform, sensor or technique developed, provided or used for environmental science. This also includes information and communication technology, high performance computing and e-science technologies, as well as mathematical and statistical techniques.
7. NERC relies on technologies for measuring, observing, monitoring and predicting the past, present and future state of the environment. Technologies enable us to collect, distribute and share data, information and knowledge. In some cases we can adopt or adapt commercially available technology and components. However, there are challenging areas where NERC must provide and drive its own bespoke technologies. Examples include miniaturisation, autonomy or ruggedness to operate in extreme environments, such as the deep sea or polar regions.
8. NERC has multiple technology roles
  - **We provide** technologies for our research community. For example, the NERC FAAM research aircraft (Facility for Airborne Atmospheric Measurements) is equipped with state-of-the-art measurement instrumentation, supporting a wide range of atmospheric science applications.
  - **We use** technologies, such as information and communication technology. Today, every research project needs such technology to manage data and communicate results.
  - **We develop** technologies to underpin our research objectives. For example, NERC funds supported the development of a satellite instrument to measure the Earth's radiation (the Geostationary Earth Radiation Budget, GERB). These measurements are used in climate and atmospheric science.
  - We commercialise technology in **spin out companies** for commercial and public services. An example is Geotek, a company which is now a world-leading supplier of equipment for the automated analysis of marine sediment cores.
  - We research the **environmental implications** of new technologies. For example, we support developing carbon capture and storage technologies by characterising sites where carbon dioxide could be stored underground, and investigating the implications of leaks.

9. NERC's key role in technology is to *integrate* components and sub-systems into a specific system that can be used for environmental science. In most cases NERC scientists use commercially available technology and components, but often it is necessary to adapt such components or systems to work in extreme environments.
10. Developing scientific solutions to environmental and societal problems, including depleting natural resources, is part of all of NERC's strategic science themes. Examples include mitigation measures, such as carbon dioxide sequestration, flood defence management, bioremediation, bio-refining and development of alternative energy. Technologies that underpin the research needed to understand the environment, in turn, help us exploit natural resources, reduce hazards and monitor mitigation technologies. Many of these technologies are either novel or need tailoring for environmental mitigation.
11. Where developing technology for mitigation is on the margins of our remit, we will work in partnership with others. NERC will develop the underlying science that lets technologies exploit a resource or reduce a hazard. For instance, we might develop technology that underpins the science needed to characterize the potential of an aquifer, but we would not develop the associated extraction technologies. For this reason, mitigation technologies are not considered further here, but there are many examples where we should be involved in sharing good practice.
12. Technology is pervasive, not just throughout NERC's science activities, but also in how knowledge is exchanged between researchers, the private and public sectors, and society.

## Making state-of-the-art atmospheric measurements



### Design and technology

The Facility for Airborne Atmospheric Measurements (FAAM), at Cranfield University, is a collaboration between the UK Met Office and NERC and is part of the National Centre for Atmospheric Science. The BAe 146 aircraft is modified specifically for atmospheric research, carrying three crew, and up to 18 scientists, and a wide range of instruments and equipment. It can fly for up to six hours at a time and can operate at altitudes from 50 to 35,000 f t.

### Environmental application

FAAM has a range of state-of-the-art instrumentation to measure the chemical composition, dynamical structure and distribution of aerosols and clouds. This helps researchers better understand atmospheric processes. FAAM's core measurements include: temperature profiling; relative humidity; wind speed and direction; and analysis of atmospheric gases, aerosol particles and clouds. The facility is also equipped with instruments to measure altitude, air speed, temperature, water vapour and total water content, in addition to down and broadband radiometers.

Our Core-Strategic Measurements for Atmospheric Science programme has developed a portable, fast and sensitive, mid-infrared diode laser spectrometer, capable of operating in from the aircraft and also on the ground. It can measure up to three 'tracer gases' associated with atmospheric chemistry, dynamic mixing or stratosphere/troposphere coupling simultaneously.

