



Government  
Office for

**Science**

 Foresight

# **Wider Implications of Science and Technology (WIST) Programme**

Report of Findings

Foresight Horizon Scanning Centre, Government Office for Science

[http://www.foresight.gov.uk/HORIZON\\_SCANNING\\_CENTRE/index.html](http://www.foresight.gov.uk/HORIZON_SCANNING_CENTRE/index.html)

This report is published by the Foresight Horizon Scanning Centre. The views expressed in it are those of the participants in the WIST programme, are independent of Government and do not constitute Government policy.

The Horizon Scanning Centre gratefully acknowledges the time and effort put into the WIST programme by the participants, and those involved in running the programme. In particular, Pippa Hyam, Andrew Ackland, Dr Amy Sanders and Hannah Vernon, the facilitation team from Dialogue by Design, Gary Kass and Karen Folkes from the DIUS Science in Society Directorate, and the project's science writer, Aisling Irwin.

## 1. Executive Summary

The Wider Implication of Science and Technology (WIST) programme is intended to help Government better prepare for a future in which the safety, health, environmental, ethical, regulatory and social implications of developments in science and technology will have a major influence on whether and how they are used. It recognises that most developments in science and technology both offer benefits and pose risks. It has been conducted in response to Recommendation 21 of the joint report on nanotechnologies produced by the Royal Society and the Royal Academy of Engineering in July 2004. The WIST programme's large scale, broad scope, wide range of consultative and engagement processes, and involvement of both stakeholders and the public distinguish it from previous consultative activities about future developments in science and technology.

Views on the safety, health, environmental, ethical, regulatory and social implications of a wide range of new and emerging areas of science and technology were sought. More than 300 stakeholders and organisations were consulted in facilitated workshops and online. In addition, over 3100 members of the public participated in Sciencewise's programme of public engagement on the future direction of science and technology: *sciencehorizons*. This comprised a deliberative panel, and both facilitated and unmanaged discussions in over 430 events throughout the UK over a period of 6 months.

In addition to identifying implications of new and emerging areas of science and technology, views were obtained on how Government should respond whether by legislation, investment, or providing advice. Views were particularly sought on which topics should be considered for further public engagement.

The consultations and public engagement activities produced a substantial number of views and opinions which are synthesised in this report. They are presented in the form of issues – of which there are 61 – that, for communication purposes were brought together into 16 themes:

- Theme 1.** Ascent of the expert patient
- Theme 2.** Better modelling enhances social and environmental understanding
- Theme 3.** Brain imaging finds multiple non-medical applications
- Theme 4.** Consequences of rapid technological change
- Theme 5.** Direction of some biological research
- Theme 6.** Enhancement of the mind and body
- Theme 7.** Exponential increase in medical advances
- Theme 8.** Health, safety and environmental effects of new materials
- Theme 9.** Information systems profoundly change social interaction
- Theme 10.** Longevity surpasses predictions
- Theme 11.** My robot: guide, labourer and friend
- Theme 12.** Need for energy leadership
- Theme 13.** Rise of complex systems
- Theme 14.** Sustaining human characteristics in an engineered world
- Theme 15.** Technology as an environmental and social saviour
- Theme 16.** The end of privacy?

An example of a theme's constituent issues is:

- Theme 16.** The end of privacy?
  - Issue 1: Fear of monitoring by the state
  - Issue 2: Public health jeopardized by privacy issues
  - Issue 3: Policing by employers
  - Issue 4: Use of information by commercial organisations
  - Issue 5: Youth and privacy: a special case

The report makes clear which of the various groups of participants raised each specific point. This provides an audit trail for those who wish to discern similarities or differences between the views of different groups. The themes are not presented in order of priority, although a number of areas where views were particularly frequently or strongly expressed are identified.

There were calls for long-term public engagement exercises on science and technology in general (of which the *sciencehorizons* programme reported here is an example) and for public engagement on three general topics related to science and technology: public trust in science, the pace of change in society driven by developments in science and technology, and vulnerability from reliance on complex systems. In addition, there were calls for public engagement on the following specific topics related to science and technology:

- i. Climate change
- ii. Health, genetics and related areas of biology
- iii. Human enhancement
- iv. Information systems and social impact
- v. Nanotechnologies
- vi. National energy production options
- vii. Privacy
- viii. Robotics
- ix. Technologies for sustainability

The issues on which views were particularly frequently or strongly expressed were:

- **Direction of certain areas of biological research.** Research areas such as genetic modification, synthetic biology and human fertilisation were perceived by many people as being likely to offer significant health benefits whilst raising concern about possible risks and other issues. There were many calls for public engagement on these issues and support for opportunities to be created for the public to influence the direction of relevant research.
- **Enhancement of the human mind and body.** Enhancement techniques such as cognitive drugs, lifestyle drugs, drugs for sporting prowess and ultimately brain-computer interfaces raised social, safety and ethical issues for many people. Public engagement on techniques to enhance the body and mind, particularly of children and in sport, was considered to be essential.
- **New materials.** Excitement about advanced materials (such as nanomaterials, biocompatible materials, smart materials, high-performance materials, nanofoods and remanufacturable goods) was tempered with caution about their potential health, safety and environmental consequences. Some participants considered it very important for the advancement of nanotechnologies that debate amongst the public occurs now. However, others pointed out that such consultation had already taken place, but that the topic had not yet seized the public imagination.
- **Non-medical uses of brain imaging.** Many participants felt very strongly about non-medical uses of brain imaging: some argued for legislation that would prohibit such applications, especially neuro-marketing<sup>1</sup>. Others argued for public debate on the topic.

- **Privacy.** This issue was raised at virtually every consultation. Although the safety and security benefits of widespread surveillance were recognised, the single most commonly expressed concern, raised by stakeholders, and by the public in the *sciencehorizons* programme, was privacy. Many commentators felt that they had a right not to be monitored; they feared draconian and ubiquitous state policing, and considered that the state's vested interests clashed with their own. Engagement was called for on all technologies that threaten privacy, particularly surveillance. There was also support for engagement to communicate the benefits of, and developments in, tracking, and for Government to listen to citizens' concerns and be prepared to compromise.
- **Public engagement.** There was clear enthusiasm and support for broad public engagement exercises about the future of science and technology (such as *sciencehorizons*) and calls for public engagement on a number of general topics – such as the public trust in science – as well as specific topics (including those mentioned above).
- **Robots.** Regulation is likely to be necessary at some point, although participants considered it is unclear at present what form it should take. However a specific review of the implications of the use of robots in warfare on the law of armed conflict (*jus in bella*), on Rules of Engagement, and on training for military and security personnel was called for.

These findings, and the others presented in detail in this report, provide a substantial and distinctive body of viewpoints and opinion relevant to a wide range of policy areas. This material will help the Government to decide which areas need further action, and what that action should be.

## Endnotes

<sup>1</sup>Neuro-marketing is commercial marketing activity which uses measurements of cognitive activity.

<b>Executive summary</b>	<b>2</b>	Theme 13. Rise of complex systems	<b>52</b>
<b>Contents</b>	<b>6</b>	Theme 14. Sustaining human characteristics in an engineered world	<b>53</b>
<b>Foreword by the Government Chief Scientific Adviser (tbc)</b>	<b>8</b>	Theme 15. Technology as an environmental and social saviour	<b>54</b>
<b>1. Introduction</b>	<b>9</b>	Theme 16. The end of privacy?	<b>56</b>
<b>2. WIST material and its structure</b>	<b>13</b>	<b>5. Topics for public engagement</b>	
<b>3. Summary of findings</b>		General areas of science and technology	
Introduction	15	a. Public trust in science	60
Key findings	15	b. Pace of change	61
Titles of the sixteen themes and their constituent issues	16	c. Vulnerability from reliance on complex systems	61
Titles of topics for public engagement	20	Specific topics	
Summary of the sixteen themes	20	i. Climate change	62
Summary of public engagement topics	26	ii. Health, genetics and related areas of biology	62
Issues where no suggestions or recommendations were made	29	iii. Human enhancement	63
<b>4. Full findings of the WIST programme</b>		iv. Information systems and social impact	63
Introduction	34	v. Nanotechnologies	64
Terminology	34	vi. National energy production options	64
The sixteen WIST themes, their component issues and participants' views of how Government should respond to each issue:		vii. Privacy	65
Theme 1. Ascent of the expert patient	35	viii. Robotics	66
Theme 2. Better modelling enhances social and environmental understanding	37	ix. Technologies for sustainability	66
Theme 3. Brain imaging finds multiple non-medical applications	38	<b>Annexes:</b>	
Theme 4. Consequences of rapid technological change	39	<b>A. Details of the WIST programme and process</b>	<b>67</b>
Theme 5. Direction of some biological research	40	<b>B. Participants in WIST events and activities</b>	<b>71</b>
Theme 6. Enhancement of the mind and body	41	<b>C. Horizon Scanning Centre's eight science and technology "clusters"</b>	<b>79</b>
Theme 7. Exponential increase in medical advances	43	<b>D. WIST workshop stimulus material</b>	<b>83</b>
Theme 8. Health, safety and environmental effects of new materials	43	WIST workshop workbook (published separately)	
Theme 9. Information systems profoundly change social interaction	44	<b>E. Range of possible Government responses</b>	<b>84</b>
Theme 10. Longevity surpasses predictions	47		
Theme 11. My robot: guide, labourer and friend	48		
Theme 12. Need for energy leadership	50		

## Foreword



The potential for science and technology to improve our quality of life is very substantial. New discoveries in research and their application in new technologies offer better treatments for health, improved protection for our environment and a better standard of living for millions of people. However, the opportunities that many new developments may bring have to be balanced against the risks that their use may also entail. It is therefore important for Government to look broadly across the entire domain of science and technology, to identify potential developments and assess their possible implications. In July 2004, Recommendation 21 of the joint report on nanotechnologies produced by the Royal Society and the Royal Academy of Engineering called for the Government Chief Scientific Adviser to identify and advise on areas where potential health, safety, environmental, social, ethical and regulatory issues may arise from emerging technologies. The Foresight Horizon Scanning Centre was asked by Government to respond and the Wider Implications of Science and Technology (WIST) project was established for this purpose. Its findings are presented in this report.

A major series of consultations and public engagement events were held to identify the implications of major developments in science and technology in the six domains identified in Recommendation 21. The Wider Implications of Science and Technology (WIST) work subsequently captured the views of over 300 stakeholders, and in a related programme of public engagement – DIUS Sciencewise's Sciencehorizons – over 3100 members of the public.

Although many of the issues raised here are, reassuringly, already matters of public debate, the issues identified by the WIST project will help Government prepare better for a future where science and technology will increasingly act as a major driver of change.

I also hope that the findings will make a useful contribution to the debate on the future direction of science and technology. Such debate is essential, and must be founded on good evidence and analysis. I hope that, in addition to raising new issues, the work described in this report will help bring science to life for all those interested in, concerned with, and excited about its future.

Professor John Beddington, Government Chief Scientific Adviser

## Chapter 1. Introduction

This chapter explains why the WIST programme has been carried out, defines its scope, and describes the nature and size of its two major components.

### Background – what WIST is, and why it has been done

Throughout history, science and technology have always been two of the major influences on our lives and on society. Science provides a coherent intellectual discipline to understand, explain, and, in some instances, predict and control. This can lead to familiar practical benefits: science and technology can stimulate wealth-creating industries, improve the longevity and health of humans (and the plant and animal species that support us), underpin security, and facilitate communication and the movement of people and goods. However, many of the same advances in knowledge that lead to these and other benefits also pose risks: established industries can be undermined by new technologies; some modern lifestyles are manifestly less healthy than others. Equally, some technological developments challenge our values and ethical positions and pose threats to the environment. In practice, most developments both pose risks and offer opportunities.

As well as being a major user of science and technology, Government also plays a major role in determining whether, and how quickly, new technologies and developments in science are taken up. However, Government is not the only influence on this process: society can embrace new technology (as it has with mobile communications), or reject it (e.g. the genetic modification of crops).

Many previous reports have examined the potential impact of new developments in science and technology on society. Some have sought the views of specific groups, or focused on particular technologies. One example of the latter was the Royal Society's and the Royal Academy of Engineering's joint "Nanotechnology" Report<sup>2</sup> that was published at a time when it was perceived that the UK Government had not been well-prepared for the potential impacts of new developments in science and technology (e.g. the introduction of food derived from genetically modified plants) or had not responded well initially (e.g. the 2001 outbreak of Foot and Mouth Disease). However, it was also clear at that time that Government could help create the conditions for successful development of controversial technologies through appropriate regulation and other timely responses. The world-leading position of the UK in stem cell research, with growing investment and a public position that is generally supportive of the research, is one such example.

Recognising the need for early intervention by Government to assess the wider implications of new technologies, Recommendation 21 (R21) of the Nanotechnology Report stated: "We recommend that the Chief Scientific Adviser should establish a group that brings together representatives of a wide range of stakeholders to look at new and emerging technologies and identify at the earliest possible stage areas where potential health, safety, environmental, social, ethical and regulatory issues may arise and advise on how these might be addressed."

In its response<sup>3</sup>, the Government stated that the Chief Scientific Adviser would oversee a process to be carried out by the Foresight<sup>4</sup> Horizon Scanning Centre, in the Government Office for Science<sup>5</sup>, that will, "...inform the Government's strategy for public engagement with science to identify at the earliest possible stages where potential health, safety, environmental, social, ethical and regulatory issues may arise and advise on how these might be addressed." This process

has been achieved through the Horizon Scanning Centre's "Wider Implications of Science and Technology" (WIST) programme, which is reported here.

The rationale for the WIST programme is that risks and opportunities offered by new science and technology can often be anticipated, and favourable outcomes are more likely, if the risks and opportunities are identified and prepared for at an early stage. Horizon scanning is increasingly recognised in Government and elsewhere as an essential tool for this purpose and for informing strategies, policies, and priorities across the policy spectrum.

### Scope of the WIST programme

The scope of the WIST programme is slightly broader than that envisaged by Recommendation 21 of the Royal Society's and Royal Academy of Engineering's joint "nanotechnology" report.

Whereas Recommendation 21 recommends examination of "... *new and emerging technologies...*", the WIST programme encompasses new and emerging areas of both science and technology. This expansion of the scope to assess developments in areas of underlying science, as well as the technologies that flow from new knowledge presented an important opportunity to broaden out the exercise. In addition, although the WIST programme, like Recommendation 21, focuses on the non-economic implications of developments in science and technology, some attention was given to economic factors and their interactions with other domains (e.g. safety, health) by holding joint meetings with committees and groups of the Confederation of British Industry (CBI).

### Summary of WIST programme activities

The WIST programme comprised two integrated workstreams that were conducted in parallel during 2007. The first consisted of a series of workshops and on-line consultations carried out by the Centre involving over 300 stakeholders from Government, industry, academia, NGOs, professional bodies and other organisations.

The second major workstream was a programme of public engagement known as *sciencehorizons*<sup>8</sup>, run by the Science-in-Society Directorate within the Department for Innovation, Universities and Skills (DIUS)<sup>9</sup>. This comprised a national series of conversations with the public about new technologies and how they might affect society in the future. It involved over 3100 members of the public in a diverse programme of 430 engagement activities carried out between January and June 2007 at venues across the UK.

In addition, material was provided to a seminar on the future of work held by the Health and Safety Executive, and the major themes that it identified<sup>10</sup> were incorporated into the findings presented in this report.

Stakeholders were presented with material describing over 70 likely key developments in all areas of science and technology, grouped into eight "clusters". They were asked to identify the safety, health, environmental, ethical, regulatory and social implications, and to indicate how they thought Government ought to respond. They were also asked to identify specific issues where they thought focused public engagement would be desirable.

The public's discussions were informed by a specially prepared set of 16 stories, derived from the clusters, illustrating the possible impact of new and emerging areas of science and technology on familiar aspects of everyday life such as work, leisure, and healthcare in 2025. Participants were

encouraged to express their responses – both positive and negative – to these developments. The stories were available in both printed form, and interactively on the *sciencehorizons* website<sup>11</sup>.

More information about the processes, participants and the clusters of key developments in science and technology is given in Annexes A, B and C, respectively.

The WIST programme's large scale, broad scope, range of consultative and engagement processes, and involvement of both stakeholders and the public distinguish it from previous consultative activities about future developments in science and technology.

### Purpose of the report

This report presents a synthesis of the findings from both the stakeholder and public engagement activities. It describes the key issues raised by these groups, and contains recommendations from those involved about how Government ought to respond. It also identifies a number of areas which participants considered would benefit from further public engagement. The report makes clear which of the various groups of participants raised each specific point. The report does not attempt to describe the actions taken within Government in response to the findings.

### Structure of the report

The nature of the material produced by the various consultations and engagement processes summarised above (and described in full in Annex A), and the way it was organised into a structured set of findings are described in Chapter 2. The titles of the issue, themes and topics that form the findings are listed and then summarised in Chapter 3, and presented in full in Chapter 4. Chapter 4 incorporates the topics about which participants called for public engagement showing the issues they are related to. For clarity, they are also presented separately in Chapter 5.

The WIST processes and participants are described in detail in Annexes A and B, descriptions of the key clusters of developments in science and technology that informed the participants are in Annex C, the workbook prepared for participants at the WIST workshops is in Annex D, and the descriptions of possible Government responses to the issues raised by the participants are in Annex E.

## Endnotes

2 Royal Society and Royal Academy of Engineering Joint Report: 'Nanoscience and nanotechnologies: opportunities and uncertainties'. 29 July 2004.

3 Government response to Royal Society and Royal Academy of Engineering joint report: 'Nanoscience and nanotechnologies: opportunities and uncertainties'. 25 February 2005. [http://www.ost.gov.uk/policy/issues/nanotech\\_final.pdf](http://www.ost.gov.uk/policy/issues/nanotech_final.pdf)

4 The aim of the Foresight Programme is to improve strategy across Government. In a small number of major projects Foresight addresses selected topics where developments in science and technology either pose a challenge or offer opportunities to the UK. The projects are based on the best peer-reviewed evidence. To complement this programme of major science-focused projects, the Foresight Horizon Scanning Centre draws on a wider and more eclectic range of evidence to address the entire spectrum of public policy futures – not just those involving developments in science and technology – in numerous, smaller projects. It also works to raise strategic futures capability across Government.

5 The Government Office for Science is the successor body of the Office for Science and Technology which was the department in existence at the time of the Government's response.

6 For example, "Long-term challenges and opportunities for the UK: analysis for the 2007 Comprehensive Spending Review." HM Treasury. Nov 06. [http://www.hm-treasury.gov.uk/spending\\_review/spend\\_csr07/spend\\_csr07\\_longterm.cfm](http://www.hm-treasury.gov.uk/spending_review/spend_csr07/spend_csr07_longterm.cfm) and the UK's National Security Strategy of March 2008: [http://www.cabinetoffice.gov.uk/reports/national\\_security\\_strategy.aspx](http://www.cabinetoffice.gov.uk/reports/national_security_strategy.aspx)

7 Sutherland, W.J. et al. Future novel threats and opportunities facing UK biodiversity identified by horizon scanning. *Journal of Applied Ecology*, OnlineEarly Articles. Published article online: 20-Mar-2008. doi: 10.1111/j.1365-2664.2008.01474.x

8 [www.sciencehorizons.org.uk](http://www.sciencehorizons.org.uk) This website contains full details of the process and findings of this workstream.

