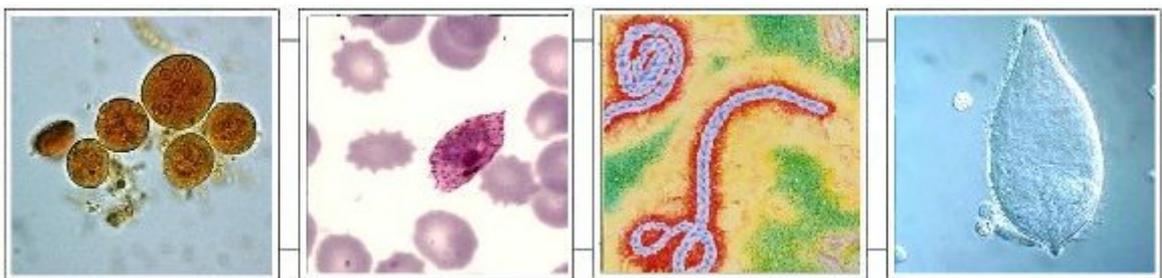


Foresight

Detection and Identification of Infectious Diseases Project



One-Year Review

April 2006 – May 2007

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Executive Summary

"The findings of the 'Infectious Diseases: preparing for the future report' provide a considerable body of scientific analysis and fresh insights to inform policy development by stakeholders at national and international level."

Sir David King, Government Chief Scientific Adviser

The findings of the Foresight project on Detection and Identification of Infectious Diseases (DIID) were published as the 'Infectious Diseases: preparing for the future' report on 26 April 2006.

The Report provides an independent, innovative vision of the challenges of infectious diseases which the UK and sub-Saharan Africa (SSA) will face over the next 25 years and explores some aspects of the role that science and technology might play in meeting them. This groundbreaking analysis is an important addition to the body of evidence which stakeholders will wish to draw on when developing their long-term policies and strategies. It is crucial that the decisions made today will exploit this evidence-base in order to maximise the benefits that future opportunities might afford and to manage future risks most effectively.

This review examines some of the Report's important impacts on stakeholders' decision-making and policy-development processes over the period April 2006 to May 2007. In particular, the Review sets out the actions which have been delivered against stakeholders' undertakings in the Action Plan which was published alongside the Project's technical reports. These activities, which are informed by and catalysed as a result of the Project, demonstrate the crucial role of cross-government partnerships and the links to academia and business in moving forward a holistic response to this work.

Key Conclusions

The Project has met its overarching aim to explore how the development and deployment of future technologies and systems might play a part in addressing DIID challenges over the next 25 years.

In achieving its aim, the Project has:

- brought innovative and exciting new approaches to assessing, analysing and modelling future risks in plants, animals and humans;
- provided a framework for how future science and technology might be developed and deployed to mitigate the future threats to health, the economy and the environment posed by infectious diseases;
- offered a fresh and innovative holistic perspective to cross-government, evidence-based policy development to manage the long-term risks associated with the evolving threats of infectious diseases in the UK at a central and local level;
- developed the concept for an innovative, multidisciplinary, cross-sectoral and agile infectious disease Observatory which would better

detect, identify and manage future outbreaks and co-ordinate the UK response to them;

- helped frame G8 priorities and declarations in the area of infectious diseases; such as linking the consideration and analysis of animal and human infectious diseases and the role of surveillance and monitoring systems in improving preparedness;
- informed the long-term policy and strategy setting of key European and major multinational organisations; for example, in the areas of human and animal health, novel technologies and systems and the impacts of infectious diseases on ecosystems;
- developed and promulgated high-level proposal for a pan-African network, which would aim to deliver a step change in capacity to manage the future infectious diseases of humans, animals and plants;
- demonstrated the key role that south-north links, so-called, 'smart partnerships' and other international collaborations will play in delivering capacity and regional and global solutions to future threats;
- identified funding gaps and informed public and private sector strategies for investment in the research and development of converging technologies for detection, identification and monitoring (DIM) systems for infectious diseases;
- provided a framework for future public and private sector technology development through the development of a suite of novel roadmaps. These roadmaps set out how the four key strands of technology and systems identified by the study might develop over the next 25 years to meet the needs of future user communities.

1. Project Overview

"This project demonstrates how technological and social developments can really reduce the negative impact of future infectious diseases on our health and wealth. These kinds of benefits are exactly why we have put science and technology at the heart of Government policy making."

Alan Johnson, the then Secretary of State for Trade and Industry

1.1 Introduction

The Project was developed out of ideas developed at a brainstorming event held in July 2002 which was chaired by Sir David King, Government Chief Scientific Adviser and Head of the Office of Science and Innovation (OSI) and which drew on contributions from leading members of the academic and business communities. This event sought to identify significant challenges facing society over the next ten or more years, for which science and technology would play a key rôle in delivering solutions.

This was the seventh project in the new round of Foresight and held its initial scoping event in September 2004.

Uniquely, this international Project delivered an inter-sectoral and multi-disciplinary analysis in the field of infectious diseases and brought together key players from government and over 400 leading experts from 30 countries. Contributions from all relevant social and natural scientific disciplines were made from areas as diverse as risk perception and data fusion to epidemiology and earth observation.

The Project also involved a wide range of UK and international stakeholders from government and elsewhere, and was sponsored by the Department for Environment, Food and Rural Affairs (Defra).

1.2 Aim

The Project produced a challenging and long-term vision for the detection and identification of infectious diseases in plants, animals and humans. This vision took account of the evolving risk of diseases; changing user requirements for detection and identification; and cutting-edge science. The Project aimed to inform policy at a national and international level.

1.3 Scope

The project:

- took a broad look across plants, animals and humans;
- considered international as well as UK issues;
- looked 10-25 years into the future; and
- built upon the best work by others in this area.

By taking a broad view, the Project successfully stimulated cross-fertilisation between different, and hitherto poorly linked, fields of science in exploring how the future threats of infectious disease might best be managed. Some of the important areas considered included the:

- evolving risks of diseases and the factors driving them;
- new technologies for detection and identification such as lab-on-a-chip, cell-based and tissue-based sensors, remote sampling, global databases and data mining; and
- societal and governmental implications of using the new technologies; for example the ethical, legal and institutional aspects of development and deployment.

1.4 Structure and Process

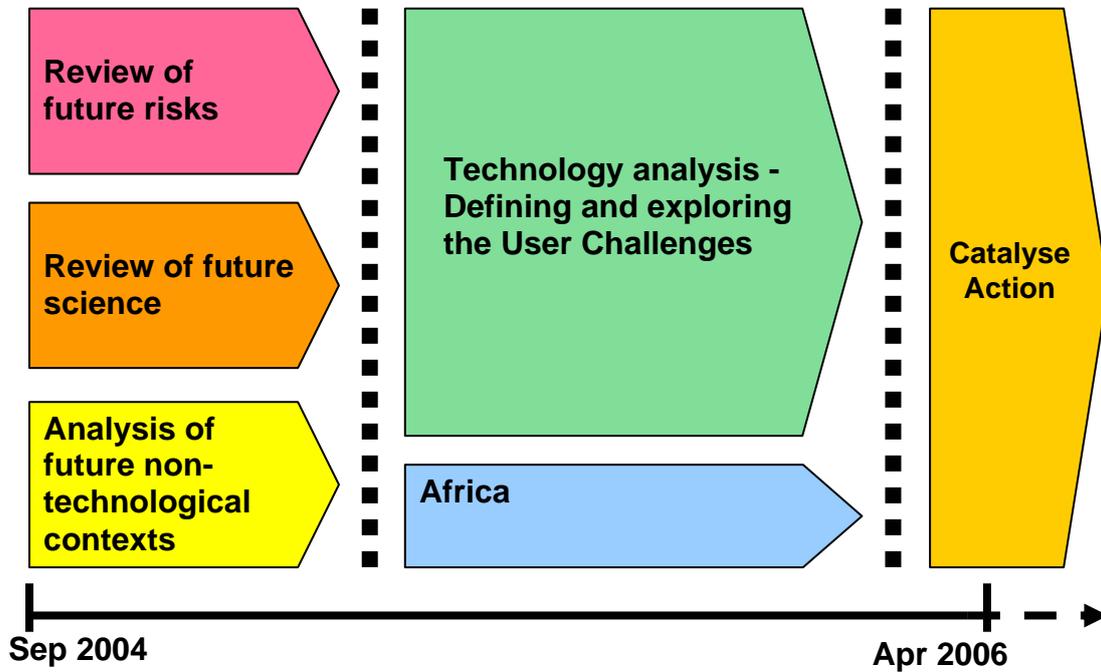
Following the scoping event in September 2004, the Project commissioned three main workstreams. These were, as set out in figure 1: a review of future risks; an evaluation of future science and a review of the future societal and non-technological context of future detection, identification and monitoring (DIM) systems.

Although designed to run throughout a substantial portion of the project, the early results of these three strands were brought together in April 2003 and considered by professionals responsible for disease prevention in all three sectors, along with technical experts drawn from government, academia and the international development community. This group was tasked with identifying the future DIM systems needed to address future disease threats. Four so-called 'User Challenges' - areas of future technology and system development – were identified ranging from global information systems to hand held devices. Each User Challenge was then investigated in detail by teams from industry and the research sector, and roadmaps for its development were prepared.

In parallel to the User Challenge analysis, and also stemming from the early synthesis of results, was the consideration of infectious diseases from a sub-Saharan perspective – the project's 'Africa' strand. Representatives from 19 countries used the same information on future risk and science to develop an African vision for DIID.

As with all Foresight projects key stakeholders were asked to consider what action(s) they might take in light of the evidence produced from the synthesis of the study's individual and collective components.

**Figure 1:
Project structure**



2. Project Outputs

2.1 Reports and Analysis

The Project outputs combine to form a very comprehensive report 'Infectious Diseases: preparing for the future'. This report provides a unique, cross-sectoral and interdisciplinary analysis of the potential rôle of science and technology in mitigating the future risk of infectious diseases over the next 10 to 25 years

This is an important and robust addition to the evidence-base to support decision-making in policy and strategy development. The Project's report structure is set out in figure 2 and includes:

2.1.1 Executive Summary

A synthesis of the project's key findings and messages captured as a series of questions and responses. The principal areas considered are the:

- threat of infectious diseases – today and in the future;
- options for responding to future challenges – detection, identification and monitoring (DIM) systems; and
- key choices for policy makers.

The Executive Summary (ES) also contains a list of the Project's many national and international contributors – the ministerial steering group, expert technical advisers, scientific authors, reviewers and those people who played a part in the key events which informed and shaped the work.

NB The ES was published in English, Chinese and French.

2.1.2 Science Review Summaries

State-of-the-science reviews of ten diverse areas which, individually and in new and innovative combinations, will provide the individual building blocks of future novel DIM technologies and systems. The subjects covered were:

Intelligent sensor networks	Interrogation of natural signals
Data mining and data fusion	Predictive and real-time epidemiology
Non-invasive screening and scanning	Earth observation
Genomics and bioinformatics	Host genetics and engineering
Biosensors and biomarkers	Immunological techniques

2.1.3 Future Threats

A vision for the future threats of infectious diseases and the factors which will impact on them. The report describes the challenges facing stakeholders and sets out the requirements for future DIM systems. This report provides an analysis of the UK, Africa and to a lesser extent China and draws on surveys of experts, reviews of existing and newly emerging infections, cutting-edge

modelling, the effects of climate change and the impacts of infectious diseases on ecosystems.

2.1.4 Vision of Future Detection, Identification and Monitoring Systems

An analysis of the four User Challenges (UC) identified by the Project.

- UC1- Novel information technology systems for early detection of disease events
- UC2 - Lab-based systems for characterization of new or newly resistant/virulent pathogens
- UC3 - Hand held and portable devices for detection and characterization of infectious diseases in individuals
- UC4 - High-throughput screening systems for non-invasive disease detection at airports and ports.

This report includes explorations of the costs and benefits of the deployment of future DIM systems for specific future disease threats. Also included in the report are roadmaps which describe how these four classes of technologies and systems might be realised and the associated technological and non-technological barriers and enabling conditions.