FAAM instruments are improving our knowledge of secondary organic aerosol production as part of NERC's research programme which is investigating aerosols and climate. Comparing information from ground based instruments and from FAAM measurements over West Africa, will improve scientific understanding and help build a model to predict malaria risks for the region.

### The future

Researchers across the world develop novel instrumentation all the time. NERC must link a strategic view of instrument evolution (reviewing state-of-the art instruments, degrees of autonomous operation, and other scientific advances), to current and predicted science needs. In many cases, acquiring state-of-the-art instrumentation does not require fundamental technology development, but simply upgrades to ensure our leading facilities deliver world-class science.

**NERC invests around £2 million per year to operate and maintain FAAM. The capital cost of establishing FAAM was £16 million, of which £12.5 million was provided by the Joint Infrastructure Fund.**

## Genomics: a new technology with great potential for environmental science



### Design and technology

'New generation' high-throughput genomics lets scientists monitor functions and processes in ecosystems, and characterise their biodiversity. They also let us explore environmental influences on the genomes of plants, animals and micro-organisms. Technologies include: high-throughput sequence generation that will help determine an ecosystem's genetic diversity; laboratory genetic profiling for parallel analysis of 10 to 100,000 genetic elements (with many applications for environmental science); and rapid in-situ biogenetic analysis for using in field studies.

### Environmental application

Adapting this new technology for environmental science could achieve a 'step change' in our genetic knowledge of the environment. For instance, massive parallel sequencing could place NERC at the forefront of environmental genomic science. This technology can determine 20 million base pairs of gene sequences in every run – more than ten times the number of the technology it replaces.. This can complete current sequencing projects in a fraction of their original time.

The data generated will require new algorithms and data handling systems. We are meeting these challenges by adopting best practice from international genomics developments. For example, we support an international programme that addresses the implications of genomics for environmental legislation. This programme is helping develop internationally-agreed quality standards for data and experimental metadata, as well as helping decision-makers base their decisions on scientific evidence.

### The future

Re-sequencing and post-genomic techniques provide novel ways to characterise ecosystems and individual organisms. This will advance our understanding of biodiversity within-populations, with major benefits in fields as diverse as conservation biology and pest and vector management.

**NERC has invested around £1.6 million over eight years in genomic technology as part of our genomics and proteomics programmes.**

## **Autosub: technology that reveals unexplored environments**



### **Design and technology**

Autosub, a seven metre-long, unmanned autonomous underwater vehicle, can venture under floating ice – the last great unexplored region on our planet. Autosub's world-leading technology was developed at the National Oceanography Centre, Southampton (NOCS).

Design began as a NERC project in 1988, and extensive system development took five years. The first autonomous mission was in July 1996. The UK Design Council awarded Autosub Millennium Product status, and in 2001 its design was licensed for use in the oil, gas and sub-sea cable markets. The original Autosub completed more than 380 missions and a new vehicle is planned.

### **Environmental application**

Autosub can collect physical, chemical, biological and geophysical data from the ocean surface to the seabed, using a suite of sensors and sampling devices tailored to individual missions. Sub-bottom acoustic profiling can reveal structures of glacial origins in the seafloor sediments, while a water sampler can collect samples for geochemical and biological analyses. Swath bathymetric sonar can measure ice shelf, sea ice and ocean bottom relief at high resolution. Autosub's missions provided scientists with a wealth of information on climate change and marine life. For example, instruments on board Autosub made the world's first good measurements of the abundance and distribution of krill under the ice, and of the thickness of the Antarctic sea ice. Sea-ice deposition and melting is a vital part of the climatic and global circulation processes, and we need to follow how ice distribution is changing to understand more about climate change.

### **The future**

Autosub engineers at NOCS are now building a deep-water version, Autosub-6000, which is undergoing trials in 2007. Meanwhile, the researchers and engineers are sharing their hard-won experience with others around the world. A bursary scheme is strengthening international links by helping young students and engineers study overseas. There are plans to send Autosub under polar ice again as part of the International Polar Year of research.