9 DIUS was formed from part of the former Department of Trade and Industry (DTI) in July 2007.

10 <http://www.hse.gov.uk/research/rrhtm/rr600.htm>

11 <http://www.sciencehorizons.org.uk/interactive.asp>

## Chapter 2. WIST material and its structure

This chapter describes the nature of the material obtained from the WIST consultations and engagements, and the way it was processed to formulate the findings (which are summarised in Chapter 3 and reported in full in Chapter 4).

The numerous events and engagement activities outlined in the previous section, described in full in Annex A, produced a mass of material, all of it opinion and viewpoint. No attempt was made to quantify it for further analysis. However, because of the way the events had been structured, the raw material was in a consistent and coherent format which made the elucidation of key findings a relatively straightforward, albeit large, task.

Material from the two workstreams of stakeholder consultations and public engagement was pooled, and a total of 61 separate issues were identified through a process of aggregating similar views and comments expressed at the multiple separate events. In framing the issues, emphasis was put on ensuring that they looked to the future, and summarised what were thought to be the key points of likely developments. This process tried to strike a balance between recording the authenticity of the views of the participants, which naturally were not always expressed with the clarity and precision that can be achieved in a considered piece of writing, and over-interpretation to fit perceptions of the current *zeitgeist*. An indication of the extent to which the issues were not "shoe-horned" into the current framework is that few of the 61 fit neatly within existing UK Government departmental boundaries.

The themes and their constituent issues are listed at the start of the next chapter. A small number of issues appear in more than one theme and are indicated by an asterisk.

**Theme 1.** Ascent of the expert patient

**Theme 2.** Better modelling enhances social and environmental understanding

**Theme 3.** Brain imaging finds multiple non-medical applications

**Theme 4.** Consequences of rapid technological change

**Theme 5.** Direction of some biological research

**Theme 6.** Enhancement of the mind and body

**Theme 7.** Exponential increase in medical advances

**Theme 8.** Health, safety and environmental effects of new materials

**Theme 9.** Information systems profoundly change social interaction

**Theme 10.** Longevity surpasses predictions

**Theme 11.** My robot: guide, labourer and friend

**Theme 12.** Need for energy leadership

**Theme 13.** Rise of complex systems

**Theme 14.** Sustaining human characteristics in an engineered world

**Theme 15.** Technology as an environmental and social saviour

**Theme 16.** The end of privacy?

An example of a theme, and its constituent issues is:

**Theme 16.** The end of privacy?

Issue 1: Fear of monitoring by the state

Issue 2: Public health jeopardized by privacy issues

Issue 3: Policing by employers

Issue 4: Use of information by commercial organisations

Issue 5: Youth and privacy: a special case

In considering the issues and themes, and the suggestions and recommendations associated with them that are presented in the rest of this report, it is important to recognise that an inevitable consequence of conducting a consultation on a broad topic with a wide range of disparate groups, using a number of different techniques, is that this report has a style and content that differs from, say, a comprehensive analysis of a single issue conducted by a committee of experts. In particular:

- There are a number of instances where some suggestions and recommendations are not fully consistent with others.
- There may appear to be omissions:
  - some issues considered important by others may not have been of concern to WIST participants;
  - not every issue that was raised generated a call for action, or a suggestion about how Government ought to respond.
- The views of the participants:
  - do not necessarily take into account aspects of an issue that would be of particular concern to Government. For example, a recommendation by WIST participants to make health tests based on advances in genetic testing freely available did not include the provisos that such tests have a low rate of both “false positives” and “false negatives”, and have a proven and cost-effective role in health protection;
  - conversely, many include recommendations for action by Government that Government may not accept are its responsibility. For example, participants called for scrutiny of the appropriateness of models used to enhance understanding of the environment. In other instances, such as dealing with the possible isolating influences of some information systems on groups, such as the elderly, much would need to be done in partnership with other bodies.
  - are not always expressed in the context of other, related work that may already be in progress.
- Not all views have been captured, but strongly or widely held views, suggestions and recommendations have been faithfully conveyed in this report, even if, like the statement, “Since we cannot foresee all the situations robots will work in, it would be necessary to prove that they behave safely in all potential environments”, those recommendations appear unachievable.

## Chapter 3. Summary of findings

This chapter lists the titles of the themes and issues that form the findings of the WIST programme and the titles topics on which there were calls for public engagement. Key findings are presented and the themes and issues are summarised, together with the key suggestions and recommendations for action by Government that were made. The issues for which there were no suggestions or recommendations are described and further categorised.

### Introduction

At virtually every consultation during the WIST process, there was excitement and optimism about future technologies and developments in science, and the benefits they could bring. There was a broad consensus that some could help mankind meet major challenges of the future, such as those posed by population growth, climate change and the destruction of ecosystems, and that they could further enhance the quality of life.

However, there were also widely-held concerns about possible adverse consequences of new technologies and scientific developments. There was a conviction that a strong guiding hand from Government, involving both regulation and investment in some cases, would be needed if new technologies were to achieve their potential and if the possible disadvantages were to be avoided or minimised.

### Key findings

A small number of key findings are presented first in order to give a flavour of the results early on in the chapter. They are the areas where views were particularly frequently or strongly expressed.

- **Direction of certain areas of biological research.** Research areas such as genetic modification, synthetic biology and human fertilisation were perceived by many people as being likely to offer significant health benefits whilst raising concern about possible risks and other issues. There were many calls for public engagement on these issues and support for opportunities to be created for the public to influence the direction of relevant research.
- **Enhancement of the human mind and body.** Enhancement techniques such as cognitive drugs, lifestyle drugs, drugs for sporting prowess and ultimately brain-computer interfaces raised social, safety and ethical issues for many people. Public engagement on techniques to enhance the body and mind, particularly of children and in sport, was considered to be essential.
- **New materials.** Excitement about advanced materials (such as nanomaterials, biocompatible materials, smart materials, high-performance materials, nanofoods and re-manufacturable goods) was tempered with caution about their potential health, safety and environmental consequences. Some participants considered it very important for the advancement of nanotechnologies that debate amongst the public occurs now. However, others pointed out that such consultation had already taken place, but that the topic had not yet seized the public imagination.
- **Non-medical uses of brain imaging.** Many participants felt very strongly about non-medical uses of brain imaging: some argued for legislation that would prohibit such applications, especially neuro-marketing. Others argued for public debate on the topic.

- **Privacy.** This issue was raised at virtually every consultation. Although the safety and security benefits of widespread surveillance was recognised, the single most commonly expressed concern raised by stakeholders, and by the public in the *sciencehorizons* programme, related to privacy. Many commentators felt that they had a right not to be monitored: they feared draconian and ubiquitous state policing, and considered that the state's vested interests clashed with their own. Engagement was called for on all technologies that threaten privacy, particularly surveillance. There was also support for engagement to communicate the benefits of, and developments in, tracking, and for Government to listen to citizens' concerns and be prepared to compromise.
- **Public engagement.** There was clear enthusiasm and support for broad public engagement exercises about the future of science and technology (such as *sciencehorizons*) and calls for public engagement on a number of general topics – such as the public trust in science – as well as specific topics (including those mentioned above).
- **Robots.** Regulation is likely to be necessary at some point, although participants considered it is unclear at present what form it should take. However a specific review of the implications of the use of robots in warfare on the law of armed conflict (*jus in bello*), on Rules of Engagement, and on training for military and security personnel was called for.

### Titles of the sixteen themes and their constituent issues

The process described in chapter 2 generated 61 issues. In the majority of cases, participants made suggestions or recommendations for how Government should respond.

The 61 issues were grouped into 16 themes for ease of presentation. However, it did not prove possible to generate a set of entirely mutually exclusive themes, so a small number of issues appear in two themes. An example of one of these overlapping issues is “*Our relationships with robots*”. There were a sufficient number of separate issues related to developments in robots from the findings to form a theme which was labelled “*My robot: guide, labourer and friend*.” However, another group of issues formed a separate theme that was labelled “*Being human in an engineered world*”. This extended far beyond developments in robotics, so, clearly, most of the issues within it could not be subsumed into the robotics theme. However, equally clearly, the issue of “*Our relationships with robots*” formed part of the theme of “*Being human in an engineered world*”. This issue was therefore placed in two themes, as were a small number of other issues which are indicated with an asterisk in the list of titles below.

#### Theme 1. Ascent of the expert patient

- Issue 1: Increasing demands on health resources\*
- Issue 2: Preventive health opportunities in non-traditional sectors
- Issue 3: Need for new sources of support
- Issue 4: Uncovering mental health problems
- Issue 5: Protecting children
- Issue 6: Insurance: difficulties obtaining health insurance

#### Theme 2. Better modelling enhances social and environmental understanding

- Issue 1: More enlightened action
- Issue 2: Over-interpretation and abuse of models
- Issue 3: Over-reliance on models, systems and databases

#### Theme 3. Brain imaging finds multiple non-medical applications

- Issue 1: Unregulated use
- Issue 2: Side effects of imaging

#### Theme 4. Consequences of rapid technological change

- Issue 1: Dealing with growing numbers of excluded
- Issue 2: Legal, regulatory and insurance systems struggle
- Issue 3: Ethical systems struggle to keep up
- Issue 4: Safety in the workplace

#### Theme 5. Direction of some biological research

- Issue 1: Permissibility of research
- Issue 2: Confusion about biology

#### Theme 6. Enhancement of the mind and body

- Issue 1: Runaway competition
- Issue 2: Long-term health
- Issue 3: Mental health
- Issue 4: Enhancement challenges concepts of normality
- Issue 5: Social acceptability of enhancement
- Issue 6: Increasing demands on health resources\*

#### Theme 7. Exponential increase in medical advances

- Issue 1: Increasing demands on health resources\*
- Issue 2: Medicalisation of marginal dysfunctions\*

### Theme 8. Health, safety and environmental effects of new materials

- Issue 1: Nanomaterials present unknown risks
- Issue 2: Nanofoods
- Issue 3: Health effects of biocompatible materials
- Issue 4: Re-manufacturable and recyclable materials
- Issue 5: Health effects of widespread radiation

### Theme 9. Information systems profoundly change social interaction

- Issue 1: Potential to change public behaviour
- Issue 2: Increased democratic participation affects every department
- Issue 3: Increased educational participation
- Issue 4: Scope for reducing conflict
- Issue 5: Isolation from real human interaction\*
- Issue 6: Blurring of working and personal lives
- Issue 7: Information overload in every sector
- Issue 8: Identity poses complex legal and ethical challenges

### Theme 10. Longevity surpasses predictions

- Issue 1: A new phase of life
- Issue 2: Languishing in the Seventh Age of Man\*

### Theme 11. My robot: guide, labourer and friend

- Issue 1: Robots in the military and police
- Issue 2: Robot autonomy and responsibility
- Issue 3: Human emotional responses to robots
- Issue 4: Threats to jobs

### Theme 12. Need for energy leadership

- Issue 1: Urgent need for vision and strong leadership
- Issue 2: Huge potential for energy efficiency\*
- Issue 3: Persuade the public about climate change

- Issue 4: Support for conserving energy and the need for control
- Issue 5: Ethics of carbon storage
- Issue 6: Need to hone tools for international negotiations
- Issue 7: Responses to climate change should be evidence-based

### Theme 13. Rise of complex systems

- Issue 1: Collapse of systems
- Issue 2: Public backlash against complex systems

### Theme 14. Sustaining human characteristics in an engineered world

- Issue 1: Biocomputers versus humans
- Issue 2: Distanced from our basic needs
- Issue 3: Using technology to reinvent ourselves
- Issue 4: Human enhancement\*
- Issue 5: Our relationship with robots\*
- Issue 6: Our place in the automated world\*

### Theme 15. Technology as an environmental and social saviour

- Issue 1: Need for scientific and technological literacy
- Issue 2: Need for public trust in science
- Issue 3: Need to foster technologies whose primary aim is to increase sustainability rather than create wealth or improve health\*
- Issue 4: Technological help for the developing world
- Issue 5: Technology could transform life for the elderly\*

### Theme 16. The end of privacy?

- Issue 1: Fear of monitoring by the state
- Issue 2: Public health jeopardized by privacy issues
- Issue 3: Policing by employers
- Issue 4: Use of information by commercial organisations
- Issue 5: Youth and privacy: a special case

## Titles of public engagement topics

A specific aim of the WIST programme was to identify areas of science and technology in which public engagement might be beneficial.

These fell into two categories: general topics about science and technology - such as public trust – and specific topics – such as human enhancement.

The general topics were:

- a. Public trust in science
- b. Pace of change
- c. Vulnerability from reliance on complex systems

These were incorporated into calls for long-term public engagement exercises on science and technology in general (in other words, programmes like *sciencehorizons*).

There were also calls for public engagement on the following specific topics:

- i. Climate change
- ii Health, genetics and related areas of biology
- iii. Human enhancement
- iv. Information systems and social impact
- v. Nanotechnologies
- vi. National energy production options
- vii. Privacy
- viii. Robotics
- ix. Technologies for sustainability

## Summary of the 16 themes (see Chapter 4 for full version)

Theme 1. **Ascent of the expert patient:** A greatly increased amount of health-related information<sup>12</sup> is likely to become available over the next decade and beyond, much of it from sources other than conventional health services.

This could lead to:

- Enormous consequent demands on health resources.
- Preventive health opportunities in non-traditional sectors.
- Need for new sources of support, for example counselling on preventive health.
- New tools for uncovering mental health problems.
- Knowledge of personal health trajectories available to children.
- Cohorts of people who are unable to obtain health insurance.

**Key recommendations:** Reconsider the “contract” between patient and health service, giving greater responsibility to the patient for looking after their health; consider attaching health

counsellors to general practices; exploit opportunities offered by the commercial sector, for example health-testing in supermarkets.

Theme 2. **Better modelling enhances social and environmental understanding:** Improved data collection, analysis and decision-making could lead to a better understanding of environmental, social and health issues leading to improved interventions.

This could lead to:

- More enlightened social engineering, health and environmental action.
- Over-interpretation and abuse of models of social behaviour; to, for example, serve political or other agendas.
- Over-reliance on models, systems and databases that may be flawed.
- Unacceptable invasions of privacy (in the interests of collecting the data to serve these models).

**Key recommendations:** Establish ethics panels to oversee the use of modelling technologies; invest in aspects of systems and modelling that could improve our understanding of the factors influencing environmental change.

Theme 3. **Brain imaging finds multiple non-medical applications:** Employers, the police, judiciary, and advertisers may find applications for brain imaging. This may bring benefits but also raises concerns.

In particular:

- Unregulated use could lead to unsafe convictions; abuse by the military; the invasion of privacy and, through the use of neuro-marketing, unacceptable levels of manipulation for commercial gain.
- Radiation from imaging could cause harm that is not justifiable for commercial, lifestyle, legal or other non-medical reasons.

**Key recommendations:** Many participants felt very strongly about this issue and some argued for legislation that would prohibit many non-medical applications of neuro-imaging, especially neuro-marketing. Others argued for public debate on the topic.

Theme 4. **Consequences of rapid technological change:** New technologies may bring simultaneous changes to numerous important areas common to the lives of most individuals, such as: medical care; the nature of the workplace; our capacity to alter and enhance our physical and cognitive characteristics; how we interact with each other; longevity; the degree of automation in society; the way we obtain and use energy and how we regulate, use and interact with artificial intelligence and perhaps even new life forms.

Consequences may include:

- Growing numbers of the socially-excluded.
- Difficulties in keeping pace with new developments for legal, regulatory, insurance and ethical systems, and other structures that need to respond to technological change, including those that explain it to the non-scientific community.
- Challenges to safety in the workplace.

**Key recommendations:** Explore how technologies could be harnessed to promote inclusion rather than exclusion; consider, at a philosophical level, how regulatory systems may need to change;

consider reorienting social and economic support structures to incorporate a focus on wellbeing and happiness.

**Theme 5. Direction of some biological research:** Predictions of our ability in the future to manipulate genomes, create animal-human hybrid embryos and patent embryos, create genetically modified plants and animals, synthesise organisms and parts of organisms, and change our food through nanotechnology are perceived by many as being likely to offer significant health benefits whilst being disconcerting to many others.

In particular:

- Some participants questioned why researchers are allowed to work in areas of science and technology where outcomes might be unacceptable to many.
- Many of the participants in the *sciencehorizons* programme of public engagement felt confused about biological sciences and felt this confusion impeded their ability to judge the issues.

**Key recommendations:** There were many calls for public engagement on these issues raised by biological developments and support for opportunities to be created for the public to influence the direction of relevant research.

**Theme 6. Enhancement of the mind and body:** Enhancement techniques, such as cognitive drugs, lifestyle drugs, drugs for sporting prowess and, ultimately, brain-computer interfaces, raise social, safety and ethical issues for many people.

In particular:

- There could be runaway competition in the workplace, in sport, in social life and even between nations.
- There may be long-term health effects.
- A quest for perfection may lead to significant pressures on mental health.
- There may be a loss of a collective sense of the normal range for human performance and capability.
- Enhancement may widen social divisions if it was available only to the affluent, but if it were cheap, or an entitlement, it could be an equalising force.
- Health resources are likely to be stretched.

**Key recommendations:** Public engagement is vital in order to understand which elements of enhancement are the most controversial. This should be undertaken over the longer term in order to detect changes in public sentiment. Some participants felt very strongly that this area should be highly regulated.

**Theme 7. Exponential increase in medical advances:** Significant advances in areas of medicine such as neuroscience, genetics, prosthetics and diagnostics are expected over the next decade and beyond.

Consequences are likely to include:

- An increasing strain on health resources.
- The medicalisation of marginal dysfunctions.

**Theme 8. Health, safety and environmental effects of new materials:** Excitement about advanced materials (such as nanomaterials, biocompatible materials, smart materials, high-performance materials, nanofoods and remanufacturable goods) should be tempered with caution about their

potential health, safety and environmental consequences.

In particular:

- Nanomaterials present unknown risks; techniques for measuring and monitoring nanoparticles are underdeveloped.
- Food engineered at the nanoscale – “nanofoods” – presents abundant opportunities, but potential risks should not be ignored, and might lead to the “next GM” (in the sense that the public may reject the technology).
- Health effects of biocompatible materials: nanoscale bio-mimetic materials offer great potential for regenerative medicine, but could have unforeseen effects on health.
- New re-manufacturing and recycling industries may reduce consumption of energy and raw materials, but may be high-risk environments for employees in these sectors.
- Electromagnetic radiation from a range of new technologies could damage health.

**Key recommendations:** Government may need to introduce new regulations in response to the development of many of these new technologies; there was a strong demand for public engagement on nanotechnologies.

**Theme 9. Information systems profoundly change social interaction:** The “always-on”, hyper-connected nature of society, that many already see occurring, and which is likely to continue to grow, will allow people permanent access to high-quality information on many topics; displays will integrate with our lives; virtual worlds may merge with the real.

Consequences include:

- Potential to change public behaviour.
- Possible increased participation in democratic processes.
- Potential for increased educational participation.
- Scope for reducing conflict.
- Isolation from real human interaction.
- Blurring of working and personal lives.
- Information overload in every sector.
- Issues of identity may pose complex legal and ethical challenges.

**Key recommendations:** Conduct research into the ramifications of these changes; investigate how these technologies can be directed towards useful social ends and away from those that cause harm.

**Theme 10. Longevity surpasses predictions:** Life expectancy might far surpass current expectations and spans.

Consequences include:

- Decades of healthy, active, retired life could present a social and economic resource.
- Decades of chronic ill-health, and the social and economic consequences, could cause society to re-examine how we deal with the end of life.

Theme 11. **My robot: guide, labourer and friend:** Robots endowed with autonomy, intelligence and perhaps some emotional intuition may have abundant uses but the notion of them was generally greeted with incredulity or fear.