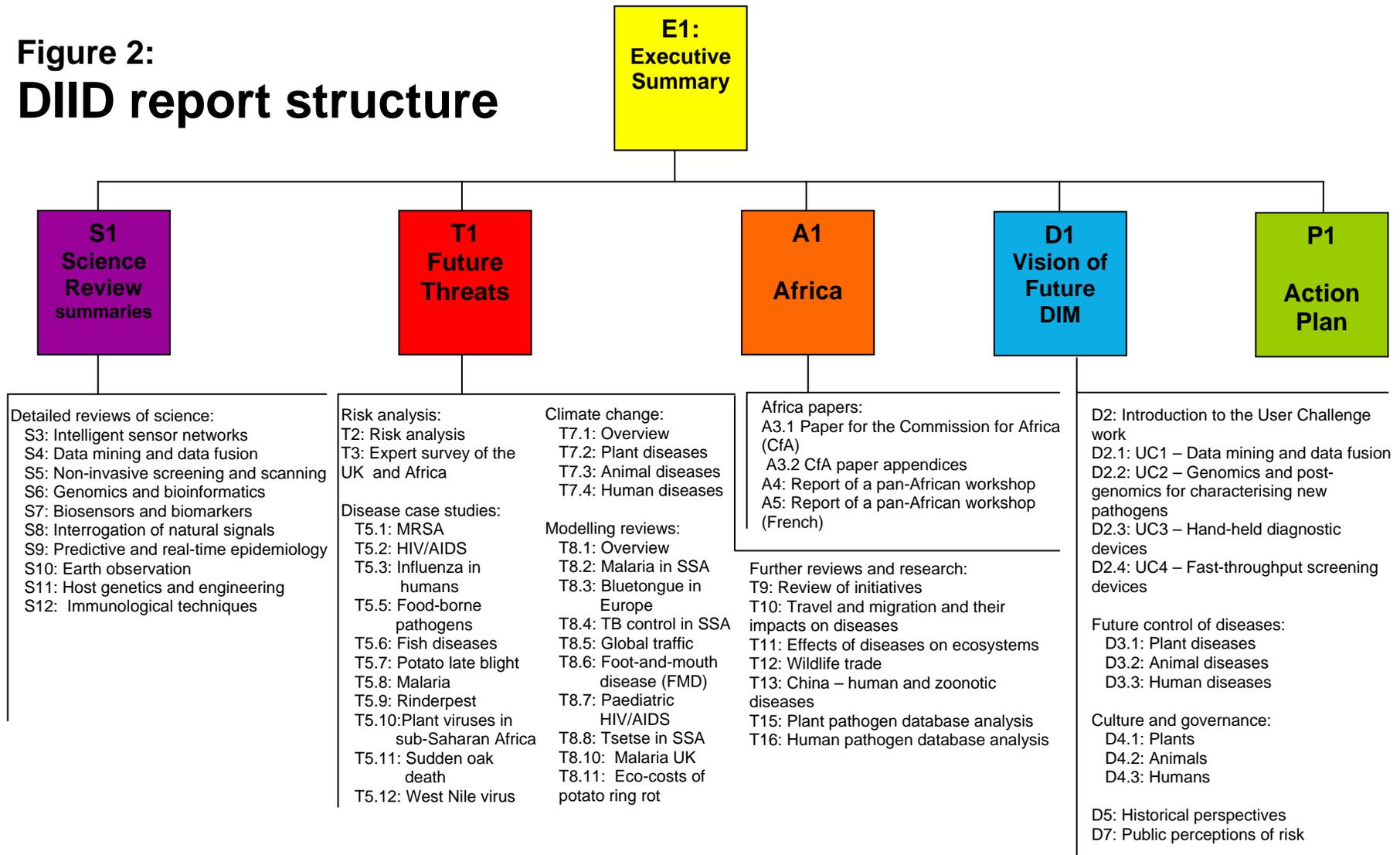
2.1.5 Africa

A report based on outputs from the Project's workshop in Entebbe, Uganda, which was led by and convened for experts drawn from across SSA, and on studies and papers commissioned by Foresight. This synthesis of African perspectives describes the current health and economic impacts of infectious disease, their societal and governmental contexts and how they might evolve. It concludes by setting out high-level strategic proposals for a way forward.

2.1.6 Action Plan

As with all Foresight studies, it is crucial that the DIID report has a substantial, important and demonstrable impact on the actions of its stakeholders. The Action Plan, published alongside the Project's technical reports, is made up of commitments from stakeholders to use the findings to inform their work. These undertakings and reports on progress reports are listed at Annex A.

**Figure 2:
DIID report structure**



3. Project Outcomes

This section reports on actions that have taken place since the launch, many of which were proposed in the project's Action Plan. Several actions are still ongoing and there are plans for some additional activities that will be informed by the project. This reflects the importance and timeliness of the subject, as well as a legacy effect in which many of the participating organisations continue to find value in the project. Cross-organisational actions with a relatively even spread of responsibility are described first (section 3.1.1), followed by actions led significantly by individual organisations (sections 3.1.2 to 3.1.4).

This project was initiated at a time of considerable UK and global interest in spreading and emerging infectious diseases. The spread of avian influenza to Europe and UK during the project heightened interest in this issue and many national and international institutions intensified their planning for future disease risks. For many of these, the Project gave timely and authoritative analyses, which helped them to secure their new institutional initiatives in disease preparedness. This was particularly true for institutions taking the leap into inter-sectoral and inter-disciplinary initiatives.

3.1 UK

3.1.1 Cross-organisational activities

Action Plan Working Group

Following the launch of the project the cross-governmental Foresight Infectious Diseases Action Plan Working Group (FIDAP-WG) was set up by Defra to collectively produce part of the Project Outcomes section of the One-year Review and to allow organisations to discuss action implementation together. Importantly, members of the FIDAP-WG (see Annex B) included most of the government departments and agencies with actions proposed in the Action Plan. The FIDAP-WG meetings helped to maintain and add weight to the project's momentum. For example, they permitted an extended discussion of the current barriers to sharing existing and new forms of data increasingly provided through technology. This topic, previously stressed in the Foresight project reports, was subsequently raised by numerous FIDAP-WG members in activities both within and outside of their own organisations.

FIDAP-WG members have also attended workshops together, a useful channel for communicating the views of the group. These included a British In Vitro Diagnostics Association (BIVDA) 'point of care' (or near-to-patient) diagnostics conference and a disease observatory workshop, both held at the DTI's Conference Centre in London.

Health Protection Agency and Veterinary Laboratories Agency

The relationship between the Health Protection Agency (HPA) and the Veterinary Laboratories Agency (VLA) continues to be strengthened and advanced through a memorandum of understanding (MoU) and the Interlab Forum. Current activities include joint posts for creating compatible pathogen profiling approaches, assessing new methods of identification and typing, and evaluation of cost implications both nationally and internationally.

Interlab Forum

The Interlab Forum is a collaborative agreement between six Public Sector Research Establishments to promote knowledge sharing, including emergency response and disease control, in the best interests of the public. The Forum consists of three executive agencies of Defra, namely, the VLA, the Central Science Laboratory (CSL) and the Centre for Environment Fisheries and Aquaculture Science (CEFAS), along with the Health and Safety Laboratory, HPA and the Defence Science and Technology Laboratory (Dstl). The Foresight infectious diseases reports have informed discussions in the Forum. During the last 12 months the Forum has had active collaborations on emergency response, modelling and simulation, detection, and sharing of facilities. The Dstl work on Avian Influenza has been shared with other members of the Forum.

Ministry of Defence and Health Protection Agency

During 2006 the Ministry of Defence (MoD) and the HPA held a joint conference entitled "Preparing Preventing Protecting". The purpose of this conference was to increase collaboration and information exchange. It was clear that the boundaries between civilian resilience and military expeditions were becoming less defined from a medical perspective. Increased inter-agency cooperation should increase the exploitation of research, reduce duplication of effort and enhance overall national capabilities. Following this conference the Surgeon General and the Chief Executive of the HPA directed a small project team to identify common issues, prioritise areas for future work, and nominate further groups to take these areas of work forward. Working Groups have been identified to develop action plans that will forge closer links in the following areas:

1. Medical intelligence
2. Diagnostics
3. Improving emergency preparedness (pandemics)
4. Chemical, Biological, Radiological and Nuclear (CBRN) liaison
5. Surveillance of infectious diseases
6. Therapeutics

The first meeting of the working group on medical surveillance and diagnostics, consisting of key researchers from the two organisations and representatives from the Defence Medical Services Department took place in

February 2007. The recommendations of Foresight DIID informed the discussions in this working group.

Research Councils UK

The Research Councils UK (RCUK) Research and Development Group (RDG), comprising Research Directors of the Research Councils, invited the DIID Project team to give a presentation at its meeting in October 2006. Councils reported on resultant actions at the RDG meeting in February 2007. All the appropriate Research Councils had undertaken activities as shown in the Action Plan, along with some additional work. For example, the Arts and Humanities Research Council (AHRC) is considering its engagement with medicine, and the Medical Research Council (MRC) has undertaken reviews of vaccines and of research in Africa. Also, the Cross-Council Genomics Coordinating Committee aims to discuss the Foresight DIID report. RCUK is collating cross-Council activities in the DIID Area and will continue to engage with the long term DIID research agenda.

Research Funders Groups

A significant component of the Report concerned the risks posed by new and emergent infectious organisms to plant, animal and human health in Africa. Focusing on human health, the UK Funders Forum on Global Health provides a mechanism for information sharing and coordinated action across the MRC, the Economic and Social Research Council (ESRC) and The Wellcome Trust. The UK Collaborative on Development Sciences, a more extensive group of development and funding agencies, will take a broader development focus. Work to establish the Collaborative is led by the Department for International Development (DfID), ESRC and The Wellcome Trust.

Public health research is a particular focus of the new Office for the Strategic Coordination of Health Research, established to facilitate the development by the Department of Health (DH) and the MRC of joint strategies. Infection is emerging as a key theme for joint work.

These new structures will strengthen the UK's ability to coordinate and enhance human health protection, research and international development strategies and action in surveillance, detection of infectious agents and disease, risk assessment, public health response and infection control.

UK Clinical Research Collaboration

The DIID reports informed the thinking of the UK Clinical Research Collaboration (UKCRC) Strategic Planning Group in Microbial Infectious Disease Research (SPG). The DIID programme was considered in the first meeting, with the SPG Secretariat also consulting with the DIID project team. At the request of SPG members, a full paper summarising the final DIID report was included and considered by the group at its third meeting. The process has catalysed the development of the UKCRC-coordinated Translational Infections initiative, with £15m committed in principle by BBSRC, the DH,

MRC and The Wellcome Trust, to promote the formation of multidisciplinary research consortia to address critical research gaps. The scope of the initiative, which will be open to the UK's human health protection agencies and to industry (as participants in academic-led projects) as well as to academia, will include pathogen identification and detection.

3.1.2 Government

This section offers a detailed update on implementation of actions proposed by individual organisations and listed in the April 2006 Action Plan. However, it is important to note the substantial collaboration that lies beneath many of the organisational actions described. This considerable effort to involve others partly reflects the Foresight DIID emphasis on officials tackling infectious disease together. For example, many newly emerging diseases cross host and organisational boundaries – in 'zoonoses' pathogens are transferred from animals to humans. It is important that organisations continue to work together where appropriate as they perform their various responsibilities in disease detection and control.

Department for Environment, Food and Rural Affairs

Defra played a strong role in the follow-up activities of the infectious diseases Foresight project, setting up the cross-governmental FIDAP-WG to discuss implementation of the project's Action Plan. Defra also provided the FIDAP-WG Secretariat, resourced through Defra's Chief Scientific Adviser. The secretariat maintained close contact with the OSI Foresight team and kept FIDAP-WG members informed of relevant developments.

Effective molecular diagnostic tools are keystones in the successful fight against infectious diseases. The Biochip project, a substantial research initiative to develop, by 2009, diagnostic viral microarray technology for detection of about 600 viral pathogens, is led by Defra's CSL and supported by Defra's Chief Scientific Adviser. It benefits from the collaborative efforts of CSL, CEFAS, VLA, the Institute of Animal Health (IAH), HPA and the Royal Veterinary College. Uniquely, this research draws together diverse expertise to develop methods for early diagnosis of infectious viral pathogens across the animal, plant, bee and fish sectors. The project also aims to improve detection of newly emerging pathogenic threats.

Defra has developed a prioritisation decision-support-tool in order to inform and enable evidence-based, socially and economically appropriate, distribution of government funds for animal health and welfare issues. The tool will generate summary reports that quantify the relative importance of infectious diseases in the context of the four reasons for government intervention (trade, wider societal, animal welfare, public health protection) and includes assessment of risk and epidemiology. Work continues to expand the tool to include welfare concerns, non-infectious and wildlife diseases.

The Foresight project has enhanced the thinking behind several other streams of technological research, namely, the development of portable diagnostic technologies for field-based detection, e.g., portable PCR (polymerase chain reaction) thermocyclers for the diagnosis of Foot and Mouth Disease, and alternative immunological assays for the detection of *Mycoplasma bovis* in badgers. Other important activities include modelling and epidemiology for prediction of high risk areas for entry of Avian Influenza and for modelling the potential for disease spread, and also for predicting whether increased ambient temperature (e.g., climate change) facilitates the competence of UK midges to act as vectors of Blue Tongue Virus. Data analysis and data mining techniques complement some of this molecular and modelling research.

Defra also funds work on the detection and identification of quarantine plant and bee diseases to support their exclusion or management. Several new activities are relevant to Foresight DIID and have been influenced by it. One project will develop a model epidemiological framework to optimise detection and intervention strategies for statutory plant pathogens, and draws on expertise from a range of disciplines. Defra also proposes to develop novel methods for detection, identification and monitoring of such pathogens, and is considering a project that builds on earlier work on electronic nose technology.

Defra and CSL also took the Foresight project's findings into the European arena through talks delivered at an October 2006 EU Standing Committee on Agricultural Research (EU-SCAR) Collaborative Working Group meeting on Animal Health at the Royal College of Veterinary Surgeons in London. The Foresight project was discussed at some length. EU-SCAR members were interested in tackling infectious diseases across national boundaries and in hearing about Defra's Biochip project. International co-operation has been initiated by the UK (with Defra agreeing to fund and support development) for the Global FMD (Foot & Mouth Disease) research alliance, that aims to provide a new generation of vaccines and diagnostics aimed at FMD control in developed and developing countries.