**Autosub's development cost approximately £10 million, of which NERC provided £5.5million.**

## NERC's technology management plan principles

### 13. **Using and developing technology are essential components of NERC science.**

We have identified technologies as a strategic priority. All our strategic science themes have identified specific technologies their science challenges need. We have also highlighted informatics and data management tools as particularly important for delivering NERC's science strategy. Our active involvement using and developing cutting-edge technology is essential for healthy environmental science and to keep the UK at the forefront of environmental sciences internationally. We recognise that many technology developments involve long lead times, high risk and high cost. In particular, reliability is often a key risk in technology. Implementing the technology management plan will require a long-term commitment of budget and resources, and for us to work with partners.

- We recognise technology as an important part of our national capability to carry out environmental science.
- We will encourage a culture that values technology as a pervasive aspect of our science, and will reflect this in staff development and financial reward, and in our science and society activities.
- We will communicate technology needs and achievements to a wide range of stakeholders.

### 14. **Working with partners, we will ensure maximum leverage of funding, efficient use of resources and transfer of knowledge, information and technology.**

Partnerships and knowledge transfer into, within and out of NERC are critically important to a successful technology programme. Successful partnerships will: provide cross-discipline skills for technology development; provide stronger links between technology developers and the academic community; and make the UK science and technology base more competitive internationally. While NERC already works with a wide range of organisations nationally and internationally, a thriving technology programme will provide new and stronger partnership opportunities. We recognise that collaborating with industry and other technology providers and developers reduces our risks when developing new technologies.

- New NERC research programmes and collaborations will build on our national capability in technology and technology development.
- We will work closely with other research councils, eg through the Basic Technology programme, and with the Technology Strategy Board (an independent non-departmental public body since April 2007).
- We can provide the environmental science framework to support technology developments in government departments and agencies, and to measure their impact on the environment.
- We will use existing knowledge transfer mechanisms and networks to strengthen our links with industry and other technology providers and users.
- We will actively seek partnerships with other national or international organisations and industry to leverage funding and transfer knowledge and technology.
- Our activities will help develop international standards.
- We will encourage commercialisation of technology developments.

15. **Through effective horizon scanning and portfolio management, we will identify strategic technology requirements and priorities for investment, while maintaining our flexibility.**

We need to be able to understand future science needs and what drives emerging technologies. Implementing our strategic science priorities requires developments and investments in technologies, and we will ensure that appropriate technologies are available to implement our science strategy. Although NERC technology development primarily supports scientific objectives ('science pull'), advances in technology enable us to reach out for new scientific challenges and applications ('technology push') and we need to make emerging technologies and new ideas available for science.

- We will continuously review our strategic technology priorities through effective portfolio planning, including horizon-scanning activities and by developing technology roadmaps. Portfolio analysis will inform our investment decisions.
- We will identify areas where the UK can be world-class in environmental technology development.

**16. Training and skill development are essential to maintain and increase our capabilities.**

A successful technology programme requires skilled people. The increasingly multi-disciplinary nature of environmental science requires combinations of skills from different disciplines, such as physics, mathematics, statistics, engineering and computer science. We already undertake a range of training activities, but recognises that there are significant skills shortages in some areas, for example physics, mathematics and statistics.

- We will review our training activities in the light of this Technology Management Plan, and support training in the science and engineering skills necessary for our technology development activities.
- We will continue to encourage the use of our scientific facilities for hands-on training in technologies, in particular for graduate students.

**17. A range of funding approaches will be available to provide flexible and agile support of technology development and other activities.**

NERC already supports technology through existing funding streams, including research and collaborative centres (ca. £10 million pa), research programmes (ca. £10 million pa), responsive mode grants (ca. £1 million) and our contribution to the European Space Agency (ca. £28 million). Reflecting the pervasive nature of technology, this diverse funding will continue and be built upon, as opposed to providing a single funding stream for technology. However, there are areas of activity where new funding approaches may be needed. These include:

- proof of concept and feasibility studies to reduce the risk linked to technology development programmes;
- support for networking and horizon scanning activities;
- improving and upgrading existing technology to ensure it remains state-of-the-art;
- developing prototypes that are tested in the real environment; and
- grants to develop and maintain UK skills and capabilities for the longer term.