In particular:

- Robots in the military may make it more likely that wars will be started whilst increasing the potential for casualties amongst the opposition and non-combatants.
- Robot autonomy, and responsibility for robots, will pose legal and ethical challenges.
- Human emotional responses to robots are complex, and may, for example, exacerbate the neglect of basic responsibilities to the old and young.
- Robots may erode job security.

**Key recommendations:** These focused mostly on the need for further investigation of, and reflection on, the issues above through, for example, public engagement and demonstration projects. Although regulation is likely to be necessary at some point, it is unclear at present what form it should take. However a specific review of the implications of the use of robots in warfare on the law of armed conflict (*jus in bello*), on Rules of Engagement, and on training for military and security personnel was called for.

Theme 12. **Need for energy leadership:** Many new technologies could go some way towards meeting society's energy needs and/or mitigating environmental impacts, but participants from most sectors (including the public, industry and stakeholders) feel little is being done to achieve this.

In particular:

- There is an urgent need for vision and strong leadership from Government to drive forward a new era for energy.
- There is huge potential to implement measures to improve energy efficiency, but this is largely, it was felt, being ignored.
- The public feels uninformed, and in some cases, unconvinced, about climate change.
- The public wants to be helped to take individual action to conserve energy.
- Storing carbon dioxide was felt to raise inter-generational ethical issues analogous to those related to the burying of radioactive waste.
- Mechanisms for international negotiations needed to be made more effective.
- Responses to climate change should be evidence-based.

**Key recommendations:** Government should boldly support a selection of new energy and environmental technologies; Government must decide the degree to which its response to climate change is to be centralised and the degree to which it is to be left to the individual; public engagement is vital on the challenges of climate change; Government should harness social science in the quest to alter individual behaviour.

Theme 13. **Rise of complex systems:** The world is likely to be more "joined-up" with an increasing number of decisions made by agent-based software drawing on interlinked and disparate databases supplied by an expanding number of sensors that will be widely distributed and embedded in materials, objects and the environment. As a result, decision-making and the control of numerous complex systems which will run and influence many aspects of our lives will involve humans

to a lesser and lesser extent. This was considered to be an existing trend that would continue indefinitely.

Consequences could include:

- Complex systems and systems of networks can show unplanned emergent behaviours and are vulnerable to collapse in unexpected and unpredictable ways with extensive consequences.
- A public backlash against complex systems is possible because our culture prizes individual autonomy.

**Key recommendations:** Government needs to examine the underlying, often hidden, assumptions on which society is based as a first step towards dealing with such problems, and to find ways of ensuring that redundancy is built into complex systems in order to improve their resilience against unexpected occurrences in the future.

Theme 14. **Sustaining human characteristics in an engineered world:** Some developments in future decades may challenge the notion of what it is to be human and alter our ideas of normality and authenticity.

In particular:

- Biocomputers, derived from biological materials, may "think" in a manner very similar to that of humans and so challenge human identity.
- Increasing isolation of people from the natural world may be damaging to health in hitherto unperceived ways.
- Several areas of technology may allow us to overcome some physical and mental constraints.
- Human enhancement may test our collective sense of what is normal.
- Robots may undermine the matrix of social obligations
- Automated decision-making may be perceived as a threat to human autonomy.

Theme 15. **Technology as an environmental and social saviour:** Science and technology could provide creative solutions to the challenges posed, for example, by climate change, population growth, food security and the collapse of ecosystems. However, more needs to be done to create the right conditions for innovation, including explicit recognition by Government of science as a tool for public good, as well as wealth creation<sup>14</sup>. Such an acknowledgement might allow Government greater freedom to foster technologies that have the potential to benefit society and/or the environment, as well as encouraging the public to have trust in science.

In particular:

- There is a need for scientific and technological literacy, particularly at management level in organisations.
- There is a need for public trust in scientists and in science.
- There is a need to foster technologies that have the potential to offer major benefits in responding to climate change, conserving biodiversity, and reacting to other major environmental challenges.
- We should give more technological help to the developing world, particularly in fields such as renewable energy and water purification.
- We should direct technology to transform life for the elderly.

**Key recommendations:** Some global problems might be more likely to be solved if the purpose of science was acknowledged by Government to be furthering the science as a tool for public good, as well as wealth creation.

Theme 16. **The end of privacy?:** There are deep and widespread reservations about the future of privacy in a world permeated by surveillance, “sousveillance” and enduring digital footprints.

In particular:

- There was fear of monitoring by the state.
- Public health might be jeopardised by privacy issues.
- Employers may be able to monitor their staff in great detail.
- The uses to which personal information could be put by Government and commercial organisations are still unclear.
- The young may relinquish privacy online and face adverse consequences later in life.

**Key recommendations:** Government should consider distancing itself from personal information about its citizens by creating independent information repositories run by guardians of the public interest. Government should embrace imaginative technological solutions to issues of data privacy. Government should consider commissioning a major independent study of privacy issues.

## Summary of public engagement topics

(see Chapter 4 for full versions embedded in the themes and issues from which the topics arose, and Chapter 5 for the full topics presented separately for ease of assimilation).

Scientists need to keep the public informed about their work and to listen to their aspirations and concerns. Public engagement is one way of doing this. It differs from public education by being a dialogue, rather than a one-way process. One of the aims of the WIST Programme was to discover which areas of science and technology might benefit from public engagement.

The general topics were:

### a. Public trust in science

Broadly-based trust in scientists will be vital in order to help solve global problems arising from population growth.

Many of the members of the public on the *sciencehorizons* deliberative panel felt that the consultation had awoken in them a conscience about scientific issues and a feeling of connection with the governance of the country. They called for Government to stimulate public debate, channel positive information about research to the public, and outreach into the community. There was a call for engagement with the public to be embedded in the process of technology assessment as early as possible. (*Public: deliberative panel*)

### b. Pace of change

The “have-nots” and the “skill-nots” may be joined by an increasing group of “will-nots”.

There was a need to help people, through engagement, accept change as a constant and positive force, and to encourage them to look within themselves and their communities to promote wellbeing for all. (*Strategic futures analysts*)

### c. Vulnerability from reliance on complex systems

The failure of ubiquitous complex networks, with poorly understood emergent properties, could plunge society into crisis. (*Commentators: workshops; senior commentators; CBI science and innovation panel; strategic futures analysts: business workshop*)

Some called for constant, long-standing public engagements and better science education; others felt engagement with the public is inadvisable as there are so many unanswered questions. (*Commentators: workshops*)

These general topics were incorporated into calls for long-term public engagement exercises on science and technology in general (in other words, programmes such as *sciencehorizons*).

There were also calls for public engagement on the following specific topics:

#### i. Climate change

Some members of the public do not believe in anthropogenic climate change; others are confused by the science underlying climate change and are seeking clarity on the messages they hear.

Engagement with the public is desirable to educate them about generalities as well as specifics such as methods to reduce individual carbon footprints. (*Public: deliberative panel*)

#### ii. Health, genetics and related areas of biology

There were calls for public engagement on a number of related topics within the area of health and the disciplines of genetics and biology. These are presented together because of the close links and overlap between some of their constituent technologies

- As patients increasingly gain health-related information from non-traditional sources, some patients could become isolated from support in the face of potentially disturbing new health information about themselves. (*Senior commentators; public: deliberative panel*)
- Public engagement to strengthen people's capacity to deal with information about their genetic profile. Encourage debate on the ethical issues raised by genetic testing, its applications, and the use to which the results will be put by individuals, industry and Government. (*Strategic futures analysts*) [see also “Human enhancement” below]
- The potential for unregulated use of brain imaging led to calls for an urgent debate on the use of neuro-imaging outside medicine to be required urgently. (*Commentators: workshops*)
- Some participants questioned why researchers were allowed to continue working in several fields of biological research (e.g. genetic modification, synthetic biology and the creation of animal-human hybrids) where outcomes might be so unacceptable to so many. (*Public: deliberative panel; public: facilitated discussions; commentators: workshops*)
- Public discussion of these issues was considered to be vital, to help people grasp the implications and to get a sense of what might be controversial<sup>15</sup>. (*Commentators: workshops*)

### iii. Human enhancement

Techniques to enhance the body and mind, particularly of children and in sport, raised disquiet. (*Commentators: workshops; public: deliberative panel*)

Public engagement was considered to be essential to help people grasp the implications and to enable society to get a sense of what might be controversial. Discourse will need to be long term to help people realise the possible implications. (*Commentators: workshops*)

[see also "Genetics" above]

### iv. Information systems and social impact

If people develop the skills to access, analyse and use information, democratic participation might increase. (*Commentators: workshops*)

Engagement exercises should be used to develop best practice so people have positive experiences of contributing to policy development. (*Strategic futures analysts*)

### v. Nanotechnologies

The long-term effects of advanced materials on health, on the environment and on each other are not understood. (*Commentators: workshops*)

Some commentators considered it very important for the advancement of this emerging technology that debate amongst the public occurs now. (*Commentators: online survey*)

However, it was pointed out that such consultation had already taken place, but that the topic had not yet seized the public imagination. (*Senior commentators*)

### vi. National energy production options

Public debate is currently polarised, with the media presenting new technologies as a potential answer, then "proving" that they cannot meet future energy requirements. This activity is propagating a cynical view that alternative technologies will not work, whereas the media could be a forum for an energy debate that could accompany a process of public engagement (*Commentators: online survey*)

### vii. Privacy

Many commentators felt that they have a right not to be monitored: they fear draconian and ubiquitous state policing, and consider that the state's vested interests clash with their own. (*Senior commentators; public: deliberative panel; public: facilitated discussions; strategic futures analysts; commentators: workshops; commentators: online survey*)

Engagement was called for to communicate the benefits of, and developments in, tracking, but Government should also listen to citizens' concerns and be prepared to compromise. (*Strategic futures analysts*)

Engagement was also called for on all technologies that threaten privacy, and in particular on surveillance. Participants thought the public would be sceptical about the robustness of new security systems. (*Commentators: workshops*)

### viii. Robotics

There are already concerns about robots, and there could be a public backlash if preparation does not begin now. (*Commentators: workshops; Commentators: online survey; Public: deliberative panel; Public: facilitated discussions*). This should include public consultations. (*Public: deliberative panel*)

### ix. Technologies for sustainability

Many technologies whose principal potential benefit is increased sustainability<sup>16</sup> need fostering if that potential is to be realised.

Engagement is required to educate consumers so that they can make informed choices about whether to buy goods and services that cause greater or lesser harm to the environment. (*CBI science and innovation panel*)

## Issues where no suggestions or recommendations were made

There were a number of issues, listed below, where there were no suggestions or recommendations for Government action.

### Theme 1. Ascent of the expert patient

Issue 5: Protecting children

### Theme 2. Better modelling enhances social and environmental understanding

Issue 3: Over-reliance on models, systems and databases

### Theme 3. Brain imaging finds multiple non-medical applications

Issue 2: Side effects of imaging

### Theme 5. Direction of some biological research

Issue 2: Confusion about biology

### Theme 6. Enhancement of the mind and body

Issue 3: Mental health

### Theme 7. Exponential increase in medical advances

Issue 1: Increasing demands on health resources

Issue 2: Medicalisation of marginal dysfunctions

### Theme 8. Health, safety and environmental effects of new materials

Issue 2: Nanofoods

Issue 3: Health effects of biocompatible materials

Issue 5: Health effects of widespread radiation

### Theme 9. Information systems profoundly change social interaction

Issue 4: Scope for reducing conflict

### Theme 11. My robot: guide, labourer and friend

Issue 4: Threats to jobs

### Theme 12. Need for energy leadership

Issue 4: Support for conserving energy and the need for control

Issue 6: Need to hone tools for international negotiations

**Theme 14. Sustaining human characteristics in an engineered world**

**Issue 3: Using technology to reinvent ourselves**

**Theme 15. Technology as an environmental and social saviour**

**Issue 1: Need for scientific and technological literacy**

**Issue 5: Technology could transform life for the elderly**

**Theme 16. The end of privacy?**

**Issue 3: Policing by employers**

Examination of the detail of the issues (presented in chapter 4) reveals a significant number where the appropriate action is self-evident, but, for some reason, was not made or was not recorded. An example is:

**Theme 2. Better modelling enhances social and environmental understanding**

**Issue 3: Over-reliance on models, systems and databases:** Models need to be valid, verifiable and robust, based on a full understanding of the principles governing the system that is being modelled and how the system alters as a result of external influences. As we are drawn ineluctably into dependence we may overlook the risks that poor quality data (and poor modelling) tend to lead to poor quality analysis and results. Undesirable consequences might include individuals being plagued by inappropriate outcomes flowing from decisions based either on inaccurate data held about them or invalid assumptions about their behaviour or other characteristics. (*Commentators: online survey*)

In this case, appropriate Government responses might include investment in research to define rigorous validation, verification and accreditation techniques<sup>17</sup> for data, models and systems, and regulation to require their use in some circumstances.

Similarly, the nature of at least part of the appropriate Government response that participants might have been expected to call for is fairly clear in the following cases:

**Theme 7. Exponential increase in medical advances**

**Issue 1: Increasing demands on health resources**

**Theme 8. Health, safety and environmental effects of new materials**

**Issue 2: Nanofoods**

**Issue 3: Health effects of biocompatible materials**

**Issue 5: Health effects of widespread radiation**

**Theme 11. My robot: guide, labourer and friend**

**Issue 4: Threats to jobs**

**Theme 12. Need for energy leadership**

**Issue 4: Support for conserving energy and the need for control**

**Issue 6: Need to hone tools for international negotiations**

**Theme 15. Technology as an environmental and social saviour**

**Issue 1: Need for scientific and technological literacy**

**Issue 5: Technology could transform life for the elderly**

**Theme 16. The end of privacy?**

**Issue 3: Policing by employers**

A number of issues remain where the possible nature of Government response is less obvious. These are reproduced in full below.

**Theme 1. Ascent of the expert patient**

**Issue 5: Protecting children:** Can we balance the child's right not to know about his or her likely future health trajectory against the potential for early intervention to divert or prevent the onset of disease? If so, how? (*Public: deliberative panel*)

**Theme 3. Brain imaging finds multiple non-medical applications**

**Issue 2: Side effects of imaging:** The side effects of radiation might be justified in a medical context but would need to be considered afresh in settings where brain imaging is used for commercial, lifestyle or legal reasons. (*Commentators: online survey*)

**Theme 5. Direction of some biological research**

**Issue 2: Confusion about biology:** The public reported overload and confusion in these areas of biological research, particularly in genetics. They expressed multiple fears and many indicated that they did not understand the issues. Some wanted to have the responsibility for choices removed from them, while others questioned whether such work should continue at all. (*Public: deliberative panel; public: self-managed groups*)

**Theme 6. Enhancement of the mind and body**

**Issue 3: Mental health:** Regarding enhancement as normal may cause significant pressures for some groups (for example employees under pressure to enhance themselves in order to improve their performance at work). Mental health might also be affected in more unexpected ways, for example from the information overload that might result from bio-computing interactions. (*Senior commentators*)

**Theme 7. Exponential increase in medical advances**

**Issue 2: Medicalisation of marginal dysfunctions:** A new medical interpretation of marginal dysfunctions or conditions that people previously tolerated or did not even see as afflictions may be developed. Treatments may be designed to combat them. (*Commentators: online survey*) [see also Theme 6 (Enhancement of the mind and body).]

**Theme 9. Information systems profoundly change social interaction**

**Issue 4: Scope for reducing conflict:** New information technologies could help develop and build political consensus, making it easier for politicians to prioritise. (*Senior commentators*) There is potential to increase mutual understanding and reduce conflict, integrating diverse

communities. However, defining national identity when information, and its interpretation, is obtained from global sources may be a growing problem. (*Commentators: workshops; commentators: online survey*)

#### Theme 14. Sustaining human characteristics in an engineered world

**Issue 3: Using technology to reinvent ourselves:** Several forms of technology, ranging from virtual worlds to a variety of enhancements, will encourage people to question constraints on their appearance, or on their abilities, that they have hitherto accepted. In this sense, technology could be a source of liberation from existing identity. (*Strategic futures analysts: business workshop*)

Many of these issues appear rather vague compared to the issues for which action was recommended. This could be because the issues were poorly expressed, captured or formulated during the WIST process, or it could be because these issues are unusually complex and genuinely contain more elements of uncertainty than the majority of issues. This latter explanation is supported by the observation that many of them contain ethical dilemmas, which tend to be inherently complex and uncertain.

Many of these issues are related to how we should regard our minds and our bodies – and how, and in what circumstances, we should intervene to repair or enhance their functionality. This points to the particular difficulties and uncertainty, and hence importance, of Government maintaining an effective horizon scanning capability in these areas.

#### Endnotes

12 In order to keep this summary chapter short, and to avoid repetition, much of the amplifying and illustrative material (in this instance, examples of “health-related information”) is not given in this chapter, but is reserved for Chapter 4 – full results.

13 Neuro-marketing is commercial marketing activity which uses measurements of cognitive activity.

14 This view suggests that Government may need to strengthen the communication of its long-standing commitment to funding science, through the Research Councils, in a way that recognises the value of intellectual exploration and the generation of knowledge in all areas, rather than being tightly tied to specific areas of benefit such as wealth creation.

15 The HFEA launched in April 2007 a public consultation on whether or not scientists should be allowed to create embryos containing animal DNA for embryo research.

16 Sustainability was a word commonly used by numerous participants. It is taken to mean an approach to managing the world’s resources which meets the needs of the present without compromising the ability of future generations to meet their own needs (derived from the World Commission on Environment and Development, *Our Common Future*, 1987: “The Brundtland Report”).

17 VERIFICATION: testing to ensure that there are no deviations from the intended design caused by errors in the model structure, the data or the software. VALIDATION: testing the agreement between the behaviour of the model and the real system in the context of the purpose(s) for which the model has been designed. ACCREDITATION: the official certification that a model or simulation is acceptable for use for a specific purpose.

## Chapter 4. Full findings of the WIST programme

This chapter describes in full the findings of the WIST programme. The terminology used in the findings is explained. The sixteen themes, their component issues and participants' views of how Government should respond to each issue are described in full. The descriptions of topics for which public engagement was called for are included, but these are also presented separately in chapter 5.

### Introduction

As described in Chapter 2, the views and opinions expressed in the stakeholder consultation events and online survey run by the Horizon Scanning Centre were combined with those from the hundreds of meetings which formed the sciencehorizons programme of public engagement on the future direction of science and technology.

From these views and opinions a total of 61 separate issues were identified and grouped into 16 themes, and a number of topics on which further public engagement was felt to be desirable were identified.

The titles of the themes and issues were listed and summarised in the previous chapter. In this chapter, each theme is described in a separate section containing a summary of the principal possible future developments in science and technology; the issues raised by participants about the safety, health, environmental, ethical, regulatory and social implications of those developments; and, in most cases, the responses to those issues that participants felt Government ought to consider.

### Terminology

#### Action

The label "Action" is used to describe the gamut of possible Government responses suggested or recommended by participants to deal with most of the issues they raised. Options included the following (which are not all mutually exclusive):

- Legislate/regulate
- Make policy changes
- Advise
- Invest (including investment in research)
- Enable/convene
- Consult/deliberate
- Participate in international debate
- Laissez-faire
- Engage with the public

Each of these responses, with examples, is described in Annex E which was given to workshop participants, and to facilitators, to make them aware of the range of possible responses that were open to Government, and to help participants and facilitators structure the discussions.

### Groups

The specific group of WIST participants (e.g. participant at a stakeholder workshop or a facilitated discussion of members of the public) from which a viewpoint, opinion, suggestion or recommendation came is shown in italics at the end of each issue and action. The 8 different groups are described in Annex B.