Defra was central in ensuring Plant Health's inclusion in the EU Framework Programme 7 (FP7). Developing Pest Risk Analysis Science was a topic in 2007; a diagnostic topic is scheduled for 2008. Again, expertise may be drawn from animal and human health sectors. The European Phytosanitary (Plant Health) Research Coordination (EUPHRESKO) project, led by Defra, will coordinate plant health research programmes across Europe. Joint calls are anticipated for research supporting EU plant health priorities potentially including diagnostic methods or infrastructures which may go beyond purely plant health.

The project's findings were discussed at a workshop on climate change-induced pathogen spread, organised by CSL. Attendees included members of a CSL-led cross-governmental research consortium investigating the affects of climate change on the spread of agricultural pathogens, pesticides and contaminants. Attendees were especially interested in modelling future changes.

The Foresight Programme and Defra held a joint Wildlife Health Workshop on 2 May 2007. The objective of this workshop was to consider how future scientific innovation might improve knowledge and management of wildlife diseases. It drew on outputs from Foresight DIID and put these in the context of ongoing initiatives in the Defra Wildlife Health Strategy, to identify gaps and opportunities that might be considered in future planning by Defra.

Foresight DIID reports were also very useful for Defra's development of its departmental Earth Observation (EO) strategy. The DIID project successfully raised the profile of EO for disease-related activities and is helping the EO team to bring the subject into discussions with policy stakeholders and advisers. For example, Defra aims to investigate the utility of EO for assessing and forecasting the risk of vector-borne disease.

Office of Science and Innovation

The OSI contribution comprises two separate elements: follow-up to the project by the Foresight and International Directorates and support for knowledge transfer between the research base and business through competitions managed by the Technology Strategy Board (TSB).

The Foresight team has maintained a strong interest in follow-up work after publication of the project's main findings and Action Plan. For example, the team organised a workshop on 29 January 2007 to consider the case for a UK Disease Observatory which has resulted in a draft proposal being presented to the FIDAP-WG for comment. The TSB Emerging Technologies Programme organised a Workshop on new areas of bio-nanotechnology, which included infectious diseases as one of the priority areas for consideration. It will continue to seek to identify opportunities for business to develop innovative projects in this important field.

The TSB has also sought to encourage the development of innovative disease detection devices by offering support for projects involved in their development. In October 2006 the DTI announced that the TSB had agreed to provide £800,000 support for a project led by Akubio Ltd, Cambridge (in collaboration with the University of Cambridge and Reagent Mine Ltd of Melton Mowbray) to develop a new portable and low cost, rapid response disease diagnosis device, which could help doctors make instant and accurate diagnoses for diseases such as Malaria and Meningitis. The project aims to develop biosensor chips and hardware for real-time healthcare monitoring (i.e., rapid clinical in vitro diagnosis and efficient blood screening) and for environmental monitoring. It will bring together three technologies: Reagent Mine's pre-concentration of analytes from complex biological samples on magnetic beads and nanoparticles, Cambridge University's novel polymeric biocompatible surface coatings, and Akubio Ltd's breakthrough acoustic detection methodology. An integrated magnetic pre-concentration module will be fabricated for use in Akubio Ltd's desktop instrumentation. This will ultimately lead to a portable, hand-held device that will enable more efficient,

reliable and rapid diagnosis of disease, and the same-day screening of patient samples.

The Foresight Programme's Horizon Scanning Centre (HSC) is currently 'refreshing' its Sigma and Delta Horizon Scans, which form the basis for its interactions with government departments on strategy and policy work. Material from the DIID project will be referenced in the next public release of the Scans (estimated December 2007). The HSC has also created a space on its Scan development database dedicated to the Project. The Project's scientific papers entered in this 'project space' will be immediately accessible to over 90 registered government users, principally active in the strategy and policy fields.

In September 2006 the HSC's Future Analysts' Network ('FAN club') held a workshop to explore how a range of media might be used to develop innovative and interesting ways to communicate the Project's key findings and messages. Following a short briefing session on the Project from Ms Nana Abadji (DIID project manager), participants were invited to use tools such as writing, images, video and acting to create presentations. The writing workshop, led by Think-Lab Ltd, focused on using creative writing techniques and characterisation to explore ways of conveying the issues; the stills and video workshops used library material to create PowerPoint presentations (using images) and quicktime movies (using video); and the acting workshop, led by AKT Productions with a short dramatised scenario in which a businessman travelling to the UK fails to declare that he is carrying a plant infection – with unexpected consequences. Participants then went on to write and direct two new sketches with the actors.

The OSI submitted a paper outlining the Project's core findings for consideration to the flu pandemic working group (now known as the Ministerial Committee on Influenza Pandemic Planning (MISC 32)) officials group. The paper set out the key steps that the Project highlights, which might form the basis of the Government's action plan. These include:

- building a more sustained, pro-active and integrated approach to international surveillance for infectious diseases of humans, animals and plants;
- developing effective and sustainable partnerships between richer and poorer countries that help provide infrastructure, technologies and skills to support detection, identification and monitoring activities, specifically the UK and Africa;
- encouraging the development and deployment of new detection, identification and monitoring systems nationally and internationally (including making new systems more flexible); and,
- fostering an inter-disciplinary approach to infectious disease problems, incorporating traditional biomedical science with economics, social sciences, demographics and agricultural science.

The paper also states that a wide range of stakeholders will need to act together in order to realise the full benefits of the project findings.

Department for International Development

Department for International Development (DfID) is reviewing the Foresight DIID findings and will use them as appropriate to inform relevant areas of policy development. For example, the project outputs and future infectious disease challenges will be referred to in the new DfID health strategy to be issued in mid-2007. A Science and Technology Strategy is also currently under development, led by DfID's Chief Scientist, and this will be informed by DIID outputs.

The new DfID research strategy highlights the Product Development Public Private Partnership (PDP) model to develop new generations of drugs and vaccines, and refers to the need for investment in new diagnostics as new funding comes on stream. DfID's 2006 Development White Paper commits to double research spending from £120m to £240m per annum and highlights the need for investment to build African research capacity. DfID currently supports a health metrics network, a global health partnership that seeks to strengthen health information systems. The management arrangements for future DfID research are under review with attention to greater co-ordination of UK research interests.

Department for Transport

Foresight DIID has informed scoping work by DfT on behalf of the Science and Innovation Cabinet Committee's 'Data Grand Challenge' to assess how government can realise the potential benefits of the increasing amounts of real-time and archived data. Rapid advances in information technologies facilitate the collection, communication, analysis and presentation of information and data from many federated sources. However, significant barriers to realising the full potential of such technologies include issues over data access, standardization and validation of data, safeguarding confidentiality and building public trust in new data applications. DfT is working closely with Defra, the Office of Public Sector Information and other government departments to raise awareness of the potential benefits and risks of greater data exploitation through the hosting of a series of workshops on public sector information, and on "data mashing". The latter can be defined as the novel combination and presentation of information and data from several remote sources generally using open standards and web-based applications.

Department of Health

Early and rapid detection and diagnosis of infectious diseases underpins DH public health policies and the Department is committed to using the Foresight DIID reports to inform its policy considerations of infectious diseases. The Foresight report has already been brought to the attention of several DH advisory committees with a view to identifying issues of potential relevance to future policy development. For example, the Advisory Group on Hepatitis (AGH) has used the Foresight approach of analysing future threats and

options for responding to future challenges to identify two areas that are of current and future concern. As a result, AGH has:

- identified the need to investigate ways to increase diagnosis of hepatitis B and C in minority ethnic communities from high prevalence areas of the world. A working group has been set up to look at this.
- endorsed the development, by the HPA, of a web-based surveillance system that will aid the investigation of drug resistance arising during anti-viral treatment for hepatitis B and C.

The National Expert Panel on New and Emerging Infections (NEPNEI) has been involved with the DIID Foresight project since its inception. The Panel has set up the Human and Animal Infections Risk Surveillance Group (HAIRS) to provide a forum for detailed analysis and scrutiny of animal and human health surveillance data. The development of an agreed methodology for assessing zoonotic risk potential in a consistent manner has strengthened the Group's ability to undertake rapid horizon scanning for infections with potential for transfer between species. This methodology and accompanying algorithm has been published by the HPA as provider of the Secretariat to HAIRS. The results of the analysis and conclusions of the Group are presented to NEPNEI for wider consideration and there are mechanisms in place for 'fast tracking' risk assessments when necessary. This process now provides necessary transparency to zoonotic risk assessment in its earliest phase.

DH officials have also promoted the Foresight report vigorously throughout the 2006 G8 process. The G8 Summit Communiqué entitled "Fight Against Infectious Diseases" reflects several of the Foresight recommendations, as can be seen, for example, in the sections headed "Strengthening the Global Network for Surveillance and Monitoring of Infectious Diseases", and "Fighting Highly Pathogenic Avian Influenza and Increasing Global Preparedness for a Human Pandemic". The communiqué, issued 16 July 2006, can be found on the web at <http://en.g8russia.ru/docs/10.html>

Home Office

Whilst not participating directly in projects that have developed out of the Detection and Identification of Infectious Disease Foresight project, the Home Office remains interested in future developments and will maintain an oversight of continuing work.

Ministry of Defence and Defence Science and Technology Laboratory

The Chief Scientific Adviser for the Ministry of Defence (MoD) sponsored an external audit of the quality of MoD research programmes and their alignment to MoD's requirements. The alignment study considered internal MoD policy and strategy documents, and also external influences including the Foresight study on infectious diseases.

The MoD has an active research programme in the medical surveillance and diagnostics area. Areas of research include field deployable post-

symptomatic diagnostic and surveillance systems; non-invasive methods for detecting infection and novel means of detecting infection pre-symptomatically by detecting changes in the host immune response. The later programme has proven particularly promising, indicating that changes in host immune response can predict infection up to four days before the appearance of symptoms. This work has the potential to be exploited in a variety of applications, both civilian and military.

Health Protection Agency

The DIID report was cascaded through HPA Centres, research communities and information management routes to ensure wide distribution, discussion and debate. The Research Committee, jointly with Theme Leaders from all research and development strategic sectors, met in November 2006 and January 2007, where the report was discussed. Enthusiasm and support for its approach and findings were expressed.

Several HPA corporate goals (4, 6 and 8) provide a platform for synergy and interaction with the DIID reports in mapping new and emerging threats of infection, enhancing preparedness to threats (including CBRN) and building the evidence base for Detection Identification and Monitoring (DIM) systems through programmes of development and tools for implementation.

Several key projects across the HPA are in progress to create mechanisms and tools for direct detection of biothreat agents. These are in collaboration with, and sponsored by, government agencies. The HPA is utilising these initiatives to enhance multi-pathogen detection capabilities with wider applications to emerging health threats.

The Centre for Infections is participating in the World Health Organisation (WHO) Laboratory Twinning Scheme which is intended to develop capacity along with laboratories in developing countries; partnerships with public laboratories in Uganda and Kazakhstan have been agreed.

Identifying and meeting tomorrow's needs requires the HPA to be in a constant state of preparedness, being proactively equipped to develop rapid diagnostics and to support science-based activities and data mining and interpretation capability. Direct patient testing and biomathematical tools for data interpretation, dissemination and modelling are examples of areas growing and expanding throughout the Agency's programmes of research. Improved and novel bioinformatical and biostatistical approaches will continue to be developed over the coming years as a component of the multi-disciplinary approaches for improved infectious disease detection and surveillance.

Centre for Protection of National Infrastructure

In February 2007, the National Security Advice Centre (NSAC) was merged with the National Infrastructure Security Co-ordination Centre (NISCC) to become the Centre for Protection of National Infrastructure (CPNI). CPNI is

an inter-departmental organisation with resources from a number of government agencies and departments. These include the Security Service, Communications-Electronics Security Group (CESG) and other Government departments. In legal terms, CPNI is accountable to the Director General of the Security Service (MI5) and operates under the Security Service Act.

CPNI has worked closely with those involved in the Foresight DIID study to ensure that they are aware of potential security applications for their work. This has resulted in direct collaborations with individual research institutions and universities. In addition, CPNI has utilised the results of the DIID work to inform the strategic planning of its protective security research programme in order to ensure that horizon scanning activities are targeted at key areas.

Regional Development Agencies

One NorthEast is targeting growth of £1bn in the NorthEast Healthcare sector. CELS (www.celsatlife.com) is the organisation tasked with driving this growth by focusing on innovation, technology development, research and development, infrastructure and business support and has drawn on the Project's outputs and lead experts in achieving this.

Members of the Project's Science Co-ordination Group have made a very valuable contribution to CELS foresighting events in the area of microbiology and infectious diseases. These events bring together industry, academic and clinical scientists to discuss research strengths in the region and how they may be applied to address healthcare issues.

Professor Joe Brownlie spoke at the November 2007 infection diagnostics meeting, which was inspired by the Project. He described the emerging trends and priorities in infectious diseases and, importantly, the Project's methodology for foresighting future trends. This provided invaluable insight not only into the current market but also the future market for these products as well as the technical challenges which must be addressed. This included vital information regarding what would be key features of future infection DIM products.