The first two categories, need an initial investment of around £1m over three years. Costs for the other activities will be identified as part of implementing this plan. Funding for these new activities has to be balanced with our current funding streams.

18. Much of our technology capability resides in our research and collaborative centres and we will help wider community access it. This and some other technology activities will fall within our national capability funding stream, while other activities will be within the research programme funding stream. Further work will determine which activities belong to each of the funding streams.

- We will continue supporting technology activities through a range of funding streams.
- We will establish dedicated enabling funding to support technology where the current arrangements are inadequate.
- We will track our total expenditure on technology activities.
- We will assess whether current assessment criteria, particularly for the responsive mode, are suitable for technology-focussed proposals.
- We will facilitate access to centres with technology capability, eg for responsive mode projects.

## CryoSat: measuring continental ice sheets and marine ice cover



### **Design and technology**

The CryoSat satellite mission is to determine variations in the thickness of the Earth's continental ice sheets and marine ice cover. It is funded by the European Space Agency (ESA), and is the idea of UK scientists. A consortium of UK and European scientists work with ESA engineers and industry to ensure CryoSat will address the scientific community's needs.

CryoSat's primary payload is the SAR/Interferometric Radar Altimeter (SIRAL), which has extended capabilities to measure ice-sheet elevation and sea-ice freeboard. In addition, a radio receiver called Doppler Orbit and Radio Positioning Integration by Satellite (DORIS) and a small laser retroreflector ensure that CryoSat's position will be accurately tracked. UK industry has played a key role in the mission's technology. For example, UK space software experts at SciSys developed the onboard application software that will control the precise orbit and attitude of the spacecraft and handle all communications with ground control.

### **Environmental application**

NERC scientists will use data from CryoSat to test the prediction that global warming is thinning sea ice, and to accurately predict sea level rise caused by melting ice sheets in Antarctica and Greenland.

We need better observations to establish whether observed changes in polar ice result from global warming rather than natural variability. By precisely measuring ice thickness on both land and sea over a three-year period, CryoSat will establish conclusively whether there is indeed a trend towards diminishing polar ice cover, and in the process will help us understand the relationship between ice and global climate.

### **The future**

CryoSat's initial launch on 8 October 2005 ended in failure. The satellite loss brought home the value of this mission to the climate change scientific community, who have persuaded the space agency's Earth Observation Programme Board to invest in a second mission – CryoSat-2. Its mission will remain the same, and CryoSat-2 is due for launch in 2009.

## Strategic technology clusters

19. **An important element of this technology management plan is to establish 'clusters' in key NERC technology areas.**

A cluster will be a flexible and evolving group of researchers and stakeholders with an interest in a particular technology area. We will make use of existing networks and partnerships when setting up the technology clusters. These existing mechanisms will provide a direct link to relevant businesses, facilitating information sharing and knowledge transfer. The role of the clusters will be to:

- promote networks and 'clubs';
- identify future technology requirements and priorities through horizon scanning and technology road mapping; and
- coordinate proposals for technology activities.

The clusters will be given freedom and flexibility to reflect the particular characteristics of their topics. Over time there will be evolution and turnover of clusters, with some being disbanded and others being created.

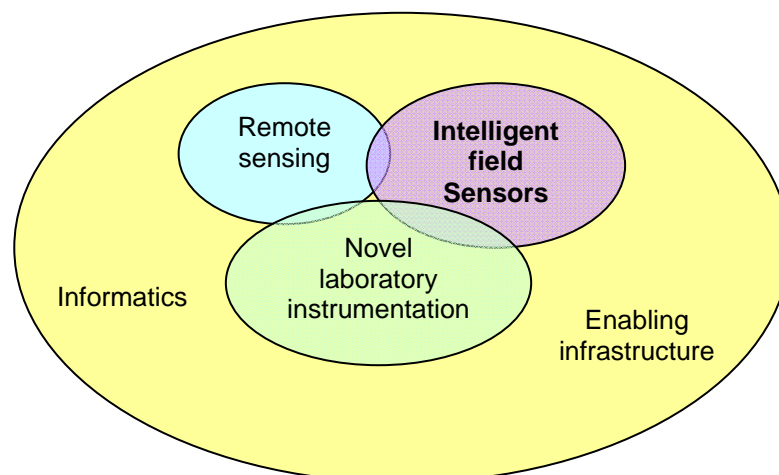
20. We have created an initial 'map' of NERC's existing technology development areas, in consultation with the NERC community. Many of these areas coincide with areas that the Technology Strategy Board has identified to be priority areas for the UK as a whole from international comparisons. This mapping, examination of the Technology Strategy Board's priorities, and analysis of our high priority needs as given in the new NERC strategy, has identified three initial strategic technology 'clusters':