### The sixteen WIST themes, their component issues and participants' views of how Government should respond to each issue

#### 1. Ascent of the Expert Patient

**Background:** Anticipated developments in the next 15 – 20 years mean that a patient is likely to have the opportunity to be appraised of important health-related features of his or her genome. People are likely to have access to a wide array of diagnostic tests and implanted devices monitoring important aspects of their physiological and biochemical status. Online health information will be much more sophisticated than now and might extend to personalised advice and opportunities to buy many more treatments than are currently available. These changes may displace the GP as the main focus of primary health care. For example, supermarkets might set up health booths offering customers rapid genetic and diagnostic tests, followed by printed, personal advice

**Issue 1: Increasing demands on health resources:** A more knowledgeable patient is likely to be a more demanding one. Health services are likely to experience significantly increased pressure for tests, preventive medicine and treatments. Health professionals will need greater technical literacy in order to compete with lower quality information emanating from other sources, and to satisfy the need to identify, search, find and evaluate the right information at the right time. *(Commentators: workshops; commentators: online survey; senior commentators; public: deliberative panel; public: facilitated discussions; CBI science and innovation panel)*<sup>18</sup> [Theme 7 (Exponential increase in medical advances) Issue 1 (Increasing demands on health resources).]

#### Action<sup>19</sup>:

*Consultative/Deliberative:* Monitor the issue. Examine the boundaries between public and private health care, between what is deemed by Government to be essential health care and what is additional. *(Commentators: workshops)*

*Policy Change:* Consider whether the "contract" between the patient and the health service could evolve to give the patient greater responsibility for looking after their own health – for example, limiting access to treatment unless the patient can show they have undergone certain tests and acted on the results. *(Public: deliberative panel)*

*Invest:* In equipping health professionals with relevant technical literacy skills that will support them in making clinical decisions. *(Commentators: workshops)*

**Issue 2: Preventive health opportunities in non-traditional sectors:** The availability of better, earlier, personalised health information will offer the opportunity to help people take steps to prevent ill-health action outside traditional healthcare settings in venues such as supermarkets,

virtual worlds and other settings, both state and commercial. (*Senior commentators; CBI science and innovation panel*)

**Action:**

*Legislative/Regulatory:* Make high-quality diagnostic tests freely available. (*Public: deliberative panel*)

*Invest:* Consider attaching a counsellor or other professional to every primary health care practice in order to manage changed patient demand for preventive care and advice. Compare the costs of such an initiative with altering the role of the GP to adapt to new patient needs. (*Senior commentators*)

Government could collaborate with businesses exploiting the market potential of such systems. For example, it could give discounts to consumers whose results advise an increase in fruit consumption. (*Senior commentators*)

Consider the cost-benefit trade-off of using new diagnostic tests to develop annual health “MOTs”. (*Senior commentators*)

**Issue 3: Need for new sources of support:** If there is indeed a trend away from the GP as the main provider of primary care, some patients could become isolated from support in the face of potentially disturbing new health information about themselves. It is unclear how people would respond to this kind of information, so new support structures, such as additional health counsellors, may be needed. (*Senior commentators; public: deliberative panel*)

**Action:**

*Legislative/Regulatory:* Regulate on the sale of over-the-counter (OTC) and internet tests. (*Commentators: workshops*)

*Invest:* See suggestions of “counsellors” above.

Government needs to act to safeguard the patient in such scenarios – providing the resources for counselling, or for referral to an expert. (*Senior commentators*)

*Public Engagement:* Strengthen people’s capacity to deal with information about their genetic profile. Provide information to the community about the safety of new relevant health technologies. Encourage debate on the ethical issues raised by genetic testing, its applications, and the use to which the results will be put by individuals, industry and Government. (*Strategic futures analysts*)

**Issue 4: Uncovering mental health problems:** Some commentators fear that the widespread availability of tests may expand the cohort of “worried well”. Others contend that hypochondria is in reality the socially acceptable expression of an underlying, and less socially acceptable, mental health problem, and that an expansion in self-testing might reveal that large numbers are suffering from conditions such as depression. (*Senior commentators*)

**Action:**

*Advisory:* Take advantage of “supermarket diagnosis” by advising (or requiring) the inclusion of three simple questions in over-the-counter tests – questions known to reveal existing mental health problems. The answers to these questions could lead to a score (expressed perhaps in socially acceptable language such as “stress quotient”) that the patient could use as a basis for action. (*Senior commentators*)

*Invest:* In research aimed at developing an understanding of how people respond to information about their current and future health. (*Commentators: workshops*)

**Issue 5: Protecting children:** Can we balance the child’s right not to know about his or her likely future health trajectory against the potential for early intervention to divert or prevent the onset of disease? If so, how? (*Public: deliberative panel*)

**Issue 6: Insurance: difficulties obtaining health insurance:** An expanding cohort of people may be unable to obtain insurance cover. (*Commentators: workshops*). Appropriate regulation to restrict the information to which companies are allowed access may lead to resolution of this issue. It is important for insurers to know that they all have access to the same range and depth of health-related information. (*Senior commentators*)

**Action:**

*Consultative/Deliberative:* Consider new paradigms for health insurance. (*Commentators: workshops*)

## 2. Better modelling enhances social and environmental understanding

**Background:** Improvements in sensors and other technologies for data collection, developments in networks and information management, and a better understanding of brain science and other factors (e.g. genetic and environmental) that shape human behaviour could combine to provide a better understanding of complex health, social and environmental issues and relationships such as the links between diet, lifestyle & physical health, or between environment, education, life-experience, and mental health. Our understanding of such relationships relies on identifying and quantifying the sources of variation. A specific example is that the ability to understand the variability introduced by genetics through accurate genotyping will allow environmental effects (which are manipulable) to be more easily identified. Developments in mathematics, modelling and simulation will in turn make the visualisation and comprehension of these complex relationships more tractable. Potential applications are widespread. Examples include increasing use of modelling in place of animal testing, use of social identity theory in conflict management, and simulations and gaming in contingency planning and other areas.

**Issue 1: More enlightened action:** New developments within this theme could be applied in a wide variety of health-related, social and environmental areas, to produce better-informed decisions both by individuals, and potentially by policy-makers and regulators. (*Commentators: workshops; senior commentators*) As a specific example, non-medical neuro-imaging to reveal brain function could lead to new approaches to working with socially-excluded adolescents and re-engaging them in society. (*Strategic futures analysts*)

**Action:**

*Invest:* Fund more research on neurological development in adolescence. (*Strategic futures analysts*)

Invest in the infrastructure required to improve our understanding of the complex factors influencing environmental change; invest in demonstration projects to show what could be possible. Government must ensure the best computing power is available for environmental modelling, in order to help researchers understand ecosystem breakdown, global warming and flooding. (*Commentators: online survey*)

*Consultative/Deliberative:* Use advances in modelling to investigate social issues such as the influence of violent games and virtual reality on behaviour. (*Strategic futures analysts*)

**Issue 2: Over-interpretation and abuse of models:** Models, simulations and game theory could be subverted to suit political or religious aims (producing “results” that are skewed). For example, models might be used to describe behaviours – such as groups of teenagers regularly gathering

after dark in urban centres – as “anti-social”, resulting in the stigmatisation of some individuals and groups, when in many circumstances such behaviour is nothing of the sort. (*Commentators: online survey*)

**Action:**

*Policy change:* The appropriateness of potential models should always be subject to scrutiny. Transparency in modelling methodologies, objectives and applications should be required. Extend the use of ethical review panels, as is required in many other research areas, to cover these aspects. (*Commentators: online survey*)

**Issue 3: Over-reliance on models, systems and databases:** Models need to be valid, verifiable and robust, based on a full understanding of the principles governing the system that is being modelled and how the system alters as a result of external influences. As we are drawn ineluctably into dependence we may overlook the risks that poor quality data (and poor modelling) tend to lead to poor quality analysis and results. Undesirable consequences might include individuals being plagued by inappropriate outcomes flowing from decisions based either on inaccurate data held about them or invalid assumptions about their behaviour or other characteristics. (*Commentators: online survey*)

### 3. Brain imaging finds multiple non-medical applications

**Background:** Advances in our understanding of how the brain functions, coupled with improvements in our ability to analyse the brain at the level of the cell, will enhance the diagnosis and monitoring of physical and mental states. Theories of learning, and hence education, may be transformed. Reliable markers for recognition, memory, lying and some emotional states may be identified. Researchers are exploring the use of fMRI (functional magnetic resonance imaging) to monitor what people perceive when they view certain images. Ultimately it may be able to identify individual thoughts. Some predict that, in the future, we might not be able to hide our opinions from others.

**Issue 1: Unregulated use:** Although highly regulated in the field of medical research, brain imaging may leak into the wider, more permissive world. The technology could be of use to employers, the police, judiciary, and advertisers. Although there may be benefits, issues such as the invasion of privacy, over-interpretation of scientific data, and, in the case of neuro-marketing, unacceptable levels of manipulation of people for commercial gain would raise serious concerns. (*Commentators: workshops*)

**Action:**

*Legislative/Regulatory:* Some commentators considered that brain imaging techniques should be permissible for well-regulated criminal justice and military purposes, although others disagreed. There were calls to legislate against the non-medical, commercial use of neuro-imaging, and in particular to prohibit neuro-marketing (provided a demonstrable effect is confirmed). (*Commentators: workshops; commentators: online survey*)

*Consultative/Deliberative:* Ensure that the dangers that might arise from over-interpreting and misinterpreting information from scans are understood and highlighted. (*Commentators: workshops*)

*Public Engagement:* A debate on the use of neuro-imaging outside medicine is required urgently. (*Commentators: workshops*)

**Issue 2: Side effects of imaging:** The side effects of radiation might be justified in a medical context but would need to be considered afresh in settings where brain imaging is used for commercial, lifestyle or legal reasons. (*Commentators: online survey*)

### 4. Consequences of rapid technological change

**Background:** New technologies are expected to be introduced over the next decades at an increasing pace, bringing intense and simultaneous changes to many areas of people's lives, including: medical care; the nature of the workplace; our understanding of consciousness, sentience and other concepts that help explain our sense of self; our capacity to alter and enhance our physical and cognitive characteristics; how we communicate with each other; human longevity; the degree of automation in society; the way energy is obtained and used and how we regulate, use and interact with artificial intelligence and perhaps even new life forms. Institutions, groups and individuals may find it hard to cope with such rapid change.

**Issue 1: Dealing with growing numbers of excluded:** The “have-nots” and the “skill-nots” may be joined by an increasing group of “will-nots”. This last category of people may refuse to use new technologies for numerous reasons: dislike of the speed of change (many elderly people, who will be increasingly numerous, may join this group); paranoia fostered by abundant security monitoring systems; the rejection of human enhancement; a desire for privacy. All three groups may become unable to participate in mainstream society, economically marginalised and possibly inaccessible to Government. (*Commentators: workshops; public: deliberative panel; public: facilitated discussions; HSE workshop; CBI science and innovation panel*)

**Action:**

*Invest:* Equip children with the ability to appraise the engineered world from a critical perspective. (*Senior commentators*)

*Consultative/Deliberative:* Explore how new and existing technologies could be harnessed to promote inclusion, rather than drive exclusion. (*Senior commentators*)

*Public Engagement:* Help people accept change as a constant and positive force; encourage them to look within themselves and their communities to promote wellbeing for all. (*Strategic futures analysts*)

**Issue 2: Legal, regulatory and insurance systems struggle:** New technologies may arrive so quickly, and economic competition with less regulated nations may become so great, that it may be hard even to investigate all of the potential health, safety and other concerns that may be raised. Conceptual changes in the regulatory system may be necessary. For example, regulations may need to reflect consequences of actions rather than the actions themselves. (*Commentators: workshops; strategic futures analysts: business workshop*)

**Action:**

*Consultative/Deliberative:* Consider how regulatory and ethical frameworks can be developed in a way that allows for public consultation while keeping pace with rapid developments that may outstrip evolving ethical standards. (*Commentators: workshops*)

Consider to what extent Government departments should be considering the speed of technological change itself to be an issue (for example as a health issue or a safety issue)? Do they have a role as a brake on, or regulator of, change per se? (*HSE workshop*)

**Issue 3: Ethical systems struggle to keep up:** Ethical frameworks may struggle to evolve in the face of fast-paced change. (*Commentators: workshops*) Society may begin to call for a change in the measurement of success away from economic indicators such as GDP and productivity towards more societal models such as wellbeing and happiness. (*Commentators: workshops; senior commentators*)

**Action:**

*Consultative/Deliberative:* Promote research into economic models that create competitive advantage based on wellbeing and happiness as well as growth and productivity. Develop and monitor “wellbeing” indicators. Consider reorienting social and economic support structures to incorporate a focus on wellbeing and happiness. (*Commentators: online survey*)

**Issue 4: Safety in the workplace:** Pervasive computing may lead to a vastly increased number of small enterprises that operate within tight financial margins. They may find it hard to comply with the increased number of health, safety and environmental regulations introduced by Government in response to environmental and technological change. (*HSE workshop*)

**Action:**

*Policy change:* Regulators may need to move towards a single, high-impact, integrated, regulatory intervention in a business. Such an intervention would deal with risk-management and sustainability simultaneously, in a combined environmental, health and safety framework. In some cases these combined aims may clash – the safest approach, for example, is not necessarily the most sustainable. But, in general, a single framework may lead to a wider, more strategic, view. (*HSE workshop*)

## 5. Direction of some biological research

**Background:** Our ability to manipulate aspects of human biology will grow. We will be able to generate stem cells more easily and will create animal-human hybrid cell lines to help attain this goal. We may be able to synthesise organisms, and parts of organisms; enhance human performance through genetic therapies; join living cells with non-living materials to create biomechanical hybrids; create DNA vaccines and perhaps effect germline changes (genetic alterations that pass down generations). Meanwhile, nanotechnology may enable us to manipulate our food in unprecedented ways (by, for example, using food to “smuggle” medicines or other substances into the body, where they can be released in specific tissues, on demand). Genetic modification (GM) of crops and animals will continue to develop.

**Issue 1: Permissibility of research:** Several of these fields might provoke a public backlash: the patenting of human embryos; GM animals and plants (public disquiet is thought not to have diminished); “messing with DNA” (distasteful to public participants); synthetic biology (there is disbelief that scientists could ever build a new organism) and the creation of animal-human hybrids. Some participants question why researchers are allowed to continue working in areas where outcomes might be so unacceptable to so many. (*Public: deliberative panel; public: facilitated discussions; commentators: workshops*)

**Action:**

*Legislative/Regulatory:* Consider whether legislation is adequate to control research within the areas that provoke the most concern: the ability to build lethal pathogens for use as bioweapons, and the containment of new organisms (*Commentators: workshops*). The business practices of the biotechnology industry need to be carefully defined so that ethical problems do not arise. (*Commentators: online survey*).

*Consultative/Deliberative:* Issues such as those described above relating to synthetic biology should be pursued in a designated forum. (*Commentators: workshops*)

*Policy Change:* Consider whether there should be lay input at the early stages of decision-making about research funding. (*Public: deliberative panel*)

Consider whether there are emerging areas of research, other than those already strictly scrutinised (for example by the Human Fertilisation and Embryology Authority), which should also be regulated, or even “off-limits”. (*Public: deliberative panel; commentators: workshops*)

Consider whether the Human Fertilisation and Embryology Authority does enough to alleviate public unease over the use of human embryos in research. Its decisions require openness and accountability, given that it has responsibility for setting, as well as reflecting, the boundaries of acceptable practice. (*Commentators: online survey*)

*Participate in International Debate:* If it becomes possible to profit from research on human embryos, there could be a public reaction against work in this area. Patenting and commercialisation of inventions arising from stem cell research could raise similar issues to those characterising the scientific struggle between private and public research objectives over sequencing of the Human Genome Project. These possible developments would merit considerable international co-operation. (*Commentators: online survey*)

*Public engagement:* Public discussion of these issues is vital, to help people grasp the implications and to get a sense of what might be controversial<sup>20</sup>. (*Commentators: workshops*)

**Issue 2: Confusion about biology:** The public reported overload and confusion in these areas of biological research, particularly in genetics. They expressed multiple fears and many indicated that they did not understand the issues. Some wanted to have the responsibility for choices removed from them, while others questioned whether such work should continue at all. (*Public: deliberative panel; public: self-managed groups*)

## 6. Enhancement of the mind and body

**Background:** Enhancement of the brain (for example with drugs for improving memory or conquering social phobias) and of the body (with undetectable nanodrugs or genetic therapies) could become widespread within a few decades. Enhancement of sporting prowess may become undetectable. Brain-computer interfaces will extend both our mental and physical faculties – initially for the disabled or ill, then to enhance people beyond what is “normal”.

**Issue 1: Runaway competition:** Competition in the workplace, in sport, in social life and even between nations may lead to an enhancement “arms race”. (*Commentators: workshops*)

**Action:**

*Legislative/Regulatory:* (As for issue 2), given the pace of change, many participants felt that it is almost too late to regulate, although an attempt should be made. Drugs for enhancement may need to be classified as prescribed drugs. (*Commentators: workshops; commentators: online survey*)

*Policy change:* Does Government need a stance on enhancement and the 2012 Olympics? (*Commentators: workshops*)

*Participate in international debate:* Particularly with regard to sport, and employment. (*Commentators: workshops*)

**Issue 2: Long-term health:** All forms of enhancement may have long-term, currently unknown health effects. When medicines and other interventions are used to combat disease, their risks may be acceptable. But the risk-benefit calculation will be different when interventions are only for enhancing an individual who is already in good health. (*Commentators: online survey*)

**Action:**

*Legislative/Regulatory:* (As for issue 1), given the pace of change, many participants felt that it is almost too late to regulate, although an attempt should be made. Drugs for enhancement may need to be classified as prescribed drugs. (*Commentators: workshops; commentators: online survey*)

**Issue 3: Mental health:** Regarding enhancement as normal may cause significant pressures for some groups (for example, employees under pressure to enhance themselves in order to improve their performance at work). Mental health might also be affected in more unexpected ways, for example from the information overload that might result from bio-computing interactions. (*Senior commentators*)

**Issue 4: Enhancement challenges concepts of normality:** Enhancement may test our sense of what it is to be human and lead to the loss of a collective sense of what is normal and what is authentic. At the same time, greater genetic knowledge may lead us to consider ourselves to be imperfect versions of a perfect genome, and thus in need of perfecting. Genetic knowledge combined with the tools of enhancement could lead to unethical practices such as eugenics. (*Senior commentators*)

**Action:**

*Legislative/Regulatory:* (As for issue 5), enhancers of performance should remain a technology in medical hands to treat disease states or impairments. They should not be made available to healthy people to give them a competitive edge either in sporting contests or in other competitive situations, such as education or the workplace. (*Commentators: online survey*)

*Public engagement:* (As for issue 5), this is essential to help people grasp the implications and to enable society to get a sense of what might be controversial. Discourse will need to be long term to help people realise the possible implications. (*Commentators: workshops*)

**Issue 5: Social acceptability of enhancement:** There could be considerable public disquiet, particularly on the enhancement of children and in sport. However, conceptual shifts and societal adjustments may gradually occur. (*Commentators: workshop*). If enhancement is available only to the affluent, social divisions could widen and issues of equity may become paramount. Conversely, enhancement could come to be seen as a right (with resource implications) or even an equalising force. (*Commentators: workshops; public: deliberative panel*)

**Action:**

*Legislative/Regulatory:* (As for issue 4), enhancers of performance should remain a technology in medical hands to treat disease states or impairments. They should not be made available to healthy people to give them a competitive edge either in sporting contests or in other competitive situations, such as education or the workplace. (*Commentators: online survey*)

*Public engagement:* (As for issue 4), this is essential to help people grasp the implications and to enable society to get a sense of what might be controversial. Discourse will need to be long-term to help people realise the possible implications. (*Commentators: workshops*)

**Issue 6: Increasing demands on health resources:** The boundary between tackling disease on the one hand, and promoting health and boosting performance on the other is likely to become increasingly blurred. This could lead to disputes about the allocation of resources. (*Commentators: workshops*) [See also Theme 1 (Rise of the expert patient) Issue 1 (Increasing demands on health resources) and Theme 7 (Exponential increase in medical advances) Issue 1 (Increasing demands on health resources).]