The information provided by the Project and its lead experts will be used to inform CELS' strategy for developing technologies in the area of infectious disease, including development of diagnostic, vaccine and antibiotic products. Although the projects emerging from this event are at the very early stage, they are likely to include a potential spin-out company developing novel antibiotics as well as new product development in a regional diagnostics company and a regional vaccine company. The information will no doubt also be used by academic, industry and clinical participants in the meeting to inform their research policy.

3.1.3 Research Councils and RAEng

Biotechnology and Biological Sciences Research Council

The Biotechnology and Biological Sciences Research Council (BBSRC) has continued to work with Defra in delivering the Pirbright Site Redevelopment Programme. BBSRC has encouraged networking within its community in the area of exotic and emerging diseases through a workshop involving scientists from its 'Combating Viral Diseases of Livestock', involving Defra and Scottish Executive Environment and Rural Affairs Department (SEERAD) support and 'Combating Avian Influenza' programmes. Scientists funded through MRC's pandemic influenza initiative also contributed. The Animal Sciences Research Committee discussed the DIID report in the context of its Control of Infectious Disease (CID) Programme, which covered most of the relevant issues. The Agri-Food Committee and Plant and Microbial Sciences Committee also discussed the report. Systems biology approaches to study the animal or plant host response to infection were considered valuable and to be encouraged. The Studentships and Fellowships Panel will discuss implementation of the recommendations for multidisciplinary training later in 2007.

Animal disease research was made a priority area in awards for 2006 Travelling Fellowships. BBSRC is investing £10.15m in a Combating Endemic Diseases of Farmed Animals for Sustainability initiative, with additional funding from industry, Defra and, possibly, SEERAD. The last round of the Rural Economy & Land Use (RELU) initiative, primarily funded by BBSRC, ESRC and NERC with contributions from Defra and SEERAD, focused on animal and plant disease research and policy advisors from relevant Government Departments were involved in the project selection process. Talks are underway between Research Councils on funding multidisciplinary research of relevance to global security, including plant and animal disease. These will all be informed by the DIID report.

Medical Research Council

The MRC promotes and funds long term fundamental and public health research on infection and immunity in the UK and internationally (mainly in Africa). But there is a well-recognised gap in the UK's capacity (and MRC's portfolio) in clinical and translational research (such as the application of basic science discoveries to development of new diagnostics). MRC is addressing that gap through several initiatives to promote translational research, including through the UKCRC Translational Infections initiative (see UKCRC in section 3.1.1). In addition, development-gap funding is available to MRC researchers from MRC Technology (MRCT). An MRCT-funded project on "fingerprinting" markers of infection recently led to the transfer of new technology into industry.

In 2005, MRC awarded £2m to establish a Centre for Outbreak Analysis and Modelling, a partnership between Imperial College and the HPA. The Centre aims to deepen and systemise the exploitation of epidemiological research on

outbreaks by public health agencies and policy makers tasked with formulating and implementing response strategies to novel infectious disease threats. The Centre strengthens existing work to develop the first global epidemic simulation and analysis platform, with the aim of providing next generation predictive modelling tools for epidemic planning and response.

The DIID process and interim reports informed MRC's development in 2005 of its Pandemic Influenza initiative. Half of the 18 new influenza projects and infrastructure funded (£8m) during 2005/6 will contribute to strengthening viral strain identification, surveillance and risk assessment and one project is focused directly on novel diagnostic technology development. Several projects involve the HPA. A further £6m is available under the current call for investment in 2007/8. Funders and agencies coordinate their activities in influenza research through a number of formal and informal means.

Economic and Social Research Council

The Risk Analysis team at the ESRC Innogen Centre continues to disseminate information about the project findings via its website and newsletters. To stimulate further debate about risk management practices and to contribute to the development of robust decision- and policy-making methodologies for infectious diseases, the Risk Analysis team will write two articles targeted at international risk journals ('Journal of Risk Research' and 'Risk Analysis'). These articles will address the risk analysis of future infectious disease incidence, which underpinned this Foresight project, and propose a new decision-making tool to enable better understanding of the socio-economic risk factors of disease to be captured and integrated in the risk analysis process.

Engineering and Physical Sciences Research Council

The Engineering and Physical Sciences Research Council (EPSRC) has ongoing interests in applying knowledge from the DIID project. Current activities include engagement and dialogue with stakeholders on potential research priorities, including data mining and ICT-driven health and well being.

Royal Academy of Engineering

The Royal Academy of Engineering's (RAEng) working group on Privacy and Surveillance published its report, 'Dilemmas of Privacy and Surveillance: Challenges of Technological Change', on March 26, 2007. The report identified likely developments in information technology relevant to surveillance, data-capture and identity management, considering their impact on the citizen and making recommendations on how to optimise their benefits to society. Among the issues that the Group considered was the collection of large-scale databases of personal data for the monitoring and control of infectious diseases.

3.1.4 Business

The DIID project has excited considerable interest in the business community; in particular, the British In Vitro Diagnostics Association (BIVDA) - the UK trade association for manufacturers and distributors with major involvement and interest in the in vitro diagnostics industry (www.bivda.co.uk).

In view of this interest, and to help explore potential traction between the Project findings and the priorities of BIVDA members and others with an interest in technology development, Dr Penny Wilson, the Project's lead technology consultant, organised and led a 'Point of Care' (POC) Conference in partnership with BIVDA. This built on Dr Wilson's earlier presentation to BIVDA's POC Working Party and discussions with the association's Director General, Doris-Ann Williams.

With particular reference to the detection of infectious diseases, the Conference highlighted the need for, and opportunities and trends in, POC diagnostics in the developed and developing world. The meeting aimed to encourage companies to include these products in their development programmes and its three sessions were entitled:

1. Future Possibilities – A Way Forward for POC Devices;
2. Devices that Link Directly into Global Networks (UC1/UC3 interface); and
3. Innovative Diagnostics for Developing Countries.

Delegates, including those with an interest in POC devices, but hitherto not linked to infectious diseases, benefited from the excellent mix of topics and exposure to the Project's key messages and its cross-sectoral and multidisciplinary analysis. Whilst the conference looked to the future, it also demonstrated that POC devices, for infectious diseases, are effectively in use today and that this trend is only set to grow.

At the time of writing, it is too early to gauge the true impact of the Conference, such as its influence on the direction of research and opportunities for commercial exploitation; for example, in the area of the UC1:UC3 interface. However, delegates reported that they expect that tangible benefits will arise from the event. In particular, they anticipate collaboration between companies and between the private and public sectors; for example, the Centre for Evidence-based Purchasing expects to receive at least two proposals for project work following discussions catalysed by the event.

3.2 International

Although many Foresight projects have drawn on experts from the global scientific community and have had impacts on international organisations and other countries, this was the first study to have an international remit from the outset. More than any other, the subject of this Foresight project, demanded consideration in a global context. With this in mind, the work compared and

contrasted the perspectives and experience of the UK, Africa and to lesser extent China. It explored how science and technology developments might deliver converging solutions to, and mitigation of, future risks in a range of international contexts in the developed and developing world.

Many key international stakeholders took these findings and used them to inform their policy and strategy development – some examples of what has been achieved are set out below.

3.2.1 Multinational Organisations

G8

DH officials promoted the Foresight report vigorously throughout the 2006 G8 process. These efforts were supported by a position paper submitted by Sir David King, Dr Bernard Vallat, Director General (World Organisation for Animal Health) and Dr Joseph Domenech (Chief Veterinary Officer and Chief of the Animal Health Service, Food and Agriculture Organization). The paper reviewed some of the Project's key findings suggested lines of action that the Presidency might wish to consider within the 'infectious diseases: general surveillance' priority line.

The G8 Summit Communiqué entitled "Fight Against Infectious Diseases" reflects several of the Foresight recommendations, as can be seen, for example, in the sections headed "Strengthening the Global Network for Surveillance and Monitoring of Infectious Diseases", and "Fighting Highly Pathogenic Avian Influenza and Increasing Global Preparedness for a Human Pandemic". The communiqué, issued 16 July 2006, can be found on the web at <http://en.g8russia.ru/docs/10.html>.

The integration of the Report's key messages into the Russian Federation's high-profile communiqué 'Fight against infectious diseases' – a key output of its 2006 presidency - was particularly useful to many of the international stakeholders. This helped promote and facilitate their high-level consideration of the Report and, where appropriate, the uptake of its key findings.

In addition to informing the Russian Federation's G8 considerations and outputs during its presidency, the Project also delivered a strand of work in early 2005 which was specifically aimed at supporting the work of the UK G8 presidency; in particular, the Commission for Africa. This workstream culminated in the publication of the report: 'Infectious Diseases in Africa: using science to fight the evolving threat'. This report highlighted the importance of infectious diseases in plants, animal and humans in Africa, how these evolving threats are changing and the need for better understanding to inform policy and strategy development. This work was supported by nine infectious disease case-studies which were written by leading UK and African experts.

Infectious diseases, and the Foresight study in particular, was raised as a key topic for discussion at 'Carnegie' meetings of G8 science ministers and advisers in December 2005 (New York) and June 2006 (St Petersburg).

Food and Agriculture Organization

Food and Agriculture Organization (FAO) has been particularly sensitive to the cross-sectoral features of infectious disease problems. Dr. Peter Kenmore of the Plant Protection Division contributed an important case study to the project, illustrating how donor-funded road improvement in Lao People's Democratic Republic had created opportunities for the spread of HIV AIDs, Avian Influenza and important crop pests. In the Foresight Project, FAO has played an important role in linking animal and plant disease thinking, as well as interacting with OIE and WHO on zoonotic disease issues, stimulated by recent outbreaks of Avian Influenza.

During the course of the Foresight Project, FAO management considered the integration of animal and plant health activities, and Foresight outputs were useful to this activity. Eventually, it was decided that disease units would remain in their respective animal and plant divisions.

However, the Foresight Project did give useful and continuing impetus to the development of FAO's new Crisis Management Centre (CMC) which would bring together rapid response and monitoring capacity for disease outbreaks on crops and animals and food-related outbreaks in humans (http://www.fao.org/docs/eims/upload/217648/leaflet_cmc_en.pdf).

This Centre was approved by FAO's executive Council in November 2006. The CMC covers animal disease, plant pest, and food safety crises with a coherent coordinated strategy and approach. The experiences of the Desert Locust Campaign of 2003-2005 and the ongoing Highly Pathogenic Avian Influenza campaign are reflected in the CMC's design. On April 2, 2007, FAO held a full-day's seminar on "Transboundary Pests and Diseases and other Disasters: from Prevention to Building Back Better". This was attended by Permanent Representatives from over 100 countries. The opening presentations referred explicitly to the Foresight initiative as pointing out new, scientifically sound convergence among animal, human, and plant diseases. The seminar was well received and emphasised the importance of building national capacity, especially in FAO's developing member countries, in thematic areas supporting the management of transboundary pests and diseases.

On a more specific level, following the G8 summit, Russia approached FAO to put together a project which involved FAO, OIE and WHO cooperation on infectious diseases. A proposal for work to reduce the movement of avian influenza across Russia into Europe was prepared, but as yet has not been funded. Overall, interaction between FAO and WHO on zoonotic diseases, including the Global Early Warning System, has been increasing. The UK Delegation to FAO continues to promote Foresight outputs and ideas in FAO activities on infectious diseases.

World Organisation for Animal Health

The current H5N1 avian influenza crisis demonstrates that without effective veterinary services and governance, countries are unable to prevent the introduction or emergence and re-emergence of animal diseases or to bring outbreaks under control. The World Organisation for Animal Health (OIE) has therefore, with the support of international donors, initiated a Performance, Vision and Strategy (PVS) evaluation tool to assist Member Countries to identify their shortcomings in meeting and applying the international standards for the delivery of veterinary services. With the support of several donors to the World Animal and Welfare Fund, an initial pilot programme of 15 national OIE Member Country evaluations was launched with provision already made to evaluate 60 more countries in 2007-2008.

The evaluation of Veterinary Services using the PVS-tool, coordinated by the Central Bureau of the OIE and supported by its Regional Representations and offices on the five continents, will play a vital role in characterising the investments needed to prevent and control disease on a global scale. To date, the OIE has trained and certified over 60 experts to conduct PVS missions in Member Countries. For the above reasons, the work of the Veterinary Services is now increasingly recognised as a global public good. With the financial support of DfID the capacity of OFFLU (OIE/FAO Avian Influenza network) has also been strengthened by the appointment of seconded professional staff at the OIE headquarters in Paris. Linked to this initiative is the establishment of twinning arrangements between OIE Reference Laboratories and laboratories in developing and in-transition countries as a collaborative support program to enhance the scientific expertise and access to diagnostic expertise within these countries.

World Health Organisation

WHO welcomed the report on detection and identification of infectious diseases. In particular, it welcomed the breadth and scope of the report, its demonstration of linkages between technology development and biomedical and systems requirements, and its attention to the broad range of drivers of epidemiological change and the risk of emergent and re-emergent infections. In this latter regard, the linkages between animal and human health, particularly highlighted by the danger of Avian Influenza, is particularly significant. There are many complementary messages and overlap between the conclusions of this report and WHO strategies on health security. Some of these, such as the need for appropriate governance and regulation and the need to deal with issues in a linked-up way can be seen within the context of the International Health Regulations which came into force this year.