- **Remote sensing**
- **Intelligent field sensors**
- **Novel laboratory instrumentation**

Two additional cross-cutting technology clusters will support these, addressing:

- **Informatics**
- **Enabling infrastructure**

The clusters are interlinked and overlap in their activities. The role of informatics is particularly ubiquitous.



## **Remote sensing**

Remote sensing is defined as any remote or indirect measurement made using specific parts of the electromagnetic spectrum. Sensors can be based on satellite platforms, airplanes, unmanned autonomous vehicles (UAVs), on the ground or under the ocean.

NERC researchers use primary data products supplied by organisations such as ESA and NASA, but space-based sensors are generally developed outside NERC. In some cases, we fund feeder technologies that underpin sensor development; these are later developed by space technology companies for use on satellite platforms. Occasionally, we may fund complete satellite instruments, such as GERB, when there is a compelling scientific case and no alternative suppliers. Other examples include ground-based weather radar and LIDAR that are used for atmospheric measurements.

These technologies are often developed for NERC by external companies, frequently in partnership with NERC scientists. Some of these technologies have a limited market, and are developed ad hoc to meet specific scientific needs (eg airborne Differential Absorption Lidar (DIAL)). Sometimes, developments help miniaturise or package technologies for potentially wider applications (for example to be carried on UAVs).

NERC scientists also put existing technologies on novel fixed and mobile platforms, which may have been developed and used for other purposes (including autonomous platforms). An important part of this cluster will be to develop methods to use these observations to test predictive models of the environment.

## **Intelligent field sensors**

Models of environmental processes need to be validated against observations, often in inclement or inaccessible environments. There is a strong need, identified in all of NERC's strategic science themes, for information from novel sensors deployed in the field.

Many new technologies are changing how we can observe the environment, and how we can manage those observations, for example low power, rugged and miniature instruments. Many new sensors can now be programmable, with autonomous power supplies and communications, changing how and where they can be deployed. Sensors can be programmed to switch between sampling modes, for instance sampling occasionally to monitor a process but sampling much more frequently when an event occurs. This cluster will include work on sampling methodologies.

The significance of such observations can only be judged by using models, some of which could be run locally on the sensor. So assimilation research is important here, as in the other technology clusters. We also need to develop protocols, so that sensors can communicate with each other, perhaps changing sampling frequencies or what measurements are taken across a whole area if one sensor detects an event.

While in principle many of these tasks can be done now, the sensor systems often need tailoring for environmental use. Scientists adopt new sensor technologies early, but many new sensors can later be employed by a wide range of users, including government departments, for environmental monitoring. So there is a particular need for focussed knowledge transfer activities in this cluster.

## **Novel laboratory instrumentation**

The challenge for the new generation of laboratory instrumentation is to analyse environmental samples at the system level. This requires devices and techniques that can provide many parallel arrays of data on chemical, physical or biological properties of samples. Observing ecosystems at an increasing level of resolution is an additional challenge, demanding platforms that provide higher resolution and detection sensitivity. These data collection platforms require data handling systems that can integrate meta-data and analyse the information.