**Action:**

*Consultative/Deliberative:* Regular consideration of whether lifestyle drugs should be state-funded may be necessary to avoid the have/have-not divide. (*Public: deliberative panel*)

*Laissez faire:* (A contradictory view to those above) Non-medical enhancement should be available to those who can afford it and should not be funded by the state. (*Public: deliberative panel*)

## 7. Exponential increase in medical advances

**Background:** Advances in our understanding of genetics will bring insight into the fundamental, molecular basis of life. We may be able to redesign life, reprogramming cells or correcting genetic defects. Our understanding of the brain may improve significantly. In the next few decades, medical technology is expected to lead to new and improved diagnostic techniques, advanced prostheses, and the opportunity to grow new tissues and organs.

**Issue 1: Increasing demands on health resources:** Many of these advances are likely to strain the health service. (*Commentators: workshops; commentators: online survey; public: deliberative panel*) [See also Theme 1 (Ascent of the expert patient) Issue 1 (Increasing demand on health resources) and Theme 6 (Enhancement of the mind and body) Issue 1 (Increasing demands on health resources).]

**Issue 2: Medicalisation of marginal dysfunctions:** A new medical interpretation of marginal dysfunctions or conditions that people previously tolerated or did not even see as afflictions may be developed. Treatments may be designed to combat them. (*Commentators: online survey*) [see also Theme 6 (Enhancement of the mind and body).]

## 8. Health, safety and environmental effects of new materials

**Background:** Advanced materials can improve the performance of infrastructure, vehicles and machinery, and reduce their costs. Advances in materials for hostile environments are at the core of much advanced high value manufacturing. Smart materials will be able to change certain properties in response to their surroundings or some other stimulus. One key trend (linked to nanotechnologies) is the embedding of sensors, computing power and communication systems within materials to make them more controllable and connected.

**Issue 1: Nanomaterials present unknown risks:** The long-term effects of advanced materials on health, on the environment and on each other are not understood. The measurement and monitoring of nanoparticles (nanometrology) is an immature science, limiting our understanding of their fate in the body and in the environment. Likewise, is enough known about nanotubes, given the similarity in structure of some nanotubes to asbestos? (*Commentators: workshops*)

**Action:**

*Legislative/Regulatory:* Some commentators think that existing legislation to protect health and safety includes an extensive list of directives and guidelines that could cover the research and development, manufacture and commercialisation of nanomaterials. These could be adapted should future assessments identify the need for additional control (*Commentators: online survey*). Some thought there is an urgent need to ban potentially dangerous areas of nanotechnology; others thought it is too early for regulation in a field where measurement techniques have not yet been developed; a third view was that it will be impossible to regulate nanotechnologies because of the rapid evolution of the field. A solution to this problem may be to introduce generalised regulation which controls those technologies that can be “put into a person without their knowledge”. (*Commentators: workshops*)

*Invest:* Government should focus on nanometrology, risk assessment, and toxicology research. (*Commentators: workshops*)

*Consultative/deliberative:* Given the obstacles facing regulation, some participants thought that the very nature of possible regulation should be debated. Should existing regimes be adapted to incorporate nanomaterials? Would regulation stifle a technology that could bring such benefits? How, in short, should the development and use of nanotechnologies be governed in the light of uncertainty, poor understanding or low public confidence? (*Commentators: workshops*)

*Public engagement:* Risk assessments should be publicised in order to direct responses of the public to nanomaterials onto a more productive course from that of genetically modified plants (*Commentators: workshops*). Some commentators considered it very important for the advancement of this emerging technology that debate amongst the public occurs now. (*Commentators: online survey*) However, it was pointed out that such consultation had already taken place, but that the topic had not yet seized the public imagination. (*Senior commentators*)

**Issue 2: Nanofoods:** The development of food engineered at the nanoscale, for example to insert nutrients or medicines into the digestive tract and thence into the body to be released in a controlled way, presents abundant opportunities for business and for the improvement of human health. However, there was a view that there were also potential risks to health and the environment which the food industry should not ignore. (*Commentators: workshops*).

**Issue 3: Health effects of biocompatible materials:** Materials that mimic biological material, or are compatible with it, offer great potential for regenerative medicine but should be treated with caution as biological systems are considerably less predictable than chemical and mechanical systems. (*Commentators: online survey*)

**Issue 4: Re-manufacturable and recyclable materials:** Materials that are designed to be re-manufactured and reused could cut the amount of energy and raw materials used in manufacture. They will give rise to re-manufacturing and recycling industries that may be high-risk, given the vast variety of toxic materials that will be reprocessed. These industries may employ unskilled workers, possibly migrants, who may not be as well represented by Trade Unions and similar bodies as higher-skilled or more established groups of employees. (*HSE workshop*)

**Action:**

*Invest:* Protecting the health and safety of workers in these industries may require strong intervention. (*HSE workshop*)

**Issue 5: Health effects of widespread radiation:** Medical imaging systems, communication devices, new interfaces and ways of representing data, and many other new technologies, will together subject the body to increased electromagnetic radiation, but the health effects seem to be unclear. (*Commentators: workshops; commentators: online survey*)

## 9. Information systems profoundly change social interaction

**Background:** Cheap, broadband, wireless, “always-on”, mobile services are likely to be pervasive by 2015. People will be able rapidly to obtain good quality information about many topics. Display technology will become more powerful. Virtual worlds that are increasingly “real” may merge with real worlds that are increasingly virtual, thanks to omnipresent sensors, wireless communications and flexible displays. People could be permanently aware of much more than their five senses tell them, for example by wearing head-up displays. Social networks may alter how people converse, what they discover and converse about and the size and nature of their audience.

**Issue 1: Potential to change public behaviour:** These technologies hold immense potential for nurturing public opinion in areas such as the environment and health. Spending power could for example be directed towards “greener” products, thus creating the economic demand industry needs. People may feel that they are able to take more rapid action in an “always-on” society to protect their health. (*CBI science and innovation panel*)

**Action:**

*Policy change:* Use insights generated by research in the social sciences into behaviour, attitudes to change, and the adoption of technology, to support development of public policy. (*Strategic futures analysts: business workshop*)

*Invest:* There is scope for developing systems that harness individual accountability which will also be useful for tackling environmental issues. (*CBI science and innovation panel*)

*Invest; Enable/convene:* Government should participate in getting accurate, reliable, robust and timely information to the citizen. (*CBI science and innovation panel*)

*Consultative/Deliberative:* Consider who should be responsible for facilitating behaviour change. (*Strategic futures analysts: business workshop*)

**Issue 2: Increased democratic participation affects every department:** If people develop the skills to access, analyse and use information, democratic participation might increase. Political activism could expand, with more single-issue organisations, rapidly organised lobbying or even acts of civil disobedience. People might become more involved in local environmental issues. (*Commentators: workshops*)

**Action:**

*Policy Change:* For Government to remain sufficiently connected to those it seeks to govern, it has to be more reactive and responsive to citizens. This may require the redesign of Government structures and decision-making processes. (*Strategic futures analysts*)

*Invest:* In research to better understand, and ultimately harness, this phenomenon. Government could enter virtual worlds such as “Second Life”. (*Commentators: workshops*)

Act to ensure universal access to information sources. (*Strategic futures analysts*)

*Public Engagement:* Educate people in how to access and use knowledge, how to exercise judgement and develop and use critical thinking skills. Experiment with interactive engagement exercises to develop best practice so people have positive experiences of contributing to policy development. (*Strategic futures analysts*)

**Issue 3: Increased educational participation:** There is scope for reaching those currently excluded from education. Technology could be directed towards: developing virtual educational institutions (*Senior commentators; CBI: science and innovation panel*); better learning facilities for the disabled; flexible learning; learning on demand (*Strategic futures analysts: business consultation*); and mobile e-learning for engaging young learners who are not in formal education. (*Commentators: online survey*)

**Action:**

*Invest:* Invest in directing technologies towards these goals. (*Sources as above*)

**Issue 4: Scope for reducing conflict:** New information technologies could help develop and build political consensus, making it easier for politicians to prioritise. (*Senior commentators*) There is

potential to increase mutual understanding and reduce conflict, integrating diverse communities. However, defining national identity when information, and its interpretation, is obtained from global sources may be a growing problem. (*Commentators: workshops; commentators: online survey*)

**Issue 5: Isolation from real human interaction:** Humans need face-to-face relationships within small groups, a requirement that communication technologies seem to undermine. There is a perception of negative impacts which include: the erosion of family relationships; the loss of an important moderating influence on behaviour; and potential depression amongst the elderly (communication technologies may extend their independence at home but may also reduce their direct human contact). Research into blogging indicates that the medium seems to encourage aggressive expression, but participants disagreed over whether it has the potential to increase aggression in society or act as a useful vent for aggression. However, information technologies could, for example, be redirected so that they actually enhance the human experience. (*Senior commentators; commentators: workshops; public: deliberative panel*) [See also Theme 14 (Sustaining human characteristics in an engineered world) Issue 6 (Our place in the automated world).]

**Action:**

*Policy Change:* Government could encourage the development of communication technologies so that they are actually tools for enhancing the human experience. For example, networking technologies could be redirected to help enable flexible working. This might allow a reconstruction of communities based around the home and reinforce the family. (*Senior commentators*)

*Invest:* Following on from the proposals above, harness these technologies to build local infrastructure to support low environmental impact businesses and recreation. Build online communities that substitute for physical movement of goods and people. Enable free, or affordable, access to the internet for the poorest. (*Strategic futures analysts*)

Use new forms of interfaces and representation for extending and improving educational access to support individuals with learning disabilities and similar problems, or use mobile e-learning for engaging school children and those not in formal education. (*Commentators: online survey*)

Invest in more community care workers and explore other approaches to maintain connections with the elderly in the community. (*Commentators: online survey*)

*Research:* Investigate how people may respond to new constraints such as a reduced ability to travel. Research the social and health impacts of spending more time in virtual communities. (*Strategic futures analysts*)

*Public Engagement:* Consider educating people about networking technologies both to encourage their use and to alert them to potential dangers. Care should be taken, however, as educating teenagers about a socially dubious activity can serve merely to alert them to it. (*Senior commentators*)

**Issue 6: Blurring of working and personal lives:** The blurring of the distinction between home and workplace may lead (or force) people to take on more responsibility for ensuring their working environments are healthy and safe. Divisions such as “occupational health” and “social welfare” may lose their meaning, and new, closer working relationships may develop between these sectors in Government. Sectors might operate by taking a more person-centred focus on overall “wellbeing”. (*HSE workshop*)

**Action:**

*Policy Change:* It may become more logical for Government to approach health and welfare from the perspective of the individual rather than the part of Government responsible for these matters. On the one hand, a sectoral approach might make a more holistic, person-centred focus on overall “wellbeing” possible. On the other, responsibility for ensuring health, safety and welfare may increasingly fall to individuals because there is no obvious authority to take the blame. (*HSE workshop*)

**Issue 7: Information overload in every sector:** Information overload is already a severe problem not just for individuals but also for institutions. How are we going to cope with further, massive increases in the demand for, and delivery of, information? (*Commentators: workshops*)

**Issue 8: Identity poses complex legal and ethical challenges:** Identity will be defined in multiple and complex ways as people obtain access to a variety of communities online and choose to present themselves in different ways in different diverse settings. There is the potential to build greater global understanding through these communities, but problems will include identity theft, the difficulties of ensuring people act responsibly in each of the identities they may have developed, and enforcing privacy laws. (*Commentators: online survey*)

**Action (issues 6,7,and 8):**

*Invest/Consultative/Deliberative:* Learn from the scientific community, which has been working within global networks for some time. Study the sociology of online communities to discover their strengths, the ethical codes which govern the behaviour of their members, their organisational features, their development and longevity. (*Strategic futures analysts*)

Research in the social sciences is needed on the implications of networks, in particular: self-moderating networks; how to transfer social functions such as policing from real to virtual worlds; and whether interactions in virtual networks are significantly different from those of the real world. (*Strategic futures analysts*)

## 10. Longevity surpasses predictions

**Background:** A range of medical techniques may permit us to extend the lifespan considerably, further, perhaps, than mainstream studies predict. These innovations could include: improved diagnostics, which are set to transform healthcare by predicting disease before symptoms appear; nanobots which might scour the body, eliminating disease and correcting genetic defects; new and improved prostheses made of biocompatible and biomimetic materials; and the routine replacement of ageing body parts with newly grown ones. Researchers disagree about whether the additional years gained might be spent in poor or reasonable health. Some studies suggest that diseases caused by unhealthy lifestyles will have a negative impact on this trend of increasing longevity.

**Issue 1: A new phase of life:** Assuming extra years of good health, society might benefit from a new phase of life occupied by “AGENTS” (Affluent Geriatrics Empowered by New Technology). Elsewhere in society there are, and will be, gaps which could be met by AGENTS: the voluntary sector will need staff; working families need high quality “surrogate Granny” childcare; the younger workforce needs relief from the pressure to work longer hours; younger people could benefit from mentors. (*Senior commentators*)

**Action:**

*Policy change:* Studies show that people who have done no voluntary work by the age of 40 are unlikely to take it up on retirement. Formulate policies to encourage younger people to participate in voluntary work (for example through their workplace) in order to increase their chances of offering their services on retirement. (*Senior commentators*)

*Consultative/deliberative:* Although the Department for Work and Pensions has responsibility for defining the age of retirement and, with the Government Equalities Office, regulates age discrimination, this is actually a broader, trans-departmental problem that deserves wider consideration. (*Senior commentators*)

Government should review the UK's Opt-Out to the European Working Time Directive. (*Senior commentators*)

Consider how retired people can be used to help fill other gaps in society described above. (*Senior commentators*)

**Issue 2: Languishing in the Seventh Age of Man:** There is almost certain to be a rise in the prevalence of disability, leaving many elderly people occupying a prolonged, low-quality period towards the end of their lives. This trend would increase the burden on health resources. (*Public: deliberative panel; Commentators: online survey*) Health resources might be best directed towards care-and-maintenance interventions (for example joint replacements) over and above those that extend a low-quality life. (*Senior commentators*)

**Action:**

*Policy change:* Encourage, probably through the National Institute for Clinical Excellence (NICE), the prioritisation of care-and-maintenance type interventions such as joint replacement, which prolong the active portion of life, at the expense of interventions that serve only to prolong low-quality life. (*Senior commentators*)

Take measures to encourage the proximity of families. (*Senior commentators*)

Use technology to keep people in their homes for longer. (*Senior commentators*) [see also Theme 15 (Technology as an environmental and social saviour) Issue 5 (Technology could transform life for the elderly).]

*Consultative/deliberative:* There were a few suggestions that issues raised by euthanasia should be considered anew (*Commentators: workshops*) but others dismissed this as unthinkable. (*Senior commentators*)

## 11. My robot: guide, labourer and friend

**Background:** Many robots in the future will not look or behave at all like humans. But some may mimic human appearance, have intelligence and a degree of emotion. A domestic robot might carry out chores, keep its owner safe and offer companionship. The young may grow up with them; the elderly may depend on them. In the public domain, robots could take on responsibility and be given authority. While there is some incredulity in the UK at such a scenario, in South Korea there are plans to put a robot in every home by 2020, and philosophers in that country are developing a code of robot ethics.

**Issue 1: Robots in the military and police:** Robots might reduce losses to military forces, and offer opportunities for riot control. (*Public: deliberative panel*) However, the existence of combat robots

might make politicians more willing to start wars because the likelihood of casualties amongst their military would be reduced, although the likelihood of casualties to the opposing side's military forces, and civilian population, might be increased. (*Commentators: workshops; Commentators: online survey; Public: deliberative panel*)

**Action:**

*Consultative/Deliberative:* Commission a review of the implications of the use of robots in warfare on the law of armed conflict (*jus in bello*), on Rules of Engagement, and on training for military and security personnel. The review should explore responsibility in the case of misuse and malfunction. (*Commentators: online survey*)

*Participate in international debate:* Review international conventions governing armed conflict in the context of this potential development. (*Commentators: online survey*)

**Issue 2: Robot autonomy and responsibility:** Robots have the potential to pose legal and ethical challenges. Who will take responsibility for a robot's actions? Should we impose limits on a robot's autonomy? (*Commentators: workshops; Public: deliberative panel; Public: facilitated discussions*). Since we cannot foresee all the scenarios in which robots will work, perhaps the manufacturer must prove they will behave safely in all potential environments. (*Commentators: online survey*)

**Issue 3: Human emotional responses to robots:** Anthropoid robots evoke disquiet. Some people fear that we may develop an emotional dependence on them, and also fear that robots might usurp us in some way, for example by eliminating the basic tasks that help to give life meaning (although robots that are merely tools are welcome). Many feel that we are already guilty as a society of neglecting the elderly, and sending robots to support them will exacerbate these concerns. (*Public: deliberative panel; Public: facilitated discussions; Commentators: workshops*)

**Action (issues 2 & 3):**

*Legislative/regulatory:* Regulation is likely to be necessary at some point, but it is unclear at the moment what form it should take. (*Commentators: workshops*) Certain forms of robotic research should be prohibited. (*Public: deliberative panel*) We may need to devise certification of the "safe" autonomy of robotic systems rather than just a requirement for them to be tested in particular scenarios. Since we cannot foresee all the situations robots will work in, it would be necessary to prove that they behave safely in all potential environments. (*Commentators: online survey*)

*Invest:* Demonstration projects would help society explore ramifications of developing the wider use of robots. (*Commentators: workshops*)

*Consultative/Deliberative:* Review the capacity of ethical and legal frameworks to keep abreast of developments in robotics, in the way that is being done in South Korea (see "Background" above). (*Commentators: workshops*)

*Public engagement:* There are already concerns about robots, and there could be a public backlash if preparation does not begin now. (*Commentators: workshops*) The public should be consulted about robotics. (*Public: deliberative panel*)

**Issue 4: Threats to jobs:** Robots might replace both unskilled and skilled labour, be able to perform some delicate tasks better than humans do (for example brain surgery), and perform tasks that humans cannot perform. Such possibilities raise fears about employment (*Public: deliberative panel; commentators: workshops*).

## 12. Need for energy leadership

**Background:** Many new technologies could go some way towards meeting society's energy needs and/or mitigating environmental impacts from energy use. They fall into four broad areas: management of energy demand; energy supply and energy storage; transmission and distribution; and mitigation of environmental impacts.