The emphasis on capacity, particularly within Africa, to undertake surveillance and the need to embed surveillance methodologies within broader systems was appropriate. The risks and uncertainty associated with disease outbreak and the potential for resistance development were also well discussed. The

need for a more pro-active approach to the development of DIM systems, fully utilising emerging technologies, is apparent. Linking micro technologies expertise to health expertise in such a proactive approach should aim at identifying low-cost, appropriate technology developments of practical use in developing countries as well as high-tech expensive equipment of value primarily to developed countries.

European Centre for Disease Prevention and Control

Ever since it started operations in May 2005, the European Centre for Disease Prevention and Control (ECDC) has been aware of the UK Foresight DIID project, and ECDC invited project representatives to present here in Stockholm in early 2006, even before the final report was published. ECDC also had the opportunity to discuss the project when Sir David King visited in October 2006.

As a scientific organisation, the ECDC is impressed by the scope and rigor of the Foresight process, and thinks that the project results are thought-provoking and a stimulating help in planning for future infectious disease activities. At an ECDC retreat in February, where the seven-year strategic plan was discussed by all in-house experts, Professor Jeff Waage from the Project's SCG was invited to present the process and some of the main findings. This provided a very fruitful background for the further discussions, and some of the thinking of the project is clearly visible in the parts of the plan that deal with drivers and future determinants of infectious diseases in the European Union.

European Environment Agency

The European Environment Agency (EEA) and the Commission's Joint Research Centre (JRC) are preparing an indicator report on climate change impacts in Europe to be published in September 2008. In the preparation of the report the EEA is also cooperating closely with several of its European Topic Centres (ETCs). The report is an update and extension (e.g. with new additional indicators) of the report published in 2004 'Impacts of Europe's changing climate' (see: http://reports.eea.europa.eu/climate_report_2_2004/en).

The main objectives of the report are to:

- present past and projected climate change and impacts in Europe through indicators (which should be easily understandable, scientifically sound and policy relevant);
- identify and present sectors and regions in Europe most vulnerable with a high need for adaptation;
- increase awareness of the need for global, EU and national action on both mitigation (e.g. to keep global temperature below the EU target of a maximum increase of two degrees Celsius above pre-industrial levels) and adaptation (which is needed even if the EU target for global temperature is achieved) in developing and developed countries; and

- highlight the need for enhanced monitoring, data collection and dissemination on climate change and its impacts.

The intended audience of the report includes policy-makers at EU and national/sub-national level and the interested and informed public. EEA has convened an external Advisory Group consisting of policymakers, scientists, experts and NGOs, to guide the process of development of the report.

Another EEA initiative together with JRC, and inspired by the UK Foresight project, was the workshop on infectious diseases and environmental change in March 2007 at the ECDC, Stockholm. The ECDC, World Health Organization - Europe, EEA and JRC were the organisers of this exploratory workshop with scientists, public health practitioners and other advocates. The overall objective of the workshop was to assess the implication of climate and ecological changes on the communicable disease burden in Europe and to develop strategic policy measures and strategies for member states.

3.2.2 Africa

Infectious diseases were identified by the Africa Commission as an impediment to African development. And they remain, along with the Foresight process as a whole, one of UK government's priority areas for cooperation with African countries, regions and African Union (AU)/ New Partnership for Africa's Development (NEPAD). Sir David King highlighted the Project during his visit to South Africa and Rwanda in February 2006, thereby raising its profile among Southern African Development Community and east African countries.

The Project's lead Africa experts were Dr Mark Rweyemamu, Dr William Otim-Nape and Professor David Serwadda. During pre- and post-publication phases, they were active in communicating, and promoting the uptake of, the Report findings and key messages with African institutions. In particular, they focused on the call for a pan-African vision for infectious disease and examples of key conferences and other forums at which they championed the Report are included in the list below. As part of this process, they have written to the AU chairman, a principal stakeholder organisation, to brief him on the project and its key messages. Also, they successfully briefed both the AU Commissioners for Rural Development, and Human Resources, Science and Technology - the latter in the margins of the Congress of African Scientists and Policy-makers (CASP), at which the Project experts were invited to present the Report. The outputs of the CASP event were key in shaping the programme of the January 2007 AU Summit. Foresight will seek to build on these exchanges, and other high-level interactions with African ministers, which include Uganda and Tanzania, in 2007.

Additional activities involving contributions from the Project's lead African experts which have led to the sensitisation of the AU Commission, NEPAD and African policy makers include:

- November 2006 - presentation, supported by the European Commission and Wellcome Trust, of a scene-setting paper at the Foot and Mouth Disease (FMD) international conference considering issues of science tools for the control of FMD in endemic settings. The paper drew on the Foresight studies and highlighted the need for partnership research programmes between FMD-free (i.e. OECD countries) and FMD endemic (i.e. developing countries). A concept is being developed about a two-track research pathway: one which will address the needs of FMD-free countries and the second will address FMD endemic settings. It has been agreed that the latter will be developed as a partnership research programme between institutions in developed and developing countries. For the latter objective, what has now been termed: *“The global roadmap for improving the tools to control FMD in endemic settings”*, and was launched at FAO HQ in Rome on 17 April 2007.
- January 2007 - Wellcome Trust convened an international meeting on future animal health research, as a direct follow up to the Report. Two of the Project’s SCG were members of the Coordinating Committee and Foresight input focused on the future animal disease control research needs for developing countries. The meeting advocated close links between medical and veterinary research and between developed and developing countries.
- During 2005 and 2006, an African Development Bank (ADB) team formulated and appraised a project on transboundary animal diseases in the Southern African Development Community region; this drew on elements of the Project’s pan-African vision for infectious diseases. The ADB project developed the concept of a National Virtual Centre for Infectious Diseases with participation by relevant veterinary, wildlife and medical institutions and drawn from both governmental and academic research establishments and will run from 2007 for five years.

Key Foresight inspired studies undertaken by the CSL and Imperial College London provided empirical evidence for a failing capacity amongst Africa nations to identify new and emerging plant diseases. Once identified, and with the challenge steepened by the informal farming systems that characterise such nations, the capacity to respond is worryingly inadequate. This position is strikingly apparent with diseases such as Coffee Wilt and, more recently, Banana Xanthomonas Wilt (BXW). Global trade and climate change heighten the threat and make African nations increasingly vulnerable.

Building on their contributions to Foresight, CSL has engaged in a dialogue with African nations on preparedness to new and emerging disease threats. Hosting a pre-plenary at the Forum for Agricultural Research in Africa 3rd Assembly on Plant Health, a full discussion on detection, identification and monitoring, sanitary and phytosanitary (SPS) and food safety concerns was achieved with key stakeholders of Africa, with recommendations feeding into the main plenary. And in July 2006, CSL hosted an International Workshop on 'The Road Map to Control of BXW' aimed at top-tier processes and policy that facilitate effective field-level disease intervention. Both these events

featured the ideas originating from Foresight in disease DIM and risk management. In promoting more effective policy positions to address disease threats, CSL has led, in partnership with nations of East Africa and International Network for the Improvement of Banana and Plantain (INIBAP), on developing a comprehensive Pest Risk Analysis on BXW that will serve as a state of knowledge template for progressing a more coordinated and strategic regional effort against this destructive disease.

The International Potato Centre (CIP) committed itself to leading a feasibility exercise of developing diagnostic capacity in SSA for both plant and animal health as part of the Project's Action Plan. CIP senior virologist Dr Ian Barker (the UC2 technical lead and member of the project's Expert Advisory Group) visited Kenya, Uganda, Rwanda, Ethiopia and Mozambique in February 2007 to discuss opportunities for diagnostic capacity building with relevant national research and development programs, quarantine and regulatory authorities and leading universities. A number of possible funding routes were discussed and are actively being followed up. A key message from the Report was the clear similarities that exist between plant and animal health diagnostics. Meetings were also held with the senior International Livestock Research Institute staff in Kenya and Ethiopia to explore opportunities for synergy. A great deal of goodwill exists in the region and UK diagnostics expertise from Advanced Research Institutes such as CSL, CVL and IAH was discussed and is recognised. CIP is currently negotiating an MoU with CSL and is in discussion with the others to be in a better position to mobilise this expertise in the region.

In April 2007 the Rockefeller Foundation and the Bill and Melinda Gates Foundation held a three-day international workshop in Bellagio, Italy entitled "A Roadmap for the Creation of a Coordinated Network for Plant Disease Diagnostics in Sub-Saharan Africa". Dr Penny Wilson, the Project's lead technology consultant, was invited to give a keynote presentation on "Global Trends in Human Diagnostics". In part, Dr Wilson's contribution focused on the Project's UC3 and 'synthesis' technology roadmaps and two of her fellow presenters, Dr Ian Barker (CIP) and Dr Neil Boonham (CSL), also drew on their involvement with the Foresight study. The Workshop identified areas where diagnostic capabilities could make a significant difference and Dr Wilson will continue to work with the group, to inform them of advances in new technologies and to help build a network of experts and 'Smart Partnerships'.

The meeting concluded that there is a need to co-ordinate current initiatives such as the USAID-funded Integrated Pest Management Collaborative Research Support Program and the International Plant Diagnostic Network. The output from this workshop was a roadmap for the development of a diagnostic network in SSA in which the Project conclusions were well represented.

The Project established that new and emerging diseases were a major future threat for human and veterinary medicine. Furthermore, the importance of 'one medicine' partnerships for the detection and identification of those diseases that infect both humans and animals (zoonosis) were recognised as

an essential first step in any future control of these emerging infections. It is possible that the SSA countries were particularly at risk considering their enormous wildlife and livestock diversity and the continuing high incidence of immuno-suppressive conditions. Recently both the Royal Society of London and the Wellcome Trust have recognised the potential benefit of integrated 'one medicine' approaches to disease control and, following the Foresight programme, have invited SCG member, Professor Joe Brownlie to investigate, in the first instance, the potential for such partnerships between Tanzania and UK.

The topic of infectious diseases was a priority area identified at the South Africa Day event at the Royal Society in May 2006. The event included a workshop specifically on this theme, engaging South African and UK scientists which is presently being followed up, using the OSI/Department of Science and Technology South Africa Networking Scheme.

3.2.3 China

The Project's broad scope and innovative methodology as delivered important insights which will help inform decision-making in determining likely priorities in the future risks of infectious diseases in China. This study has highlighted areas of particular interest in the fields of human and animal health and the relationship between drivers of change and the threat of infectious disease in years to come so that the Chinese authorities can decide on which are the broad types of infection that are likely to cause problems in the future and where surveillance and counter-measures should be concentrated.

This work should be considered as a pilot which has stimulated proposals for a further China-led study, a second pilot, which would aim to develop a deeper and more reliable understanding of future trends. The outputs of such an initiative are being published in a Chinese language peer-review journal and would help prepare the ground, and improve the methodology, for a more sophisticated, definitive study.

Professor Jessie Huang of the Peking Union Medical College and Professor Gonghuan Yang of China CDC have reported that the Chinese authorities are interested in the Foresight methodology for future work and not just in Infectious Diseases. Professor Huang himself is looking for funding to repeat the pilot study in an expanded form taking on board the results and experience of the first pilot which is also being written up for an English language journal.

3.2.4 The Russian Federation and Commonwealth of Independent States

The Project profile, and infectious diseases as a priority area for bilateral and multilateral cooperation, was raised significantly amongst G8 partners. In particular, OSI sought to work with the Russian Federation in a concerted way throughout its G8 presidency to help raise the profile of infectious diseases on its agenda. For example, this work included discussions of infectious

diseases during the UK-Russia Joint Commission on Science and Technology collaboration in October 2005; and funding participation of infectious diseases expert from Queen Mary College in British Council Workshop in Russia in June 2006.

International Science and Technology Center (ISTC) and OSI co-hosted a conference at the Royal Society on 10 May 2006, under the auspices of the UK-Russian Joint Commission on Science and Technology Collaboration, to promote scientific collaboration between scientists and technology developers. This was an important part of OSI International Directorate's Science and Innovation strategy for the Russian Federation and the wider Commonwealth of Independent States (CIS).

The Conference followed on from the announcement that infectious diseases was one of the main themes of the Russian Federation G8 Presidency, and from OSI discussions with the ISTC and the Ministry of Education and Science in Moscow. The conference agenda drew heavily on the Project for topics and also for the UK speakers.

The event met its four main UK objectives: to publicise the work of the Project; to inform the Russian G8 Presidency's work; to forge closer links between OSI and ISTC, which is a major sponsor of international science collaboration with the CIS; and to increase international interchange in this area of science.

Following this successful event, ISTC pledged to undertake similar activity with OSI in the future and to develop further partnerships and complementary work in the field of infectious diseases both in the UK and in the CIS.

3.2.5 Other Countries

The OSI Global Partnerships team reports that infectious diseases were identified as a strategic area for cooperation with India during the Indo-UK Science and Innovation Council in June 2006. This is influencing project funding under the UK-India Education and Research Initiative, including the OSI/DST India Networking Scheme. Also, OSI funded a UK-Korea workshop on vaccines for influenza (which also included experts from China, Vietnam and Japan) in March 2007.