These challenges can often be addressed by exploiting new technologies developed elsewhere, but these may need adapting and developing to meet NERC's science needs. An example is meta-genomic sequencing, which can produce generic bar-coding for whole communities. This may help future development of in-situ biogenetic analysis and bio-diagnostics for ecosystems, and would have a crucial role for delivering the objectives of our strategic science themes on Biodiversity and Environment, Pollution and Human Health. But this will only be possible if the large data volumes can be handled, and the techniques are adapted to analyse whole ecosystems.

## **Enabling infrastructure**

Successfully delivering innovative technology for environmental science depends on making infrastructure available, including:

- providing an environment and platforms to support the technology;
- developing enabling equipment, such as power systems (including renewables);
- communications and control systems, sometimes needed to enable autonomous operations;
- adopting common engineering practices; and
- risk management methodology needs to be used when deploying technology.

As far as possible, researchers should use common engineering practices, but these often need to be adapted for challenging and extreme environments. This cluster will champion the requirements for novel infrastructure, and to work with the other clusters to share best practice.

NERC provides technology infrastructure, such as ships, aircraft and laboratories, to help deliver its science (NERC's strategic theme on scientific infrastructure identifies priorities and challenges for this area). To undertake increasingly multi-disciplinary research in a flexible way, we need to adapt novel instrumentation and sensors for deployment on platforms or installation in laboratories. NERC will look to invest in alternative platforms, or technology developments in the underlying infrastructure, when we can decrease their costs. Reducing the cost of platforms will enable funds to be focussed on developing and deploying new sensors and instruments. We should evaluate a range of providers, including industry, for its infrastructure needs, in order to react quickly and flexibly to changing science and technology requirements.

## **Informatics**

We rely heavily on sophisticated models of environmental processes to predict the state of the environment. Rapid advances in information and communication technologies are revolutionising the way researchers are working, and working together, using computing power and scientific data repositories.

Informatics encompasses: acquiring, managing and distributing data; and information and modelling techniques, including numerical analysis, data assimilation and visualisation. The UK, largely with NERC funding, leads in developing many data analysis and assimilation technologies. We will take advantage of the many rapid advances in informatics activity, both nationally and internationally, tailoring solutions to our scientific needs. This technology is very important for delivering all of NERC's strategic science themes.

21. **Implementing this technology management plan will be challenging because technology is so pervasive throughout our activities and across our remit.**

We will appoint a technology theme leader to ensure the science community engages and takes ownership of the Plan.. This technology theme leader will drive the technology management plan's implementation, and ensure our technology priorities address the science challenges identified in *Next generation science for planet Earth*. The theme leader will promote strategic partnerships and advise NERC on portfolio planning and investment decisions, and will coordinate technology activities. The technology clusters will provide expertise and advice to NERC.

22. **We will regularly review the technology management plan, and revise and update it as necessary.**

The technology management plan will have been successful if, after three years, the following measures are met.

- Our stakeholders recognise NERC's capability and expertise in developing and adapting technology.
- The number of responsive mode applications to NERC for technology activities has increased.
- The technology clusters have built a NERC technology community.
- Partnerships with industry and government departments are effective.
- NERC is recognised as actively engaging with the Technology Strategy Board.

We will identify specific, measurable targets while implementing the technology management plan.

## Biotechnology: creating new commercial opportunities



Research and technological development from NERC's recently completed Environmental Genomics programme is spurring the growth of the biotechnology industry in the north-east of England.

### **Design and technology**

Scientists from Newcastle University and Leicester University created a genechip (a miniature set of all the genes on a glass slide) to study the pattern of switching on and off genes in marine worms such as *Nereis virens*. This was initially done to understand the complex rhythms of marine organisms. However, the biotechnology led scientists to the discovery that marine worms can produce essential fatty acids including omega 3, and giant haemoglobin molecules.

### **The future**

Seabait Ltd, a spin-out from Newcastle University, is using this biotechnology to generate aquaculture feeds and, in collaboration with the French company Hemarina SAS, is creating production systems for a new generation of human blood substitutes and other medical products

## Argo: measuring atmosphere-ocean carbon exchange at high temporal and spatial resolution – a technology challenge



### Design and technology

Determining carbon exchange rates between the atmosphere and the ocean can help improve predictions of climate change, and constrain carbon cycling models at basin and global scales. The global Argo array of subsurface profiling floats provides an invaluable network for ocean physics, but as yet does not measure the ocean carbon system. Researching and developing sensors that can be deployed on Argo floats and surface drifters presents a significant technological challenge. NERC's role is to drive research and development for the sensors, which would otherwise not be developed.