**Issue 1: Urgent need for vision and strong leadership:** Government needs to demonstrate a sense of ambition and urgency similar to that which put man on the Moon, in order to drive forward a new era on energy. (CBI science and innovation panel; commentators: workshops; commentators: online survey; public: deliberative panel; public: facilitated discussions) Many new technologies may fail to prosper without Government support. These include electric cars; biofuelled cars; microgrids; using existing technology to generate and store energy at micro levels; and wave and tidal power. Government must decide on the balance between publicly driven and centralised decision-making on energy. (Commentators: workshops; public: facilitated discussions)

### Action:

*Legislative/Regulatory:* Remove planning obstacles to microgeneration. (Public: deliberative panel)  
Make the use of carbon-friendly products mandatory (Commentators: online survey)

*Invest:* Bold investment in the relevant infrastructure at a timescale that helps nurture appropriate technologies such as hydrogen-fuelled or electric cars, and microgeneration. (CBI science and innovation panel)

*Consultative/Deliberative:* "Big-picture", strategic, thinking is vital: consider the best possible mix of technologies and clarify the role for Government in their development. (CBI science and innovation panel)

*Consultative/Deliberative and Public Engagement:* It is unlikely that there will be a "silver bullet" to combat climate change or to simplify the UK's energy choices: a mix of different technologies will probably be required. Public debate is currently polarised, with the media presenting new technologies as a potential answer; then "proving" they cannot meet future energy requirements. This activity is propagating a cynical view that alternative technologies will not work, whereas the media could be a forum for an energy debate that could accompany a process of public engagement (Commentators: online survey)

*Invest; Enable/Convene:* Government should be poised to recognise and fast-track interesting new technologies that might reduce carbon emissions (for example the proposed "Greenbox" exhaust system to capture carbon dioxide). Full scale demonstrator projects are essential if commercialisation is to be achieved. (Commentators: online survey; commentators: workshops)

*Participate in International Debate:* Tackling climate change internationally will depend on our development of institutions that will facilitate agreement on both emissions and responses in the future. (Senior commentators)

**Issue 2: Huge potential for energy efficiency:** There is enormous theoretical scope for reducing carbon emissions through technologies that increase energy efficiency and there is an imperative to realise this potential. (CBI: science and innovation panel; commentators: workshops; commentators: online survey; public: deliberative panel; public: facilitated consultations). However, there is pessimism about achieving the necessary reductions because success depends on altering people's behaviour (Senior commentators). A few believe that this gloomy prognosis results from a failure on the part of scientists and Government to grasp the sophistication of the social sciences, which can offer

powerful approaches to influencing human behaviour. (Senior commentators) Others believe that the greatest efficiency gains are to be had at the point of source or generation, rather than at the point of use. (Strategic futures analysts: business workshop)

### Action:

*Legislative/regulatory:* Regulate on energy efficiency to facilitate the public's efforts by, for example, compelling manufacturers to design appliances that switch themselves off completely, and making home-working easier. (Strategic futures analysts: business workshop)

Introduce draconian measures for energy efficiency. Incorporate carbon efficiency into taxation. Raise energy prices and allocate compensatory credit to the less well-off. (Public: facilitated discussions; public: deliberative panel)

Introduce measures to address the fact that many potential solutions are uneconomic relative to more polluting behaviours. (Strategic futures analysts: business workshop)

*Policy change:* Decide on the balance between publicly driven and centralised decision making over energy (Commentators: workshops; public: deliberative panel; public: facilitated discussions)

*Invest/Consultative/Deliberative:* Use social science as a tool to develop energy efficiency policies. (Senior commentators)

Invest in non-regulatory interventions such as demonstration projects and procurement policies (CBI science and innovation panel)

Help industry to produce green products by creating demand from the public, and investing in the infrastructure to support new technologies. (CBI science and innovation panel) [see also Theme 15 (Technology as an environmental and social saviour) Issue 3 (Need to foster technologies whose primary aim is to increase sustainability rather than create wealth or improve health).]

Invest in helping households to take action (Public: deliberative panel)

*Advisory:* Help people negotiate around the array of poorly understood alternative technologies. (Public: deliberative panel)

**Issue 3: Persuade the public about climate change:** Some members of the public do not believe in anthropogenic, i.e. man-made, climate change, while others take the view that the idea is a merely a plot perpetuated, for example, by scientists to obtain funds. Others are confused by the science underlying climate change and are seeking clarity on the messages they hear. Regardless of their opinions on climate change, most are concerned about pollution and security of energy supply. (Public: deliberative panel)

### Action:

*Public engagement:* Basic groundwork educating the public about the evidence for, and mechanisms of, climate change, its likely causes, and what can be done about it, including what is available to help people reduce their carbon footprints. (Public: deliberative panel)

**Issue 4: Support for conserving energy and the need for control:** The consultations with the public commonly elicited desires for: subsidised energy efficiency measures linking being green with saving on energy bills; microgeneration, because it confers control and thus seems to promote energy security; increased regulation to force other sectors (business, government) not to waste energy. (Public: deliberative panel) Some, however, worried about climate change coupled with confusion about the array of possible green technologies, called on Government to take decisions on their behalf. (Public: deliberative panel; Public: facilitated discussions)

**Issue 5: Ethics of carbon storage:** Storing carbon dioxide raises intergenerational ethical issues similar to those of burying radioactive waste. (*Commentators: online survey*)

**Action:**

*Consultative/Deliberative:* There is an urgent need to address the implications, both practical and regulatory, of carbon capture and storage. (*Commentators: online survey*)

**Issue 6: Need to hone tools for international negotiations:** Tackling climate change internationally will depend on the quality of the institutions that are developed for brokering deals on problems in the future. This is an area where social scientists believe they could make a major contribution in providing solutions. (*Senior commentators*)

**Issue 7: Responses to climate change should be evidence-based:** There have been some responses to climate change, such as congestion charging, that are based on scant evidence of efficacy, and that may even increase carbon production. (*Strategic futures analysts: business consultation*)

**Action:**

*Invest:* In life cycle analysis and other approaches. (*Commentators: workshops; strategic futures analysts: business consultation*)

### 13. Rise of complex systems

**Background:** The “joined-up” world will emerge, thanks to expanding bandwidth, greater and more distributed processing power, larger datasets, smaller sensors and greater understanding of the dynamics of physical, virtual and human networking behaviour. Technologies allowing data mining and pattern recognition will help us deal with the rapid growth of datasets. Radically smarter search engines may swiftly elicit highly specific information. Agent-based software may devolve decision-making away from humans – providing “intelligent personal support” through, for example, wireless technology and software that can understand speech.

**Issue 1: Collapse of systems:** Complex networks, and systems of networks, can show unplanned emergent behaviours. Interdependent systems are being created that even their designers cannot comprehend. Systems are being built and databases created without an understanding of the social dynamics of the organisations that use them. Systems may fail, through sabotage or by accident, in unpredicted and unpredictable ways. Because of their ubiquity, such failure could plunge society into crisis. (*Commentators: workshops; senior commentators; CBI science and innovation panel; strategic futures analysts: business workshop*)

**Action:**

*Consultative/Deliberative:* Examine the underlying, usually hidden, assumptions on which society is built, for example that disease will not cause the elimination of the human race, or that resources will not decline irreversibly. Examining the hidden assumptions is the first step towards addressing the risks associated with them. (*Senior commentators*)

Find ways of building redundancy back into systems. (*Senior commentators*)

Government needs to explore fall-backs, should important systems fail. (*Strategic futures analysts: business workshop; senior commentators*)

*Invest:* Invest more in understanding the socio-technical interface when setting up systems. For example, to set up complex databases, it is essential to consider industrial anthropology, i.e. the way organisations actually function, rather than the official representations of how they function. (*Senior commentators*)

Invest in the construction of robust strategies for backing-up databases, and mechanisms to defend them against cyber-attacks. (*Senior commentators*)

Education and training: people should be able to execute basic tasks of life such as hunting, cooking and so forth. (*Senior commentators*)

*Policy change; advisory; invest:* Practise doing without complex systems. This might take the form of emergency drills common in other countries. (*Senior commentators*)

*Public engagement:* Some called for constant, long-standing public engagements and better science education; others felt engagement with the public is inadvisable as there are so many unanswered questions. (*Commentators: workshops*)

Publicly admit to the problem of over-reliance. This, it was thought, might mitigate some of the risks. (*Senior commentators*)

**Issue 2: Public backlash against complex systems:** Autonomous systems (agent-based software) are predicted to become increasingly influential in decision-making over the next five to ten years in areas ranging from health to security and transport to logistics. There are fears of a public backlash against the implementation of these systems, given that we live in a culture that prizes individual autonomy (*CBI Science and Innovation Panel*). For the public, a pivotal issue in their acceptance of a range of automated technologies, from shopping to robotics to automated driving, is who controls it. They generally dislike relinquishing control to systems, or system operators, unless they gain new freedoms as a consequence. (*Public: deliberative panel; public: facilitated discussions*)

**Action:**

*Invest:* Government understanding of these systems is poor and needs to be improved. (*CBI science and innovation panel*)

### 14. Sustaining human characteristics in an engineered world

**Background:** Our ideas of authenticity and normality of the human experience are likely to alter if many of our daily tasks are performed by robots, networks or agent-based software. These systems may take over our decision-making responsibilities. Enhancement by such means would challenge the notion of what it is to be human.

**Issue 1: Biocomputers versus humans:** The creation of computers from materials that are biological rather than physical may yield a new type of artificial intelligence capable of thinking in a manner very similar to that of humans. This could pose a real challenge to our current concepts of human identity. (*Senior commentators*)

**Action:**

*Consultative/Deliberative:* Watching brief.

**Issue 2: Distanced from our basic needs:** Increasing isolation from nature (for example the seasons, or “greenery”) may damage mental and physical health in ways of which we are not yet aware (the recent discovery that exposure to the natural light cycle is important for mental health is one example). (*Senior commentators*)

**Action:**

*Policy change:* Town and city planning should take account of this issue. (*Senior commentators*)

**Issue 3: Using technology to reinvent ourselves:** Several forms of technology, ranging from virtual worlds to a variety of enhancements, will encourage people to question constraints on their

appearance, or on their abilities, that they have hitherto accepted. In this sense, technology could be a source of liberation from existing identity. (*Strategic futures analysts: business workshop*)

**Issue 4: Human enhancement:** see all of Theme 6 (Enhancement of the body and mind).

**Issue 5: Our relationship with robots:** see all of Theme 11 (My robot: guide, labourer and friend).

**Issue 6: Our place in the automated world:** [see also Theme 9 (Information systems profoundly change social interaction) Issue 5: (Isolation from real human interaction).]

## 15. Technology as an environmental and social saviour

**Background:** Science and technology could provide creative solutions to climate change, population growth, food security and the collapse of ecosystems. (*Senior commentators; strategic futures analysts*) Transformations in systems modelling could greatly enhance our understanding of biosystems. Autonomous systems could provide sophisticated control of energy use. Advanced materials and products might be manufactured using less raw material and energy, and generating less waste than currently. Chemical feedstocks could be “greened”. Nano-scale coatings might enhance existing materials. Virtual worlds could reduce travel. (*CBI science and innovation panel*)

**Issue 1: Need for scientific and technological literacy:** There is not enough technological literacy in management personnel to enable the UK to recognise and exploit significant developments in this area. As well as needing a workforce trained to deploy the technologies, we need technologically literate people in senior positions (*Commentators: online survey*). Although Government efforts to produce more scientists, and a more scientifically literate population, were praised the measures are thought to be inadequate (*CBI science and innovation panel*)

**Issue 2: Need for public trust in science:** Broadly-based trust in scientists will be vital in order to help solve global problems arising from population growth. For example, GM crops may be essential if we are to feed the predicted world population of 9.5 billion in 2050, yet the technology is mistrusted by many people. Although public esteem for scientists has improved, it should not be taken for granted. (*Senior commentators; strategic futures analysts*)

### Action:

*Policy change/Invest:* There is a need for independent scientists, unallied to Government or industry, to engage with the public – surveys show that such scientists are trusted better by the public (*Commentators: workshops*)

*Policy change:* If Government explicitly labelled science as a quest for improving the social good, trust from the public might be encouraged. (*Senior commentators*)

Put technology at the heart of education. (*Strategic futures analysts*)

*Invest:* In demonstration projects as a way of allaying fears amongst the public about new technologies. (*Commentators: workshops; CBI science and innovation panel*)

*Enable/Convene:* Encourage scientists to cultivate trust by demonstrating honesty and humanity (and thus evoking empathy) and by demonstrating that the chief aim of their work is societal benefit. (*Senior commentators*)

*Public engagement:* Many of those on the deliberative panel felt that the consultation had awoken in them a conscience about scientific issues and a feeling of connection with the governance of the country. They called for Government to stimulate public debate, channel positive information about research to the public, and outreach into the community. (*Public: deliberative panel*)

There was a call for engagement with the public to be embedded in the technology assessment process as early as possible. Engagement on GM crops took place at too late a stage, by which time participants observed that the debate had become polarised. As the development and diffusion of new technologies increasingly occurs around the world, there may be a lag before mechanisms for enabling regional global debate and dialogue emerge. (*Commentators: workshops*)

**Issue 3: Need to foster technologies whose primary aim is to increase sustainability rather than create wealth or improve health:** Many technologies whose principal potential benefit is increased sustainability<sup>21</sup> need fostering if their potential is to be realised. [See also Theme 12 (Need for energy leadership) Issue 2: (Huge potential for energy efficiency).]

### Action:

*Legislative/Regulatory:* Regulation might direct the development of technologies towards increasing sustainability. (*Commentators: workshops*)

*Policy Change:* Some global problems might be more likely to be solved if the purpose of science was acknowledged by Government to be furthering the public good, as well as wealth creation<sup>22</sup>. Such an acknowledgement might allow Government greater freedom to foster technologies that have the potential to benefit society and/or the environment, as well as encouraging the public to have trust in science. (*Commentators: workshops; senior commentators; public: deliberative panel*)

Taking a view of wealth that incorporates not just GDP but also quality of life, and basing policies on such a dual view, would help the economy by encouraging entrepreneurial approaches to developing novel goods and services that met both aims. (*Strategic futures analysts: business consultation*)

The theme of sustainability should be embedded in Government's approach to all candidate green technologies. This includes life cycle analysis to test environmental potential. (*Commentators: workshops*)

*Invest:* Government should consider various ways in which it could help develop and manage these technologies and create a demand for them. As well as regulation, Government could: invest in demonstration projects; shift its procurement policies to kick-start demand for new, environmentally-friendly products; and use novel IT systems to influence consumer purchasing. (*CBI science and innovation panel; strategic futures analysts: business consultation*)

Invest in thorough life cycle analysis to guard against erroneous choices. (*Commentators: workshops; CBI science and innovation panel*)

*Public engagement:* Educate consumers so they can make informed choices about whether to buy goods and services that cause greater or lesser harm to the environment. (*CBI science and innovation panel*)

**Issue 4: Technological help for the developing world:** There are vast and growing demands in the developing world for technologies in fields such as renewable energy and water purification, but it was said that these seem often to be passed over by research and other funding agencies. Some technologies yet to be developed, for example novel technologies for water purification, or advanced solar cells and improved diesel catalysts, could have an important impact. (*Commentators: online survey; commentators: workshops*)

### Action:

*Policy Change/ Participate in International Debate/Invest:* Britain could take the lead in getting useful new technologies to the developing world. (*Commentators: online survey*)

**Issue 5: Technology could transform life for the elderly:** Life for the elderly could be transformed by many new technologies: robots to prolong independence in the home; navigational tools and online communications. Mobility, independence and dignity could be preserved, and physical and mental activity prolonged. (*Commentators: workshops*) [see also Theme 10 (Longevity surpasses predictions) Issue 2 (Languishing in the seventh age of man).]

## 16. The end of privacy?

**Background:** Surveillance might one day be little short of total. In addition to the now-familiar cameras throughout towns, cities and the transport infrastructure, cheap, tiny sensors and tags will probably be ubiquitous. Some will be embedded in infrastructure and surroundings; others in transient locations in or on goods, vehicles, animals and people. Systems and networks could extract meaning from the resulting data, share them and act on them. Personal information will be released in other ways too: through biometrics, and, willingly, unwillingly or unknowingly, online. Incidents of “sousveillance”, the recording of life by ordinary people, for example through camera phones, may soar. As noted under the theme on non-medical applications of brain imaging, although the scanning of brain function is currently limited to a few medical applications, and requires large, costly, fixed equipment, it might develop into other application areas and become more widely useable.

**Issue 1: Fear of monitoring by the state:** Many people broadly welcome the safety, security and health benefits that may arise from state monitoring. However, many commentators felt that they have a right not to be monitored: they fear draconian and ubiquitous state policing, and consider that the state’s vested interests clash with their own. (*Senior commentators; public: deliberative panel; public: facilitated discussions; strategic futures analysts; commentators: workshops; commentators: online survey*) Some observers predicted a public backlash over the invasion of privacy which could define the boundaries within which some technologies are allowed to develop. (*CBI science and innovation panel*)

### Action:

*Legislative/Regulatory:* Government should consider distancing itself from databases of information about individuals by creating independent repositories of information. These repositories would be granted a status similar to those of the Standards Agencies (a “fingerprint standards agency”, for example). Government, the police, and any other body desiring access, would have to apply for specific purposes and permission would be granted at the discretion of those in charge of the database. Substantial controls would be needed to protect privacy. One approach might be to hold different elements of information in different locations. The elements could be linked as necessary and the link destroyed after use. Government should examine how to create an organisational, computational and moral distance between it and the holders of the information. (*Senior commentators*)

Many groups wanted Government to regulate to protect civil liberties: being watched, for example by CCTV, should be a personal choice; citizens should retain control of their data, and be able to choose not to release it. (*Public: deliberative panel; public: facilitated discussions*)

*Policy change:* Government should build trust in what it might do with data through openness. (*Strategic futures analysts*)

*Invest:* Convince the country of the benefits of tracking by using it to build better public services. (*Strategic futures analysts*)

*Public Engagement:* Communicate the benefits of, and developments in, tracking. Listen to citizens’ concerns and be prepared to compromise. (*Strategic futures analysts*)

**Issue 2: Public health jeopardized by privacy issues:** Population data and the linking of databases could alert us, cheaply, to important public health developments and concerns. But privacy concerns are already eroding this potential and may even bring certain lines of research to a halt. Government must find a remedy for this. (*Commentators: workshops; senior commentators*)

### Action:

*Regulatory/Legislative:* Similar principles to those expressed in Issue 1 (above) apply: information should be stored at arm’s length from Government, and links between large data sets should be established only temporarily. (*Senior commentators*)

**Issue 3: Policing by employers:** Smart clothing, tagging of individuals and other mechanisms could enable employers to monitor their employees very closely, for example on their whereabouts, (*Public: deliberative panel*) or on their physiology – something of ambiguous benefit to the employee. An employee might gain early warning of a health problem if he or she submits to the recording of intimate health data. But these data could also reveal information about aspects of his or her private life. Unless the individual perceives substantial benefits from wearing this technology, there could be conflict. (*HSE workshop*)

**Issue 4: Use of information by commercial organisations:** Some commentators felt that Government has a broadly benign goal in gathering data, and that data acquired by commercial organisations pose the greater threat. Many people seem unaware of the information-packed, permanent digital footprint they leave online. (*Senior commentators*) The uses to which this information might be put seem currently to be unclear. (*Senior commentators*) There are fears that in the future, businesses may use data to entice or bully potential customers. (*Public: deliberative panel*)

### Action:

*Legislative/Regulatory:* Government should consider whether there is a role for regulation that might force organisations to warn users about the implications of their actions for privacy. (*Senior commentators*)

Action should be taken to protect groups vulnerable to abuse online. (*Public: deliberative panel*) Some participants called for more specific measures, such as forcing organisations to declare publicly when they use people’s personal data (*Public: deliberative panel*).