3.3 A Socioeconomic Perspective

At Foresight's request, Professor Tony Barnett, London School of Economics, one of the Project's key Expert Advisers, provided the following reflection on some of the Project's overarching socioeconomic perspectives.

"Metal detector arches at airports are familiar to all who travel by air; in the last twenty five years they have become part of the travel ritual, a way that we pursue the common good to ensure airline safety. What would happen if similar detectors were to identify passengers in the early stages of a highly infectious disease, not sick, merely infected and infectious to others? In the case of pandemic influenza, the highest levels of infectiousness are during the

first few days of infection, before people feel sick. Obviously a good thing to catch travellers harbouring such pathogens before they leave the airport: but what to do with people who are so detected? Or what of another possible technology, the mobile 'phone which detects infection before it becomes sickness? Who should have the right to this information, the mobile 'phone company, the government, the WHO? And on what terms?

The technical possibilities revealed by the Project have profound social and economic implications. Remote sensing of infectious disease outbreaks could save enormous amounts of money; the 2003 SARS outbreak involved a total of around 8500 cases globally but the total cost to East Asian economies ran into many billions of dollars, the total economic cost per case detected has been estimated at \$2 bn. Early detection, for example when the simian immunodeficiency viruses made the zoonotic transfer which led to HIV, would have saved many millions of lives and a conservatively estimated \$30 bn.

The public health and financial sense of early detection is clear but raises complex ethical and political questions. Social science (taken to include everything from economics, through political science to social psychology) participation in Foresight DIID was important but inevitably marginal given that, outside of epidemiology – which may or may not be counted as a social science – very few social scientists in the UK have concerned themselves with infectious disease issues.

Foresight DIID demonstrated the potential role of social sciences in understanding the implications of existing or soon to be available technical capabilities in the field at a time when globalisation increases the risk of emergence and re-emergence of a wide range of infectious diseases. It also revealed the gaping absence of good social science work in this field in the UK and probably globally.

There is undoubtedly an urgent need to persuade social scientists to turn their attention to understanding the social and economic roots of infectious disease outbreaks, epidemic development and the implications of such events for national and international management of infectious diseases. We need to build this capability with great speed to help us understand how best to provide appropriate global public goods while at the same time protecting the global (rather than the solely national) public good.”

3.4 Barriers to Progress and Further Development

The Project presents an authoritative body of scientific evidence which has, and will in the future, inform stakeholders' decision-making in setting policy and also in future technology development. However, this work has importantly highlighted a range of potential barriers to future technological innovation which would need to be addressed in taking forward some aspects of the project findings.

Technologies themselves provide only part of the solution, and can, if designed and/or used inappropriately, create new and challenging problems;

such as loss of data, a breakdown of the relationship between the professional and the beneficiary and poor quality assurance. To be fully effective, new DIM systems will need to be integrated into wider disease management strategies and an appropriate and overarching infrastructure; for the management, treatment and control of infectious diseases. At best, the lack of co-ordination of policy or technology between these areas might result in nugatory effort or, at worst, untimely, inaccurate diagnosis could give rise to the unnecessary spread of disease and/or the ill-advised and sub-optimal use of therapeutic interventions, such as drugs, vaccines or pesticides. The predicted growth commercial diagnostic kits for non-professional use will pose particular challenges in this regard. Crucially, in order to maximise their effectiveness and impact, DIM systems must be developed in full cognisance of local governance infrastructure. Even highly promising technological innovation with the potential to effect a step-change in user capabilities can be rendered ineffective if unsupported by the appropriate institutional infrastructure and regulatory framework to deploy and manage it. In a global context, there is the real danger that a lack of infrastructure and failure to support new technologies will widen the gap between developed/developing countries and their ability to contain highly infectious diseases.

The vision of this Project, that DIM technologies may develop across human, animal and plant sectors so as to meet the needs of developed and developing countries will encounter considerable barriers, ranging from a need to integrate research “silos” to the practical problems of inter-operability of devices for diagnosing different tropical diseases.

The integration of natural and social science research on DIM development is also a key hurdle. The diverse cultural attributes of the user, and in the context human health, the patient, will often have a significant bearing on the acceptance of novel systems. Also significant is people’s perception of the risks associated with DIM, such as the misuse of personal and sensitive data. As stated elsewhere in this review, there are important questions surrounding data acquisition, storage and access, privacy and system interoperability which should be resolved to the satisfaction of individuals and stakeholder organisations before systems become operational. It is only by recognising, and working sympathetically within this broad non-technological context that the full benefits of future systems will be recognised.

Progress on policy and technology development will therefore be hampered by stakeholders who take a ‘silo-based’ approach to long-term risk assessment and their policy or technological response to it. Weak inter-organisational links and the lack of a funding infrastructure which would deliver opportunities for cross-sectoral and interdisciplinary research need to be addressed. Also, more effective ways might be found to exploit the UK’s world-class science base and drive the transfer of knowledge and skills between the research and business communities. In this way, we will be better placed to deliver improvements in the development of holistic and integrated solutions to the future threat of infectious diseases.

4. Dissemination

As with all projects, the Foresight team seeks to maximise the opportunities to disseminate of the IIF report. The communication and uptake of the project findings and the Report's capacity to make a significant impact to decision-making and to the development of key areas of policy and strategy are key measures of the Project's success. The principal ways in which this has been achieved are as follows.

4.1 Enduring Networks

Networks which continue to promulgate project findings are a crucial feature of all Foresight projects. Importantly, a number of networks have been created, which are well placed to promote the Project's approach and key messages. Such networks include the many experts who contributed to the Report's technical findings and their synthesis, and the working and high-level, inter-departmental links, developed during the Project rollout and follow-up phases, have helped to deliver a co-ordinated cross-government response to the Report.

4.2 Conferences and Other Events

Using the Project findings to inform the considerations of key conferences, workshops and other scientific and technical forums has been an essential and effective method of promulgating the Report findings. Foresight is grateful to the many technical contributors to the Project and to its stakeholders who have presented and injected the Project outputs at a wide range of diverse events before and after the Project launch. Examples include:

- The Control of Neglected Zoonotic Diseases, Joint World Health Organisation / Department for International Development AHP meeting, Geneva, Switzerland, 20-21 September 2005
- 7th Conference of AU Ministers Responsible for Livestock Development in Kigali, Rwanda, September 2005
- DTI – International Science and Technology Center, Scientific Collaborative Workshop, the Royal Society, London, 10 May 2006
- Department of Health Vaccine Committee, June 2006
- European Commission Directorate-General for Research, Brussels, 13 July 2006
- Network of African Academies of Science, Royal Society, 9 September 2006

- European Commission Directorate-General for Health and Consumer Affairs, Brussels, 18 September 2006
- World Health Organisation, Geneva, 22 September 2006
- Health Protection Agency, *'A novel and simple approach to anticipating likely future infectious diseases trends and needs for surveillance and counter measures in China'*, Warwick, September 2006
- British Association for Science, Annual Festival Science, Norwich, 2-9 September 2006.
- Congress of African Scientists and Policy Makers, Alexandria, Egypt, 27–29 October 2006
- Research Councils UK Research and Development Group, Swindon, 11 October 2006
- Commonwealth Partnership for Technology Management, Think Tank, London, November 2006.
- National Institute for Public Health and the Environment, Bilthoven, the Netherlands, December 2006
- British Society for Plant Pathology, 25th Anniversary Meeting, Imperial College, London, 19 December 2006
- British In Vitro Diagnostics Association, Point of Care workshop, London, 23 January 2007,
- Labworks: The Health Protection Laboratory 2016, London, 1 February 2007
- European Centre for Disease Control Stockholm, Seven Year Strategic Planning, Stockholm, 7 February 2007
- European Centre for Disease Control/ European Environment Agency/Joint Research Council workshop on Infectious Disease And Environmental Change, Stockholm, 29-20 March 2007
- Rockefeller Foundation, 'A Roadmap for the Creation of a Coordinated Network for Plant Disease Diagnostics in Sub-Saharan Africa' conference, Bellagio, Italy, 23 -25 April 2006

Planned:

- Infectious Diseases: preparing for the future workshop, Foresight / British Embassy, Washington D.C. USA, 27 June 2006

- Cambridge Healthtech Institute, Enabling Point-of-Care Diagnostics meeting, Washington, D.C., USA, 14-15 August 2007

4.3 Media Coverage

Media coverage around the time of the launch was limited. This was in part due to the 'competition' from Professor Neil Fergusson's paper on avian influenza published in Nature at the same time. However, as well as some references in the press, the Project received exposure through a range of professional and learned Journals in the months following its publication. Examples include

- The Guardian 27 April 2006
'Flu pandemic would peak in UK within 4 months'
- Research Fortnight 10 May 2006
'Interdisciplinary skills needed to tackle infectious diseases'
- The Veterinary Record, 6 May 2006
'Applying Foresight'
- Veterinary Times, May 2006
'Plans to combat disease may save money and lives'
- New Scientist, 6 May 2006
'Europe's virus zoo'
- The Veterinary Record, 13 May 2006
'Anticipating disease threats'
- Times Higher Education Supplement, 26 May 2006
'Sleuth on the trail of deadly droves'
- Science, 8 September 2006
'Infectious Diseases: preparing for the future'
- The Lancet, 10 March 2007
Health is global: proposals for a UK Government-wide strategy

Planned

- 'Journal of Risk Research' and 'Risk Analysis'
Articles to address the risk analysis of future infectious disease incidence and propose a new decision-making tool to enable better understanding of the socio-economic risk factors of disease to be captured and integrated in the risk analysis process.

Annex A

Progress report on 'Action Plan' commitments

Commitment	Action
Department for the Environment, Food and Rural Affairs (Defra)	
Defra welcomes the effort and commitment that the Office of Science and Innovation (OSI) and others have put into the Foresight project and will seek to review and take on board the findings, in the context of current policy activities and strategy development.	
The project's sponsor Minister (Lord Bach) welcomes the opportunity for the findings of the report to be considered, both within the Department and with a cross-Government perspective, so that the implications may be considered by Departments in a co-ordinated manner.	Defra set up the cross-governmental Foresight Infectious Diseases Action Plan Working Group (FIDAP-WG) to collectively review progress and to discuss implementation of the Action Plan commitments of government departments and agencies and Research Councils. Importantly, members of the FIDAP-WG (see Annex B) included most of the government organisations with actions proposed in the Action Plan. The FIDAP-WG meetings helped to maintain and add weight to the project's momentum.
<i>Specific work that Defra are currently undertaking that will be informed by the findings of the project:</i>	
A project, developed as part of the implementation of the Veterinary Surveillance and Animal Health and Welfare Strategies, to develop a transparent risk and impact, evidence based model that will generate summary reports that quantify the relative importance of animal health and welfare issues in the context of the four reasons for government intervention. This will provide a decision support tool for the prioritisation of work both in the area of emergency preparedness and surveillance for new and emerging diseases.	The Foresight Programme and Defra held a joint Wildlife Health Workshop on 2 May 2007. The objective of this workshop was to consider how future scientific innovation might improve knowledge and management of wildlife diseases. It drew on outputs from the Project and put these in the context of ongoing initiatives in the Defra Wildlife Health Strategy, to identify gaps and opportunities that might be considered in future planning by Defra.

<p>The development of the Departmental strategy for Earth Observation data, including its use for predicting the spread of diseases.</p>	<p>Foresight DIID reports were also very useful for Defra's development of its departmental Earth Observation (EO) strategy. The DIID project successfully raised the profile of EO for disease-related activities and is helping the EO team to bring the subject into discussions with policy stakeholders and advisers. For example, Defra aims to investigate the utility of EO for assessing and forecasting the risk of vector-borne disease.</p>
<p>An active research programme in the field of animal and plant health, many components of which have been and continue to improve the diagnostic tools we have available.</p>	<p>The Foresight project has enhanced the thinking behind several other streams of technological research, namely, the development of portable diagnostic technologies for field-based detection, e.g., portable PCR (polymerase chain reaction) thermocyclers for the diagnosis of Foot and Mouth Disease, and alternative immunological assays for the detection of <i>Mycoplasma bovis</i> in badgers. Other important activities include modelling and epidemiology for prediction of high risk areas for entry of Avian Influenza and for modelling the potential for disease spread, and also for predicting whether increased ambient temperature (e.g., climate change) facilitates the competence of UK midges to act as vectors of Blue Tongue Virus. Data analysis and data mining techniques complement some of this molecular and modelling research.</p> <p>Defra also funds work on the detection and identification of quarantine plant and bee diseases to support their exclusion or management. Several new activities are relevant to Foresight DIID and have been influenced by it. One project will develop a model epidemiological framework to optimise detection and intervention strategies for statutory plant pathogens, and draws on expertise from a range of disciplines. We also propose to develop novel methods for detection, identification and monitoring of such pathogens, and are considering a project that builds on earlier work on electronic nose technology.</p>

Central Science Laboratory (CSL), Institute for Animal Health, Veterinary Laboratories Agency, Centre for Environment, Fisheries and Aquaculture Science, Health Protection Agency and Royal Veterinary College

CSL will lead a Defra funded multidisciplinary project ('Defra bio-security chip') to develop a diagnostic microarray ('lab on a chip') for the surveillance, detection and characterisation of quarantine and emergent viruses of plants, animals (including zoonotic), fish and bees. The consortium (formed whilst working on the Foresight project) will exploit the clear synergies between plant, animal and clinical virology which is a clear message from the project.