### Environmental application

Global change, and its regional impacts, are becoming an increasing concern. Mankind needs to understand, and ultimately predict, changes in both the atmosphere and ocean in order to guide international actions, to optimise government policy and to shape industrial strategy. To make those predictions, scientists need improved models of the climate and the entire Earth system. Lack of sustained observations of the atmosphere, oceans and land has hindered the **The future** development and validation of climate models. Argo was developed to greatly improve data collection inside the ocean.

Argo deployments began in 2000 and new floats are being deployed throughout 2007. New sensors would be able to determine carbon exchange rates between the atmosphere and the ocean, improving predictions of climate change. They would provide constraints for carbon cycling models (at basin and global scales) by producing an inventory of ocean carbon uptake. This would be a fundamentally new data set, which is impossible to achieve by present means, ship based or otherwise. Research will continue to need global Argo observations indefinitely, though the array's technologies and design will evolve as better instruments are built, models are improved, and more is learned about ocean variability.

**Target costs of these sensors would be in the order of £8k over the cost of the basic float.**

Picture: Argo: <http://www-argo.ucsd.edu/index.html>

## Annex A

### Developing the NERC technology management plan

NERC developed the technology management plan as part of its strategy - *next generation science for planet Earth*. It is the culmination of the consultation, advice and decision-making that took place over 2006 and 2007.

The plan is based on the technologies strategy theme report, and like the theme report, it is a working document that provides the basis for the technologies theme action plan.

The published NERC strategy contains a summary of the information in the technology management plan.

Summary of how the technology management plan was developed.

- In November 2005, NERC Council identified seven strategic science themes, and a strategy development panel was set up for each theme. The panels' role was to recommend future research priorities within each theme, and provide these recommendations to NERC's Science and Innovation Strategy Board (SISB). The technologies panel met on 4-5 June and on 20-21 September 2006.
- The panel chair presented the technologies theme report to SISB on 11-12 July 2006. At this meeting, SISB provided its initial view on the relative priority of the challenges which had been identified within that theme. The panel updated the report to reflect both SISB's conclusions and the panel chair's response. The report was then presented to Council on 26-27 September 2006. Council agreed the overall priorities and the reports were updated once again to reflect this.
- The technologies panel also developed the NERC technology management plan, as a step towards implementing the theme. The technology management plan incorporates the results of a study that NERC commissioned – undertaken by Psi-tran Ltd. The study summarised NERC's current technology activities across our portfolio, and identified future technology requirements.
- A draft NERC strategy was developed from the panel reports and opened to public consultation between February and April 2007. A final version of the strategy, incorporating recommendations from the consultation, was approved by Council in June 2007 and published in November 2007. The theme reports and technology management plan were also updated in November 2007 to reflect the final strategy.

## **Annex B**

### **Meeting the challenges**

NERC's strategy highlights some of the ways in which we will be "meeting the challenges" for the technologies theme. These are essentially some of the key deliverables. They cut across the challenges within the technologies theme and technology management plan. They are not exclusive and may evolve during the strategy's lifetime.

Key deliverables are:

- Strengthen the UK science and engineering capabilities in environmental technologies, fortifying existing research groups and building new, world, leading ones.
- Strengthen existing partnerships with organisations which share similar or complementary interests in technology development, such as our sister councils and the Technology Strategy Board.
- Embark on new partnerships with both users and suppliers of technology.
- Develop a base of skilled people in crucial areas and monitor emerging technologies and new ideas.
- Manage the increasing wealth of environmental data and information so that it can be transmitted, distributed, stored, archived, analysed and visualised. Information and communication technologies are key to managing information effectively.
- Recognise and develop opportunities for knowledge and technology transfer, both nationally and internationally.