*Advisory:* Ensure that information providers are aware of their responsibilities by encouraging and providing more support for corporate social responsibility. (*Commentators: online survey*)

Government needs to consider carefully whether it has an educational role in helping people to understand the way in which they are revealing information about themselves (for example the digital footprint left on their own computers and through web searches). (*Senior commentators*)

*Consultative/Deliberative:* Although it was generally agreed that the perception of vested interests means that Government cannot itself conduct a debate on privacy, participants thought that it could usefully initiate a debate about networking etiquette. (*Commentators: workshops*)

**Issue 5: Youth and privacy: a special case:** Several data-related issues are particularly relevant to the young. First, they seem to be willingly surrendering their privacy in order to use the latest socio-technological developments, many of them oblivious to the damage that exposure could cause them in the future. (*Commentators: workshops; Public: deliberative panel*) Secondly, some feel that it

is wrong that young people, as a “vulnerable group” can have data gathered about them without their consent. (*Commentators: online survey*) Meanwhile, young people may increasingly be exposed to bullying. The current example is through images captured on mobile phones. (*Commentators: online survey*).

**Action:**

*Consultative/Deliberative:* The balance between truncating the rights to privacy of a large social group (the young), and preventing one or two significant harms (such as child abuse), needs discussion. (*Commentators: online survey*)

*Advisory:* Government should be giving guidance and support on balancing child protection issues with the realities of the ease with which images can be shared. (*Commentators: online survey*)

*Public engagement:* Young people must be encouraged to become involved in debates about the introduction of government-controlled identity management. (*Commentators: online survey*)

**Action (relevant to all Privacy issues):**

*Legislative/regulatory:* Legislation will be needed on freedom of information, data protection and privacy and especially on identity theft to protect vulnerable groups such as teenagers, and the use of health information by employers and insurers. (*Commentators: workshops*)

*Policy change:* Participants questioned whether a policy framework is even possible on issues such as intellectual property rights or privacy. They thought that Government has a weakness in that it does not have a Department that “owns” information/data collection as an issue in its broadest sense. (*Commentators: workshops*)

*Consultative/Deliberative:* We may need a major independent study on privacy as an idea and a value exploring both the practical and the philosophical aspects. (*Commentators: workshops*) One senior commentator described a general trend, occurring over centuries, of the privacy sought by individuals rising along with industrialisation. However it is not obvious whether this is because people prefer to be private, and now have greater opportunity to be so, or whether living and working conditions in industrialised societies have created, or increased, a need for privacy. Perhaps privacy is essential in order to live in large groups rather than the smaller communities of the past. Is there a material difference between the privacy we are forfeiting now (generally to strangers) and the privacy we forfeited in the past (generally to the immediate community)? Will concepts of privacy change in the future? (*Senior commentators*) Such a study should be conducted by a body at arm’s length from Government because of its perceived vested interest in the surveillance of its citizens. (*Commentators: workshops*)

Some participants contended that there have been imaginative technological solutions put forward to address problematic aspects of privacy and that these should be explored further. For example, technology could allow people to adopt different virtual identities for different circumstances, with each being ascribed different levels of trust. (*Commentators: workshops*)

*Public engagement:* This is needed on all technologies that threaten privacy, and in particular on surveillance. Participants thought the public would be sceptical about the robustness of new security systems. (*Commentators: workshops*)

## Endnotes

18 This italicised list, and the other similar ones that appear after many of the descriptions of issues and actions, indicates which of the 8 different groups of WIST participants raised the issue or suggested the action. The 8 groups are described in Annex B.

19 See Annex E for description, and examples, of the gamut of possible Government responses suggested or recommended by participants to deal with most of the issues they raised.

20 The HFEA launched in April 2007 a public consultation on whether or not scientists should be allowed to create embryos containing animal DNA for embryo research.

21 Sustainability was a word commonly used by numerous participants. It is taken to mean an approach to managing the world’s resources which meets the needs of the present without compromising the ability of future generations to meet their own needs (derived from the World Commission on Environment and Development, *Our Common Future*, 1987: “The Bruntland Report”).

22 This view suggests that Government may need to strengthen the communication of its long-standing commitment to funding science, through the Research Councils, in a way that recognises the value of intellectual exploration and the generation of knowledge in all areas, rather than being tightly tied to specific areas of benefit such as wealth creation.

## 5. Topics for public engagement

This chapter describes the topics in which the participants called for public engagement. These fell into two categories: general topics about science and technology, such as public trust, and specific topics, such as human enhancement.

One of the aims of the WIST Programme was to identify areas of science and technology in which public engagement might be beneficial.

Scientists need to keep the public informed about their work and to listen to their aspirations and concerns. Public engagement is one way of doing this. It differs from public education by being a dialogue, rather than a one-way process. Public engagement activities are also an important mechanism for improving the public contribution to policy development.

Many members of the public recruited to the main *sciencehorizons* event – the deliberative panel – suggested a variety of ways in which the public could be informed about, and asked for input on, new technologies. Many were startled by the information they received about new technologies and several expressed the view that they were normally “kept in the dark” about scientific developments. Many actively welcomed the opportunity that *sciencehorizons* provided for them to become informed, and to contribute their views.

### General areas of science and technology

There were a number of general areas where public engagement was called for, linked to public trust in science, science as a major driver of change, and the complexity and vulnerability of society caused by its reliance on science and technology. These are described below. These general topics were incorporated into calls for long-term public engagement exercises on science and technology in general (in other words, programmes like *sciencehorizons*).

In each case, the themes and issues that the topic is linked to, the description of the issue, and the group who called for the public engagement are given.

#### i. Public trust in science

**Theme 15. Technology as an environmental and social saviour Issue 2: Need for public trust in science:** Broadly-based trust in scientists will be vital in order to help solve global problems arising from population growth. For example, GM crops may be essential if we are to feed the predicted world population of 9.5 billion in 2050, yet the technology is mistrusted by many people. Although public esteem for scientists has improved it should not be taken for granted. (*Senior commentators; strategic futures analysts*)

#### Action:

*Public engagement:* Many of those on the deliberative panel felt that the consultation had awoken in them a conscience about scientific issues and a feeling of connection with the governance of the country. They called for Government to stimulate public debate, channel positive information about research to the public, and outreach into the community. (*Public: deliberative panel*)

There was a call for engagement with the public to be embedded in the technology assessment process as early as possible. Engagement on genetically modified crops took place at too late a stage, by which time participants observed that the debate had become polarised. As the development and diffusion of new technologies increasingly occurs around the world, there may be a lag before mechanisms for enabling regional global debate and dialogue emerge. (*Commentators: workshops*)

#### ii. Pace of change

**Theme 4. Consequences of rapid technological change Issue 1: Dealing with growing numbers of excluded:** The “have-nots” and the “skill-nots” may be joined by an increasing group of “will-nots”. This last category of people may refuse to use new technologies for numerous reasons: dislike of the speed of change (many elderly people, who will be increasingly numerous, may join this group); paranoia fostered by abundant security monitoring systems; the rejection of human enhancement; a desire for privacy. All three groups may become unable to participate in mainstream society, economically marginalised and possibly inaccessible to Government. (*Commentators: workshops; public: deliberative panel; public: facilitated discussions; HSE workshop; CBI science and innovation panel*)

#### Action:

*Public Engagement:* Help people accept change as a constant and positive force; encourage them to look within themselves and their communities to promote wellbeing for all. (*Strategic futures analysts*)

#### iii. Vulnerability from reliance on complex systems

**Theme 13, Rise of complex systems, Issue 1: Collapse of systems:** Complex networks, and systems of networks, can show unplanned emergent behaviours. Interdependent systems are being created that even their designers cannot comprehend. Systems are being built and databases created without an understanding of the social dynamics of the organisations that use them. Systems may fail, through sabotage or by accident, in unpredictable and unpredictable ways. Because of their ubiquity, such failure could plunge society into crisis. (*Commentators: workshops; senior commentators; CBI science and innovation panel; strategic futures analysts: business workshop*)

#### Action:

*Public engagement:* Some called for constant, long-standing public engagement and better science education; others felt engagement with the public is inadvisable as there are so many unanswered questions. (*Commentators: workshops*)

## Specific topics

There were also calls for public engagement on the following specific topics:

- i. Climate change
- ii. Health, genetics and related areas of biology
- iii. Human enhancement
- iv. Information systems and social impact
- v. Nanotechnologies
- vi. National energy production options
- vii. Privacy
- viii. Robotics
- ix. Technologies for sustainability

More detail on each of these topics is given in the section below, which indicates which of the themes and issues each topic is linked to, the description of the issue, and the group who called for the public engagement.

### i. Climate change

**Theme 12. Need for energy leadership, Issue 3: Persuade the public about climate change:** Some members of the public do not believe in anthropogenic, i.e. man-made, climate change, while others take the view that the idea is a merely a plot perpetuated, for example, by scientists to obtain funds. Others are confused by the science underlying climate change and are seeking clarity on the messages they hear. Regardless of their opinions on climate change, most are concerned about pollution and security of energy supply. *(Public: deliberative panel)*

#### Action:

*Public engagement:* Basic groundwork educating the public about the evidence for, and mechanisms of, climate change, its likely causes, and what can be done about it, including what is available to help people reduce their carbon footprints. *(Public: deliberative panel)*

### ii. Health, genetics and related areas of biology

There were calls for public engagement on a number of related topics within the area of health and the disciplines of genetics and biology. These are presented together because of the close links and overlap between some of their constituent technologies

#### Theme 1. Ascent of the expert patient, Issue 3: Need for new sources of support:

If there is a trend away from the GP as the main provider of primary care, some patients could become isolated from support in the face of potentially disturbing new health information about themselves. It is unclear how people would respond to this kind of information, so new support structures, such as additional health counsellors, may be needed. *(Senior commentators; public: deliberative panel)*

#### Action:

*Public engagement:* Strengthen people's capacity to deal with information about their genetic profile. Provide information to the community about the safety of new relevant health technologies. Encourage debate on the ethical issues raised by genetic testing, its applications, and the use to which the results will be put by individuals, industry and Government. *(Strategic futures analysts)* [see also "Human enhancement" below]

#### Theme 3. Brain imaging finds multiple non-medical applications, Issue 1: Unregulated use:

Although highly regulated in the field of medical research, brain imaging may leak into the wider, more permissive world. The technology could be of use to employers, the police, judiciary, and advertisers. Although there may be benefits, issues such as the invasion of privacy, over-interpretation of scientific data, and, in the case of neuro-marketing<sup>23</sup>, unacceptable levels of manipulation of people for commercial gain would raise serious concerns. *(Commentators: workshops)*

#### Action:

*Public Engagement:* A debate on the use of neuro-imaging outside medicine is required urgently. *(Commentators: workshops)*

#### Theme 5. Direction of some biological research, Issue 1: Permissibility of research:

Several of these fields might provoke a public backlash: the patenting of human embryos; GM animals and plants (public disquiet is thought not to have diminished); "messing with DNA" (distasteful to public participants); synthetic biology (there is disbelief that scientists could ever build a new organism) and the creation of animal-human hybrids. Some participants question why researchers are allowed to continue working in areas where outcomes might be so unacceptable to so many. *(Public: deliberative panel; public: facilitated discussions; commentators: workshops)*

#### Action:

*Public engagement:* Public discussion of these issues is vital, to help people grasp the implications and to get a sense of what might be controversial<sup>24</sup>. *(Commentators: workshops)*

### iii. Human enhancement

#### Theme 6. Enhancement of the mind and body, Issue 4: Enhancement challenges concepts of normality:

Enhancement may test our sense of what it is to be human and lead to the loss of a collective sense of what is normal and what is authentic. At the same time, greater genetic knowledge may lead us to consider ourselves to be imperfect versions of a perfect genome, and thus in need of perfecting. Genetic knowledge combined with the tools of enhancement could lead to unethical practices such as eugenics. *(Senior commentators)*

and

#### Issue 5: Social acceptability of enhancement:

There could be considerable public disquiet, particularly on the enhancement of children and in sport. However, conceptual shifts and societal adjustments may gradually occur. *(Commentators: workshop)*. If enhancement is available only to the affluent, social divisions could widen and issues of equity may become paramount. Conversely, enhancement could come to be seen as a right (with resource implications) or even an equalising force. *(Commentators: workshops; public: deliberative panel)*

**Action:**

*Public engagement:* (Issues 4 & 5), this is essential to help people grasp the implications and to enable society to get a sense of what might be controversial. Discourse will need to be long-term to help people realise the possible implications. (*Commentators: workshops*) [see also "Genetics" above]

**iv. Information systems and social impact****Theme 9. Information systems profoundly change social interaction, Issue 2: Increased democratic participation affects every department:**

If people develop the skills to access, analyse and use information, democratic participation might increase. Political activism could expand, with more single-issue organisations, rapidly organised lobbying or even acts of civil disobedience. People might become more involved in local environmental issues. (*Commentators: workshops*)

**Action:**

*Public Engagement:* Educate people in how to access and use knowledge, how to exercise judgement and develop and use critical thinking skills. Experiment with interactive engagement exercises to develop best practice so people have positive experiences of contributing to policy development. (*Strategic futures analysts*)

and

**Issue 5: Isolation from real human interaction:** Humans need face-to-face relationships within small groups, a requirement that communication technologies seem to undermine. There is a perception of negative impacts which include the erosion of family relationships; the loss of an important moderating influence on behaviour; and potential depression amongst the elderly (communication technologies may extend their independence at home but may also reduce their direct human contact). Research into blogging indicates that the medium seems to encourage aggressive expression, but participants disagreed over whether it has the potential to increase aggression in society or act as a useful vent for aggression. However, information technologies could, for example, be redirected so that they actually enhance the human experience. (*Senior commentators; commentators: workshops; public: deliberative panel*) [See also Theme 14 (Sustaining human characteristics in an engineered world) Issue 6 (Our place in the automated world).]

**Action:**

*Public Engagement:* Consider educating people about networking technologies both to encourage their use and to alert them to potential dangers. Care should be taken, however, as educating teenagers about a socially dubious activity can serve merely to alert them to it. (*Senior commentators*)

**v. Nanotechnologies****Theme 8. Health, safety and environmental effects of new materials, Issue 1:****Nanomaterials present unknown risks:**

The long-term effects of advanced materials on health, on the environment and on each other are not understood. The measurement and monitoring of nanoparticles (nanometrology) is an immature science, limiting our understanding of their fate in the body and in the environment. Likewise, is enough known about nanotubes, given the similarity in structure of some nanotubes to asbestos? (*Commentators: workshops*)

**Action:**

*Public engagement:* Risk assessments should be publicised in order to direct responses of the public to nanomaterials onto a more productive course from that of genetically modified plants (*Commentators: workshops*). Some commentators considered it very important for the advancement of this emerging technology that debate amongst the public occurs now. (*Commentators: online survey*) However, it was pointed out that such consultation had already taken place, but that the topic had not yet seized the public imagination. (*Senior commentators*)

**vi. National energy production options****Theme 12. Need for energy leadership, Issue 1: Urgent need for vision and strong leadership:**

Government needs to demonstrate a sense of ambition and urgency similar to that which put man on the Moon, in order to drive forward a new era on energy. (*CBI science and innovation panel; commentators: workshops; commentators: online survey; public: deliberative panel; public: facilitated discussions*) Many new technologies may fail to prosper without Government support. These include: electric cars; biofuelled cars; microgrids; using existing technology to generate and store energy at micro levels; and wave and tidal power. Government must decide on the balance between publicly driven and centralised decision-making on energy. (*Commentators: workshops; public: facilitated discussions*)

**Action:**

*Consultative/Deliberative and Public Engagement:* It is unlikely that there will be a "silver bullet" to combat climate change or to simplify the UK's energy choices; a mix of different technologies will probably be required. Public debate is currently polarised, with the media presenting new technologies as a potential answer, then "proving" they cannot meet future energy requirements. This activity is propagating a cynical view that alternative technologies will not work, whereas the media could be a forum for an energy debate that could accompany a process of public engagement (*Commentators: online survey*)

**vii. Privacy****Theme 16. The end of privacy? Issue 1: Fear of monitoring by the state:**

Many people broadly welcome the safety, security and health benefits that may arise from state monitoring. However, many commentators felt that they have a right not to be monitored; they fear draconian and ubiquitous state policing, and consider that the state's vested interests clash with their own. (*Senior commentators; public: deliberative panel; public: facilitated discussions; strategic futures analysts; commentators: workshops; commentators: online survey*) Some observers predicted a public backlash over the invasion of privacy which could define the boundaries within which some technologies are allowed to develop. (*CBI science and innovation panel*)

**Action:**

*Public Engagement:* Communicate the benefits of, and developments in, tracking. Listen to citizens' concerns and be prepared to compromise. (*Strategic futures analysts*)

**Theme 16. The end of privacy?, Issue 5: Youth and privacy: a special case:**

Several data-related issues are particularly relevant to the young. First, they seem to be willingly surrendering their privacy in order to use the latest socio-technological developments, many of them oblivious to the damage that exposure could cause them in the future. (*Commentators: workshops; Public: deliberative panel*) Secondly, some feel that it is wrong that young people, as a “vulnerable group” can have data gathered about them without their consent. (*Commentators: online survey*) Meanwhile, young people may increasingly be exposed to bullying. The current example is through images captured on mobile phones. (*Commentators: online survey*).

**Action:**

*Public engagement:* Young people must be encouraged to become involved in debates about the introduction of government-controlled identity management. (*Commentators: online survey*)

**Theme 16. The end of privacy?, All issues****Action:**

*Public engagement:* This is needed on all technologies that threaten privacy, and in particular on surveillance. Participants thought the public would be sceptical about the robustness of new security systems. (*Commentators: workshops*)

**viii. Robotics****Theme 11. My robot: guide, labourer and friend, Issue 2: Robot autonomy and responsibility:**

Robots have the potential to pose legal and ethical challenges. Who will take responsibility for a robot's actions? Should we impose limits on a robot's autonomy? (*Commentators: workshops; Public: deliberative panel; Public: facilitated discussions*). Since we cannot foresee all the scenarios in which robots will work, perhaps the manufacturer must prove they will behave safely in all potential environments. (*Commentators: online survey*)

and

**Issue 3: Human emotional responses to robots:**

Anthropoid robots evoke disquiet. Some people fear that we may develop an emotional dependence on them, and also fear that robots might usurp us in some way, for example by eliminating the basic tasks that help to give life meaning (although robots that are merely tools are welcome). Many feel that we are already guilty as a society of neglecting the elderly, and sending robots to support them will exacerbate these concerns. (*Public: deliberative panel; Public: facilitated discussions; Commentators: workshops*)

**Action (issues 2 & 3):**

*Public engagement:* There are already concerns about robots, and there could be a public backlash if preparation does not begin now. (*Commentators: workshops*) The public should be consulted about robotics. (*Public: deliberative panel*)

**ix. Technologies for sustainability****Theme 15. Technology as an environmental and social saviour Issue 3: Need to foster technologies whose primary aim is to increase sustainability rather than create wealth or improve health:**

Many technologies whose principal potential benefit is increased sustainability<sup>25</sup> need fostering if their potential is to be realised. [See also Theme 12 (Need for energy leadership) Issue 2: Huge potential for energy efficiency].

**Action:**

*Public engagement:* Educate consumers so they can make informed choices about whether to buy goods and services that cause greater or lesser harm to the environment. (*CBI science and innovation panel*)

**Endnotes**

<sup>23</sup> Neuro-marketing is commercial marketing activity which uses measurements of cognitive activity.

<sup>24</sup> The HFEA launched in April 2007 a public consultation on whether or not scientists should be allowed to create embryos containing animal DNA for embryo research.