Effective molecular diagnostic tools are keystones in the successful fight against infectious diseases. The Biochip project, a substantial research initiative to develop, by 2009, diagnostic viral microarray technology for detection of about 600 viral pathogens, is led by Defra's CSL and supported by Defra's Chief Scientific Adviser. It benefits from the collaborative efforts of CSL, CEFAS, VLA, the Institute of Animal Health (IAH), HPA and the Royal Veterinary College. Uniquely, this research draws together diverse expertise to develop methods for early diagnosis of infectious viral pathogens across the animal, plant, bee and fish sectors. The project also aims to improve detection of newly emerging pathogenic threats.

Department of Trade and Industry (DTI)

Early detection and identification of diseases and the need for high throughput screening of people at airports are two important areas (the Foresight report's 'User Challenge 4'), with important social and commercial dimensions, which the Technology Strategy Board will be considering in the near future.

Furthermore, the ability to capture large amounts of data and analyse/model them to predict outcomes or behaviour (the Foresight report's 'User Challenge 1') is an important feature of virtually all markets in the modern economy, such as retail and logistics, financial services and high performance engineering as well as the applications identified in this study, namely modelling the growth and spread of disease.

The Foresight team has maintained a strong interest in follow-up work after publication of the project's main findings and Action Plan. The Technology Strategy Board (TSB) Emerging Technologies Programme organised a Workshop on new areas of bio-nanotechnology, which included infectious diseases as one of the priority areas for consideration. It will continue to seek to identify opportunities for business to develop innovative projects in this important field.

The TSB has also sought to encourage the development of innovative disease detection devices by offering support for projects involved in their development. In October 2006 the DTI announced that the TSB had agreed to provide £800,000 support for a project led by Akubio Ltd, Cambridge (in collaboration with the University of Cambridge and Reagent Mine Ltd of Melton Mowbray) to develop a new portable and low cost, rapid response

<p>We shall therefore be developing our strategies around Innovation Platforms with the benefit of the information contained in the Foresight report, and their supporting technical papers, and the networks of expertise which have been developed by the study. These will form an excellent starting point for taking forward our activities.</p>	<p>disease diagnosis device, which could help doctors make instant and accurate diagnoses for diseases such as Malaria and Meningitis. The project aims to develop biosensor chips and hardware for real-time healthcare monitoring (i.e., rapid clinical in vitro diagnosis and efficient blood screening) and for environmental monitoring. It will bring together three technologies: Reagent Mine's pre-concentration of analytes from complex biological samples on magnetic beads and nanoparticles, Cambridge University's novel polymeric biocompatible surface coatings, and Akubio Ltd's breakthrough acoustic detection methodology.</p>
<p>DTI will use the work to inform the Bioscience and Healthcare aspect of the UK's Technology Strategy.</p>	
<p>Office of Science and Innovation (OSI)</p>	
<p>To ensure that the findings inform the work of the interdepartmental flu pandemic working group, co-chaired by the Cabinet office and the Department of Health</p>	<p>A paper setting out the Project's core findings was submitted to the flu pandemic working group (now know as the MISC 32 officials group) for members' consideration. The paper also set out the key steps that the Project highlights, which form the basis of the Government's action plan.</p>
<p>To work with others to build support for African Union/ New Partnership for Africa's Development (NEPAD) in following up the Foresight project's Entebbe, Uganda workshop in August 2006 and other project output relating to Africa.</p>	<p>Infectious diseases and the Foresight process as a whole remain a priority area for cooperation with African countries, regions and AU/NEPAD. Sir David King highlighted the Foresight project during his visit to South Africa and Rwanda in February 2006, raising its profile among SADC and east African countries.</p> <p>Infectious diseases was a priority area identified at the South Africa Day event at the Royal Society in May 2006, which included a workshop specifically on this theme, engaging seven South African scientists and six UK. This work is presently being followed up, using through the OSI/Department of Science and Technology South Africa Networking Scheme.</p>

	Other examples of OSI International activity outside Africa can be found in the main body of the Review
OSI's Horizon Scanning Centre (HSC) will feed the implications of the project's findings where relevant into their interactions with a wide range of government departments as part of their horizon scanning activities.	The Foresight Programme's Horizon Scanning Centre (HSC) is currently 'refreshing' its Sigma and Delta Horizon Scans, which form the basis for its interactions with government departments on strategy and policy work. Material from the DIID project will be referenced in the next public release of the Scans (estimated December 2007). The HSC has also created a space on its Scan development database dedicated to the Project. The Project's scientific papers entered in this 'project space' will be immediately accessible to over 90 registered government users, principally active in the strategy and policy fields.
HSC will ensure that findings and science reviews are incorporated into HSC's scans and other papers (e.g. CSR).	
HSC will use the project findings to inform the work of its Future Analyst Network (FAN Club).	In September 2006 the FAN club held a workshop to explore how a range of media, such as writing, images, video and acting, might be used to develop innovative and interesting ways to communicate the Project's key findings and messages.
To work with DH and others to ensure work on the role of the professional is supported by the OSI's public engagement programme	<i>to be advised</i>
Department of Health (DH)	
The DH commits to considering the implications of the findings of the report when developing policy in relevant areas.	The Foresight report has already been brought to the attention of several DH advisory committees with a view to identifying issues of potential relevance to future policy development. This process is ongoing and below is one example of where the report has fed directly into the considerations of an advisory committee.

National Expert Panel on New and Emerging Infections (NEPNEI)	
To review medico-veterinary collaborations in zoonoses surveillance and research and to make recommendations on further work in these areas.	NEPNEI has been involved with the DIID Foresight project from its inception. The Panel has set up the Human and Animal Infections Risk Surveillance Group (HAIRS) to provide a forum for detailed analysis and scrutiny of animal and human health surveillance data. The development of an agreed methodology for assessing zoonotic risk potential in a consistent manner has strengthened the Group's ability to undertake rapid horizon scanning for infections with potential transfer between species. This methodology and accompanying algorithm has been published by the HPA as provider of the secretariat to HAIRS. The results of the analysis and conclusions of the Group are presented to NEPNEI for wider consideration and there are mechanisms in place for 'fast-tracking' risk assessments when necessary. This process now provides necessary transparency to zoonotic risk assessment in its earliest phase.
Health Protection Agency (HPA)	
Will debate the wider implications of the report with respect to its development plans and futures work	The DIID report was cascaded through HPA Centres, research communities and information management routes to ensure wide distribution, discussion and debate. The Research Committee, jointly with Theme Leaders from all R&D strategic sectors, met in November 2006 and January 2007, where the report was discussed. Enthusiasm and support for its approach and findings were expressed.
Will identify synergies with its existing 2005-2010 R&D strategy	
Will seek to further strengthen its joint activities with the Veterinary Laboratories Agency through its existing Memorandum of Understanding and through the Interlab Forum	
	Several HPA corporate goals (4, 6 and 8) provide a platform for synergy and interaction with the DIID reports in mapping new and emerging threats of infection, enhancing preparedness to threats (including CBRN) and building the evidence base for DIM systems through programmes of development and tools for implementation.

<p>Will explore with key partners how current multiple pathogen detection for agents of bioterrorist threat can be adapted for conventional infectious diseases</p>	<p>Several key projects across the HPA are in progress to create mechanisms and tools for direct detection of biothreat agents. These are in collaboration with, and sponsored by, government agencies. The HPA is utilising these initiatives to enhance multi-pathogen detection capabilities with wider applications to emerging health threats.</p>
<p>Will explore with partners, especially the World Health Organisation (WHO), & The International Association of Public Health Institutes (IANPHI) how the Agency can contribute to improved laboratory diagnostic capability, and public health expertise, in resource poor countries</p>	<p>The Centre for Infections is participating in the World Health Organisation (WHO) Laboratory Twinning Scheme which is intended to develop capacity along with laboratories in developing countries; partnerships with public laboratories in Uganda and Kazakhstan have been agreed.</p>
<p>Will continue to develop and help evaluate near patients tests and bioinformatics information tools</p>	<p>Identifying and meeting tomorrow's needs requires the HPA to be in a constant state of preparedness, being proactively equipped to develop rapid diagnostics and to support science-based activities and data mining and interpretation capability. Direct patient testing and biomathematical tools for data interpretation, dissemination and modelling are examples of areas growing and expanding throughout the Agency's programmes of research. Improved and novel bioinformatical and biostatistical approaches will continue to be developed over the coming years as a component of the multi-disciplinary approaches for improved infectious disease detection and surveillance.</p>
<p>Home Office (HO)</p>	
<p>The HO welcomes the findings of the report. It will consider the findings in light of the Cross-Government CONTEST (UK Counter Terrorism strategy) Science and Technology Strategy and will use the appropriate outputs of the report to aid in the determination of future S&T requirements.</p>	<p>Whilst not participating directly in projects that have developed out of the DIID project, the HO remains interested in future developments and will maintain an oversight of continuing work.</p>

National Security Advice Centre (NSAC)

NB In February 2007, the National Security Advice Centre (NSAC) was merged with the National Infrastructure Security Co-ordination Centre (NISCC) to become the Centre for Protection of National Infrastructure (CPNI).

NSAC will use the work of this project to inform prioritisation and strategic planning of its protective security research programme - FY 06/07 and in NSAC's three-year plans.

NSAC will also seek to work closely with those involved in the project to identify areas of mutual interest and ways to work together in the future.

CPNI has worked closely with those involved in the Foresight DIID study to ensure that they are aware of potential security applications for their work. This has resulted in direct collaborations with individual research institutions and universities. In addition CPNI has utilised the results of the DIID work to inform the strategic planning of its protective security research programme in order to ensure that horizon scanning activities are targeted at key areas.

Department for International Development (DFID)

DfID, as a key project stakeholder, will review the findings and use them as appropriate to inform in relevant areas of policy development.

DfID is reviewing the Foresight DIID findings and will use them as appropriate to inform relevant areas of policy development. For example, the project outputs and future infectious disease challenges will be referred to in the new DfID health strategy to be issued in mid 2007. A Science and Technology Strategy is also currently under development, led by DfID's Chief Scientist, and this will be informed by DIID outputs.

Ministry of Defence (MOD) and Defence Science and Technology Laboratory (DSTL)

MOD has had a long interest in novel diagnostic methods to detect the presence of specific infective disease agents. We are committed to using advanced technologies for these tasks and we welcome the Foresight initiatives in this important field. We are also very committed to accurate data capture and the timely use of accurate data and its timely use to inform decisions.

The MOD Chief Scientific Adviser sponsored an external audit of the quality of MoD research programmes and their alignment to MoD's requirements. The alignment study considered internal MoD policy and strategy documents, and also external influences including the Foresight study on infectious diseases.

The MoD has an active research programme in the medical surveillance and diagnostics area. Areas of research include field deployable post-symptomatic diagnostic and surveillance

<p>Chief Scientific Adviser MOD and Dstl to consider the findings of this report and to ensure that MOD has the science base to respond in a timely way to disease outbreaks (existing and emerging) such that their impact is minimised.</p> <p>To monitor developments in DIM technology so as to utilise them appropriately for the protection of UK armed forces from endemic diseases, biological warfare and terrorism. To ensure advances made in the military arena with respect to DIM are transferred to the civil sector where appropriate.</p>	<p>systems; non-invasive methods for detecting infection and novel means of detecting infection pre-symptomatically by detecting changes in the host immune response. The later programme has proven particularly promising, indicating that changes in host immune response can predict infection up to four days before the appearance of symptoms. This work has the potential to be exploited in a variety of applications, both civilian and military.</p>
<p>Department for Transport (DfT)</p>	
<p>DfT will ensure that any relevant project findings are fed into future work on the Data Grand Challenge.</p>	<p>The Project has informed scoping work by DfT on behalf of the Science and Innovation Cabinet Committee's 'Data Grand Challenge' to assess how government can realise the potential benefits of the increasing amounts of real-time and archived data.</p>
<p>Research Councils UK and Research Councils</p>	
<p>Professor Julia Goodfellow, Biotechnology and Biological Sciences Research Council (BBSRC) Chief Executive, on behalf of Research Councils UK - The Foresight report and action plan present us with some important issues which we can consider as we move forward with a number of research programmes. Working individually and collectively through the Research Councils UK partnership, we will be considering the report recommendations as we formulate future policy and strategy, including in the context of SR07. Some specific examples follow:</p>	
<p>BBSRC will consider the implications of the report as it works with Defra on the £121M redevelopment of the Pirbright laboratory. This will provide new, secure facilities for virologists from the Institute for Animal Health and the Veterinary Laboratories Agency.</p>	<p>The Research Councils UK (RCUK) Research and Development Group (RDG), comprising Research Directors of the Research Councils, invited the DIID Project team to give a presentation at its meeting on 26 October 2006. Councils reported on resultant actions at the RDG meeting in February 2007.</p>

<p>Arts and Humanities Research Council (AHRC) to consider implications of report for Religion and Society Programme.</p>	
<p>BBSRC to consider implications of the report for its work on Control of Infectious Diseases programme</p>	<p>All the appropriate Research Councils had undertaken activities as shown in the Action Plan, along with some additional work. For example, the Arts and Humanities Research Council (AHRC) is considering its engagement with medicine, and the Medical Research Council (MRC) has undertaken reviews of vaccines and of research in Africa. Also, the Cross-Council Genomics Coordinating Committee aims to discuss the Foresight DIID report. RCUK is collating cross-Council activities in the DIID Area and will continue to engage with the long term DIID research agenda.</p> <p>The MRC promotes and funds long-term fundamental and public health research on infection and immunity in the UK and internationally (mainly in Africa). But there is a well-recognised gap in the UK's capacity (and MRC's portfolio) in clinical and translational research (such as the application of basic science discoveries to development of new diagnostics). MRC is addressing that gap through several initiatives to promote translational research, including through the UKCRC Translational Infections initiative. In addition, development-gap funding is available to MRC researchers from MRC Technology (MRCT). An MRCT-funded project on "fingerprinting" markers of infection recently led to the transfer of new technology into industry.</p> <p>In 2005, MRC awarded £2m to establish a Centre for Outbreak Analysis and Modelling, a partnership between Imperial College and the HPA.</p> <p>The DIID process and interim reports informed MRC's development in 2005 of its Pandemic Influenza initiative. Half of the 18 new influenza projects and infrastructure funded (£8m)</p>
<p>BBSRC to consider implications of the report for the Basic Technology Programme</p>	
<p>BBSRC to identify cross-Council data-sharing policies to provide better access to data, as part of its current development of its data policy</p>	
<p>BBSRC will seek to support cross-disciplinary areas of research identified in the report through mechanisms such as its mid-career Research Development Fellowship Scheme</p>	
<p>BBSRC and Medical Research Council (MRC) will consider the possibilities for further collaboration across natural and social sciences in areas related to the project as part of taking forward the work of the Cross-Council Genomics Coordinating Committee</p>	
<p>BBSRC will consider options for future opportunities for initiatives such as Rural Economy and Land Use (RELU)</p>	
<p>Engineering and Physical Sciences Research Council (EPSRC) will consider implications for its basic technology and ICT/High Performance Computing</p>	

<p>programmes, looking especially at the priorities highlighted in the User Challenge on data mining.</p> <p>MRC will assess the implications of the report for MRC in relation to</p> <ul style="list-style-type: none"> (i) Current Infections and Immunity Board priorities in (a) global infections, (b) antimicrobial resistance & healthcare acquired infections, (c) genomic epidemiology, and (d) potentially pandemic influenza. (ii) Further development of Council priorities for translational research, e.g. biomarkers [of infection and disease]. <p>The assessment will form the basis for refining existing strategies or developing additional priorities during 2006.</p> <p>The Research Councils with the Wellcome Trust and the Department for International Development will consider the implications of the report for joint working within the context of the Funders Forum for Health Research in Developing Countries.</p>	<p>during 2005/6 will contribute to strengthening viral strain identification, surveillance and risk assessment and one project is focused directly on novel diagnostic technology development. Several projects involve the HPA. A further £6m is available under the current call for investment in 2007/8. Funders and agencies coordinate their activities in influenza research through a number of formal and informal means.</p> <p>A significant component of the Report concerned the risks posed by new and emergent infectious organisms to plant, animal and human health in Africa. Focusing on human health, the UK Funders Forum on Global Health provides a mechanism for information sharing and coordinated action across the MRC, the Economic and Social Research Council (ESRC) and The Wellcome Trust. The UK Collaborative on Development Sciences, a more extensive group of development and funding agencies, will take a broader development focus. Work to establish the Collaborative is led by the DfID, ESRC and The Wellcome Trust.</p> <p>Public health research is a particular focus of the new Office for the Strategic Coordination of Health Research, established to facilitate the development by the DH and the MRC of joint strategies. Infection is emerging as a key theme for joint work.</p>
Royal Academy of Engineering (RAEng)	
<p>The RAEng Working Group on privacy and surveillance will review the Foresight project findings and consider how they might be used to inform its activity and outputs.</p>	<p>The RAEng working group on Privacy and Surveillance published its report, 'Dilemmas of Privacy and Surveillance: Challenges of Technological Change', on March 26, 2007. The report identified likely developments in information technology relevant to surveillance, data-capture and identity management, considering their impact on the citizen and making recommendations on how</p>

	<p>to optimise their benefits to society. Among the issues that the Group considered was the collection of large-scale databases of personal data for the monitoring and control of infectious diseases.</p>
<p>British In Vitro Diagnostics Association (BIVDA)</p>	
<p>BIVDA will review the project findings in relation to its work and the future of diagnostics in the UK and internationally. In particular, BIVDA is keen to ensure, as far as possible, that only validated, high quality, appropriately regulated devices are made available and that adequate records and standards are maintained. BIVDA will use the project findings to inform its members, in particular the POC Working Party, and will consider the steps required to realise the development and implementation of the four User Challenges.</p>	<p>BIVDA and Foresight held a Point-of-Care (POC) conference on 23 January 2007 to explore the potential traction between the Project findings and the priorities of BIVDA members and others with an interest in technology development. The Conference highlighted the need for, and opportunities and trends in POC diagnostics in the developed and developing world.</p> <p>Dr Penny Wilson, the Project's lead technology consultant, organised and led the Conference and this event built on her earlier presentation to BIVDA's POC Working Party and discussions with the association's Director General, Doris-Ann Williams.</p>
<p>INTERNATIONAL ORGANISATIONS</p>	
<p>World Health Organization (WHO)</p>	
<p>As a key stakeholder to the Foresight project, WHO has welcomed the opportunity to work with OSI and to provide advice at the initiative's formative stages. WHO now looks forward to reviewing the project report and to assessing the implications for its activities.</p>	<p><i>to be advised</i></p>

World Organisation for Animal Health (OIE)	
<p>The World Organisation for Animal Health (OIE) will follow with interest the outcomes of the Foresight project as it relates to supporting and strengthening the implementation of the strategic objectives of the OIE - especially those objectives related to strengthening the capacity of Member Countries to participate in the development and application of international standards for animal health and zoonosis and strengthening the involvement of the OIE in policy design and governance related to animal health and zoonosis.</p>	<p>The current H5N1 avian influenza crisis demonstrates that without effective veterinary services and governance, countries are unable to prevent the introduction or emergence and re-emergence of animal diseases or to bring outbreaks under control. The OIE has therefore, with the support of international donors, initiated a Performance, Vision and Strategy (PVS) evaluation tool to assist Member Countries to identify their shortcomings in meeting and applying the international standards for the delivery of veterinary services. With the support of several donors to the World Animal and Welfare Fund, an initial pilot programme of 15 national OIE Member Country evaluations was launched with provision already made to evaluate 60 more countries in 2007-2008.</p>
Food and Agriculture Organization (FAO)	
<p>The FAO welcomes the 'Infectious Diseases: preparing for the future' report prepared by the Foresight Project. FAO was involved from the outset of the project and worked with its steering group of UK and international stakeholders to provide input at key events and milestones during its delivery. FAO will review the project findings and consider how these might contribute to the development of key areas for policy and strategy. Of particular interest would be to explore the synergies between plant and animal disease work both within FAO and with other IGOs in the fields of human (zoonotic), animal, and plant diseases.</p>	<p>The Project did give useful and continuing impetus to the development of a new Crisis Management Centre (CMC) which would bring together rapid response and monitoring capacity for disease outbreaks on crops and animals and food-related outbreaks in humans (http://www.fao.org/docs/eims/upload/217648/leaflet_cmc_en.pdf).</p> <p>This Centre was approved by FAO's executive Council in November 2006. The CMC covers animal disease, plant pest, and food safety crises with a coherent coordinated strategy and approach. The experiences of the Desert Locust Campaign of 2003-2005 and the ongoing Highly Pathogenic Avian Influenza campaign are reflected in the CMC's design. On April 2, 2007, FAO held a full-day's seminar on "Transboundary Pests and Diseases and other Disasters: from Prevention to Building Back</p>

	<p>Better". This was attended by Permanent Representatives from over 100 countries. The opening presentations referred explicitly to the Foresight initiative as pointing out new, scientifically sound convergence among animal, human, and plant diseases. The seminar was well received and emphasised the importance of building national capacity, especially in FAO's developing member countries, in thematic areas supporting the management of transboundary pests and diseases.</p>
<p>International Potato Center (CIP), Central Science Laboratory and Veterinary Laboratories Agency</p>	
<p>New, emerging and endemic diseases present a continuing threat to food security and animal and human health in Africa; especially when capacity for surveillance and monitoring remains weak.</p> <p>In line with Foresight project conclusions and as a priority area for NEPAD's Comprehensive African Agricultural Development Program (CAADP), the Consultative Group on International Agricultural Research (CIP coordinating), along with key UK agencies (CSL coordinating, and VLA) and commercial diagnostic companies, will seek to progress capacity at the national and regional economic level for surveillance and diagnosis for plant and animal (including zoonotic) diseases in Africa.</p>	<p>CIP senior virologist Dr Ian Barker visited Kenya, Uganda, Rwanda, Ethiopia and Mozambique in February 2007 to discuss opportunities for diagnostic capacity building with relevant national R&D programs, quarantine and regulatory authorities and leading universities. A number of possible funding routes were discussed and are actively being followed up. A key message from the Report was the clear similarities that exist between plant and animal health diagnostics.</p> <p>Dr Barker attended a Rockefeller and Gates Foundation sponsored workshop in Bellagio, Italy in April 2007, which was set up to discuss the development of such a network for plant health. The output from this workshop was a roadmap for the development of a diagnostic network in SSA in which Project conclusions were well represented.</p>

European Environment Agency (EEA)	
<p>Further to discussions with EEA plans are now in place for the future work programme to include the results of the project in determining areas of Europe that are likely to be vulnerable to infectious disease arising from systemic changes in different habitats and ecosystems and exposure of the human population in contact with them. This work is intended to be carried out in partnership with the original partners from the DTI Foresight programme, European equivalents and the European office of the WHO, which is responsible for overseeing the environment and health programmes of the WHO.</p>	<p>The EEA and the EU Commission's Joint Research Centre (JRC) are preparing an indicator report on climate change impacts in Europe to be published in September 2008. The intended audience of the report includes policy makers at EU and national/sub-national level and the interested and informed public. EEA has convened an external Advisory Group consisting of policymakers, scientists, experts and NGOs, to guide the process of development of the report.</p> <p>Another EEA initiative together with JRC, and inspired by the UK Foresight project, is the workshop on infectious diseases and environmental change March 29-30th May 2007 at the ECDC, Stockholm. The ECDC, WHO - Europe, EEA and JRC are the organisers of this exploratory workshop with scientists, public health practitioners and other advocates. The overall workshop objective is to assess the implication of climate and ecological changes on the communicable disease burden in Europe and develop strategic policy measures and strategies for member states.</p>
International Science and Technology Centre (ISTC)	
<p>ISTC welcomes the opportunities for new research partnerships between Commonwealth of Independent States (CIS) and UK organisations that might be stimulated by the outputs of the Foresight project. ISTC will work with OSI to help catalyse such joint activity and will co-host an event to promote the development of UK-CIS partnerships on zoonoses.</p>	<p>The ISTC and OSI co-hosted a conference at the Royal Society on 10 May 2006, under the auspices of the UK-Russian Joint Commission on Science & Technology Collaboration, to promote scientific collaboration between scientists and technology developers. This was an important part of OSI International Directorate's Science and Innovation strategy for the Russian Federation and the wider CIS. Following this successful event, ISTC pledged to undertake similar activity with OSI in the future and to develop further partnerships and complementary work in</p>

the field of infectious diseases both in the UK and in the CIS.

Annex B

FORESIGHT INFECTIOUS DISEASES ACTION PLAN WORKING GROUP (FIDAP-WG)

Members

Department for Environment, Food and Rural Affairs (Defra)

Dr Steven Hill, Science Directorate – Chair

Dr Ruth Lysons, Surveillance, Zoonoses and Emerging Issues Division

Dr Stephen Hunter, Plant Health

Dr Kenneth O’Callaghan, Science Directorate - Secretariat

Clair Taylor, Science Directorate - Secretariat

Office of Science and Innovation (OSI)

Allan Mayo, Technology Strategy Assessment Unit

Alan Monks, International Directorate

Ministry of Defence (MOD)

Wing Commander Andy Green

Defence Science and Technology Laboratory (Dstl)

Dr Richard Scott

Department for Transport (DfT)

Jonathan Mosedale, Research and Technology Strategy Division

Department for International Development (DfID)

Dr Stewart Tyson, Head of Health Profession

National Security Advice Centre (NSAC)

Dr Rebecca Bowden, S&T Co-ordinator

Health Protection Agency (HPA)

Dr Catherine Arnold, Genomics Unit

Biotechnology and Biological Sciences Research Council (BBSRC)

Dr Nigel Brown, Head Science and Technology Group

Medical Research Council (MRC)

Dr Peter Dukes