<sup>25</sup> Sustainability was a word commonly used by numerous participants. It is taken to mean an approach to managing the world's resources which meets the needs of the present without compromising the ability of future generations to meet their own needs (derived from the World Commission on Environment and Development, *Our Common Future*, 1987: “The Brundtland Report”).

## Annex A: details of the WIST programme and processes

### Overview

The WIST programme consisted of two major workstreams: the Foresight Horizon Scanning Centre's stakeholder consultations, and the *sciencehorizons* public engagement activities. In addition, the WIST programme was linked to a Health and Safety Executive horizon scanning seminar on the future of work.

WIST's two major workstreams were integrated into a single programme by: creating common oversight arrangements; using the same material to describe major developments in science and technology (described below and in Annex C); using the same teams to arrange, plan, facilitate and run the majority of the consultative and engagement activities (e.g. workshops, deliberative panels etc); and involving a single professional science writer in all the main events and activities to record the outcomes and produce this synthesised report.

Findings from all workstreams were considered during a workshop in September 2007, led by Professor Sir David King, the former Chief Scientific Adviser to the Government, involving senior participants from academia, industry, and NGOs.

The combination of large scale, broad scope, range of consultative and engagement processes, and involvement of both stakeholders and the public distinguish the WIST programme from previous consultative activities about future developments in science and technology.

### Processes and events

#### The Horizon Scanning Centre's programme of stakeholder consultations

The programme of stakeholder consultation run by the Horizon Scanning Centre consisted of a series of facilitated consultative workshops and events, and an online survey. In total, over 300 stakeholders from a wide range of organisations including academia, NGOs, professional bodies, industry, Government and the strategic futurists community (the Horizon Scanning Centre's Future Analysts' Network (FAN Club)) participated between March and September 2007.

##### 1. The Stakeholder Workshops ("Commentators")

In March 2007 the Horizon Scanning Centre held two one-day workshops, facilitated by Dialogue by Design, involving 57 senior people from business, non-governmental organisations, government departments, academia and other sectors. These are listed at Annex B. Participants were presented with descriptions of future developments in science and technology – the Horizon Scanning Centre's S&T "clusters" (see below and Annex C) – and were given three tasks:

- To identify the potential safety, health, environmental, ethical, regulatory and social (SHEERS) implications of new and emerging technologies<sup>26</sup>.

- To explore the types of responses, ranging from the advisory to the legislative, which participants believe may be required of government.
- To consider which technologies are likely to cause concern amongst the public, and where, therefore, engagement activities with the public and stakeholders may be useful.

##### 2. The Online Survey

The workshops were supplemented by means of a web survey, run by Dialogue by Design, for invited participants from a range of professional bodies and NGOs. They were asked to analyse the Horizon Scanning Centre's clusters of key areas of emerging science and technology (Annex C) and identify safety, health, environmental, ethical, regulatory and social (SHEERS) implications, using the same methodological approach adopted in the workshops.

There were 22 respondents, listed at Annex B, which was fewer than anticipated. However, those who responded included representatives of relevant organisations who had not attended either workshop, and senior academics. Participants gave notably detailed and considered replies.

##### 3. Other meetings

Other meetings and events run (or co-run) by the Horizon Scanning Centre which contributed to WIST were:

- CBI science and innovation panel: the Outsights-Ipsos MORI Partnership developed, with the Confederation of British Industry (CBI), a workshop in which senior individuals from a range of British industries (listed in Annex B) discussed opportunities in science and technology with a 10-25 year horizon, and identified key technology themes of cross-industry interest. Some 19 leaders from a range of industries including defence, manufacturing, IT and pharmaceuticals, attended the half-day workshop at the Design Council in London on 21 June 2007.
- Strategic futures analysts: a meeting of approximately 100 individuals with an interest in futures work drawn from the public, private, academic and third sectors, known as the Futures Analysts' Network (FAN Club). This forum, run by the Horizon Scanning Centre, met in London on 16 May 2007 to discuss emerging trends that might be important for the UK over the next 20 years.
- Strategic futures analysts - business meeting: a FAN Club meeting held jointly with the CBI's National Accounts Group, on 11 September 2007. Approximately 70 participants discussed business perspectives on priorities for the future of wealth creation and where government intervention might help over the longer term.
- Senior commentators: a small group of invited senior individuals from Government, academia, industry and NGOs, led by Professor Sir David King, the former Government Chief Scientific Adviser, discussed issues emerging from the WIST programme and contributed their own views to the findings. The meeting took place on 18th and 19th September 2007 and was facilitated by Dialogue by Design.

#### The *sciencehorizons* programme of public engagement

WIST's second major workstream was the *sciencehorizons* programme: the public-facing part of WIST, intended to ascertain the public's views on the future of science and technology. *Sciencehorizons* was conducted by the Sciencewise programme, led by the Science in Society directorate within the Department for Innovation, Universities and Skills and was the first public engagement exercise in the UK to focus on the potential future uses for science and technology. Its

purpose was to inform Government decisions about how to research, regulate and communicate science and technology.

*Sciencehorizons*<sup>27</sup> comprised a national series of conversations with the public about new technologies and how they might affect society in the future. It consisted of a diverse programme of 430 engagement activities carried out over six months between January and June 2007, at venues across the UK. Over 3100 members of the public participated.

These discussions and events were informed by a set of 16 stories (derived from the Horizon Scanning Centre's material on future developments in science and technology – the “clusters” – summarised below and described more fully in Annex C) on the themes of Mind and Body 2025, Home and Community 2025, Work and Leisure 2025, and People and Planet 2025. These stories described, in a readily-assimilable format, the possible impact of new and emerging areas of science and technology on familiar aspects of everyday life such as work, leisure, and healthcare. The stories were available both interactively<sup>28</sup> and in hard copy.

Participants were asked:

What do you like about the technology in the story, and why? Please list all the things people in the group like.

What do you dislike about the technology in the story, and why?

Please list all the things people in the group dislike.

Of the things you either like or dislike, which is the most important?

Try to agree as a group - if you cannot agree, please explain why.

What else would you like to say about the stories in this theme, or about the pack in general?

and were able to submit their answers either as individual or as the views of a group, either on-line or as hard copy.

The *sciencehorizons* programme consisted of three types of event:

a. Deliberative panel

The main *sciencehorizons* events were two whole-day consultations in Bristol with 31 members of the public (constituting a stratified, representative, sample selected to cover a range of demographics<sup>29</sup>), At their first meeting, the panel discussed all 16 stories. At the end of this meeting, participants requested experts to enlighten them further on the science and implications of climate change, and the future of robotics. One month later they attended a second, day-long meeting at which they questioned the experts and reflected further on the issues.

b. Facilitated discussions

Some 36 facilitated, one-off discussions were held around the UK. Hosted by schools, colleges, museums, clubs, science and technology interest groups (see Annex B) these

generally lasted a few hours, allowing time for discussion of two or three scenarios. 842 members of the public participated.

c. Self-managed discussions

Approximately 2,400 people participated in 68 events held across the UK in a variety of settings such as schools, community groups and clubs. These are listed in Annex B. Participants were given packs describing the 16 stories, and completed questionnaires to record the views of those present: 392 were received.

### The Health and Safety Executive's horizon scanning seminar

A third contribution to the WIST programme came from a horizon scanning seminar held in the DTI Conference Centre on 30 November 2006 by the Health and Safety Executive (HSE) on the implications of new and emerging areas of science and technology for the future of work and occupational health and safety. It was attended by 100 (approximately) individuals from Government, NGOs, professional bodies, academia and industry.

The primary aims of the HSE's event were to (italics not in original):

- “Work with others in identifying and exploring the key new and emerging risks for the health and safety system
- Explore the policy implications, for regulators and others, of these new and emerging risks.
- *Support and contribute to the Wider Implications of Science and Technology (WIST) Programme, led by the Office of Science and Innovation.*
- Broaden the 'horizon scanning for health and safety' community.”

Participants considered a set of four scenarios for the health and safety system in 2017<sup>30</sup>. These were based on the Health and Safety Executive's own horizon scanning research and also drew on the Horizon Scanning Centre's clusters of science and technology (Annex C). Members of the Horizon Scanning Centre, and the WIST science writer attended the seminar, and the Health and Safety Executive made the outputs of their event available to the WIST programme.

### Endnotes

26 These 6 issues were those specified in Recommendation 21 of the Royal Society and the Royal Academy of Engineering's joint report on nanotechnologies (*op. cit.*) from which the WIST programme is derived.

27 <http://www.sciencehorizons.org.uk>

28 <http://www.sciencehorizons.org.uk/interactive.asp#>

29 e.g. age, gender, race, socio-economic group. People with any formal background in science were excluded.

All participants lived in or near Bristol.

30 <http://www.hse.gov.uk/research/rrpdf/rr600.pdf>

## Annex B: Participants in WIST events and activities

### 1. The Stakeholder Workshops

Siobhan	Campbell	HM Treasury
Doug	Brown	DfES
Alan	Malcolm	Institute of Biology
Alison	Plouviez	The Law Society
Richard	Pitts	DTI
Darren	Bhattachary	The Royal Society
Sue	Bolton	Office of Science & Innovation, DTI
Jerome	Ravetz	James Martin Institute
John	Roberts	DEFRA
Mark	Bale	Department of Health
Kamal	Hossain	National Physical Laboratory
Richard	Morgan	Momenta
Les	Fraser	British Computer Society
Mark	Wilson	British Transport Police
Guy	Taylor	LSE
Andy	Jevons	National Policing Improvement Agency
Natasha	McCarthy	The Royal Academy of Engineering
Peter	Dukes	MRC
Louise	Dove	Local Government Analysis and Research
Kate	O'Shea	The Royal Society
Chris	Shilling	Pfizer
Stephen	Hill	Defra
Peter	Ellwood	Health and Safety Laboratory
Donald	Bruce	Church of Scotland
Malcolm	Rigg	Policy Studies Institute
Andrew	Scott	Practical Action
Sophia	Abbasi	BBSRC
Victor	Anderson	SDC
John	Baker	BP
Phillipa	Bell	Royal Society of Chemistry
David	Carr	Wellcome Trust
Tony	Dunne	Royal College of Art
Paul	Ekblom	Central Saint Martins College of Art and Design

Liz	Fellman	NERC
Rob	Frost	The Academy of Medical Sciences
Dan	Gooding	NanoCentral
Megan	Griffith	NCVO
Sue	Hordijkeno	The BA
Stella	Howell	Euro Environmental Containers
Eve	Jagusiewicz	Universities UK
Gary	Kass	Science and Innovation Group
Stephen	Kinghorn-Perry	Chief Scientist Unit, HSE
Suzannah	Lansdell	Environment Council
Steve	Lea	Home Office
Iain	Mansfield	Council for Science and Technology Secretariat
Alan	Mayo	DTI
Vince	Osgood	EPSRC
Anthony	Parsons	Bristol Twerton Science Department
Tim	Parsons	BAE SYSTEMS
Rachel	Quinn	Royal Society
Denise	Randall	Medicines and Healthcare products Regulatory Agency
Gill	Ringland	SAMI Consulting
Harald	Schmidt	Nuffield Council on Bioethics
Lewis	Sida	Humanitarian Futures Project
Steve	Wells	Pfizer
Matthew	White	Dept. for Transport
Sandra	Wint	RSA

## 2. The Online Survey

Professor	John Mavor	The Royal Society of Edinburgh*
Ms	Sheila Anderson	Natural Environment Research Council
Dr	Elizabeth Bell	The Physiological Society
Professor	David Budgen	Durham University
Mr	Timothy Davies	The National Youth Agency
Ms	Susannah Diamond	Sheffield Hallam University
Professor	Michael Fisher	None
Dr	Steffi Friedrichs	Nanotechnology Industries Association
Professor	Steve Furber	The University of Manchester
Professor	Robert Gurney	Environmental Systems Science Centre
Professor	Peter Guthrie	University of Cambridge
Professor	Richard Jones	University of Sheffield
Dr	Jenny Jones	University of Leeds
Dr	Lisa Morrison Coulthard	British Psychological Society
Professor	Karen Morrow	Swansea University
Professor	Aurora Plomer	University of Sheffield
Mr	Andrew Ramsay	Engineering Council UK
Ms	Emma Visman	Humanitarian Futures programme
Prof	Tony Warnes	University of Sheffield
Mr	John Wilkinson	Association of British Healthcare Industries
Dr	Sandra Wint	RSA
Dr	Ken Young	University of Warwick

\*Prof Mavor directed a working party, consisting of a number of expert Fellows of the RSE, which responded in detail to WIST. The RSE also submitted a number of pre-existing reports and consultation responses which it felt were also relevant to the WIST programme.

## 3. The sciencehorizons events

**a) Deliberative Panel:** 31 members of the public from the Bristol area

**b) Facilitated Discussions:** 36 discussions held by the following groups (many of whom held multiple events)

London School of Economics (undergraduates)

National Museums Scotland

Pontypridd Museum (science/technology interest group)

Glamorgan University

Dana Centre (science museum)

Institute of Biology, London branch

York Café Scientifique

Oxford: St Gregory the Great School

Oxford public event (60+)

Oxford public event (males, 30-50 years)

Oxford public event (females, 30-50 years)

The Coachhouse Trust (social and environmental enterprise)

Raynes Park Community Church

Sheffield Café Scientifique

Natural History Museum

Knutsford SciBar (Science/Technology interest group)

The Science Partnership (university)

Greenwood Junior School

Staffordshire Moorlands (mothers)

Norwich Horizons Group (school/college)

Bristol Natural History Consortium

Centre for Life

**c) Unmanaged discussions:** 2,400 members of the public from the following groups:

Ist Bulwark Rangers (Girl Guides/Rangers)

Alertme.com

Anonymous Groups

Belfast Humanist Group

Blundell's School Year 10 Scholars

Bracknell Friends of the Earth

Brisham Green  
 Cambridge Federation of Women's Institutes  
 Canon Slade (school)  
 Changing perceptions (science, technology, health and environmental interest groups)  
 Chester Humanists  
 Compass Advocacy (Adults with learning disabilities)  
 Cotswold7Legends (school/college)  
 Coventry and Warwickshire Humanists  
 Crosby Explorer Scouts  
 Darlaston Community Science College  
 Diss High School (14 year olds)  
 Dorset Women's Institute  
 Down Hill High School  
 Dragon Explorers (scouts)  
 Dulwich Parents' Group  
 Durham Federation of Women's Institutes - Public Affairs Committee  
 EMS Valley University of the Third Age  
 Emsworth Morning Women's Institute  
 Essex Humanists Discussion Group South  
 Filkins and Broughton Women's Institute  
 Fort Pitt Grammar School  
 Gargrave Women's Institute  
 Gaunts and Holt Women's Institute  
 Hastings Walking and Talking Group  
 Hertfordshire and Essex High School and Science College  
 Ilkley University of the Third Age  
 Institute of Physics Staff Members, London  
 IT Users' Group  
 Martlesham Heath Women's Institute  
 Motherwell Pilgrim Group (ecumenical faith-sharing group)  
 National Women's Register Byfleet and District Branch  
 Nesta CRUCIBLE 2007 (early-career researchers)

Newcastle University of the Third Age IT Users' Group  
 Peterhead Academy  
 Picton District Explorers (scout unit)  
 Portadown College  
 Pound Hill Women's Institute  
 Science in the Environment Group  
 Scottish Resource Centre for Women in SET, returners' group  
 Sevenoaks Friends of the Earth  
 Shropshire Humanist Group  
 Society, Technology and Science, East Berwickshire University of the Third Age  
 St Albans Friends of the Earth  
 St Benedicts  
 St Columbs College  
 St Mary's RC High School  
 Strathearn School  
 The Green School Group  
 The SE group (group of friends who meet weekly)  
 Thomas Estley College  
 Thomas Estley Community College  
 Trinity Catholic High School  
 Tyneside Federation Women's Institute Science Club  
 University of Leeds  
 Warrington Collegiate  
 West Midlands Federation of Women's Institutes  
 Westcliffe High School for Girls  
 Women's Institute Science Discovery Group  
 Worcestershire Federation of Women's Institutes Science Club

#### 4. Health and Safety Executive (HSE)

100 (approx) participants attended from organisations concerned with health and/or safety, from industry (particularly the construction, engineering and insurance industries), government departments, local authorities, insurance and academia.

## 5. Confederation of British Industry Science and Innovation Panel

Trudy Norris-Grey	VP and Managing Director, UK & Ireland	Sun Microsystems
John Stageman	Vice President Biopharmaceuticals	Astra Zeneca
Daniel Mansfield	External Policy Manager	BSI
Dave Brown	Head of Foresight Research Centre	BT plc
Tony Jones	Director Product & Market Development	Corus plc
Mike Cooke	Technical Director	Devro plc
Ian Shaw	Chief Technology Officer	Electronic Arts
Robert Davis	Managing Director	EA Technology
Alastair Hughes	Client Services Director, Government Services	Ernst & Young
Chris Shennan	Research & Technology Manager	Hexcel Composites
Chris Francis	Government Programmes	IBM
Peter Craig	UK Technical Director	LogicaCMG
Professor Stephen Emmott	Group Director & Chief Scientist	Microsoft Research Ltd
Frank Rozelaar	Group Technical Director	QinetiQ plc
David Salter	Business Unit Director	Roke Manor Research
Robert Leese	Director	Smith Institute
Barry Trimmer	UK Technical Director	Thales Group
Richard Woodward	Research Director	TRL Ltd
Professor Tim Wilson	Vice-Chancellor	University of Hertfordshire

## 6. The Horizon Scanning Centre's Futures Analysts' Network (FAN Club)

Approximately 100 participants

## 7. The FAN Club Business Consultation

70 participants approx

## 8. The senior commentators' event

Professor	Rachel	Jenkins	Head of Mental Health Policy, Institute of Psychiatry, Kings College London	Institute of Psychiatry
Professor	Cary	Cooper	Professor of Organisational Psychology and Health	Lancaster University Management School
Reverend Professor	Michael	Reiss	Head of Mathematics	Institute of Education, University of London
Mr	James	Smith	Chairman	Shell UK Limited
Dr	Donald	Bruce	Director, Society, Religion and Technology Project	Church of Scotland
Professor	Catherine	Peckham	Professor of Paediatric Epidemiology, Institute for Child Health, University College of London	University College London
Professor	Stephen	Emmott	Director, European Science Programme	Microsoft Research Cambridge
Professor	David	Cliff	University of Bristol	Department of Computer Science
Lord	John	Krebs	Principal, Jesus College, Oxford	Speaker
Dr	Rupert	Lewis	Former Head, Horizon Scanning Centre	GO-Science
Professor	Sandy	Thomas	Director, Foresight Programme	GO-Science
Mr	Jeremy	Clayton	Deputy Head, GO-Science	GO-Science
Professor Sir	David	King	Former Govt. Chief Scientific Adviser	GO-Science
Professor	Sandy	Thomas	Head	Foresight

## Annex C: Horizon Scanning Centre's eight science and technology "clusters"

A critical part of integrating the various activities within the WIST programme was to ensure that all participants drew on a common view of likely developments in science and technology. This was achieved by using eight "clusters" of key science and technology developments, identified and described by the Horizon Scanning Centre in Autumn 2005, to inform and stimulate both of the WIST workstreams - the stakeholder consultations and the public engagement sciencehorizons events - and to provide significant input to the scenarios used in the Health and Safety Executive's horizon scanning seminar on the future of work.

The clusters were originally prepared by the Horizon Scanning Centre for the 2007 Comprehensive Spending Review (CSR 2007) to provide a high level framework to stimulate and test thinking across government. They were used by HM Treasury in the analysis of the CSR "challenge" on science and innovation<sup>31</sup>. They were subsequently published by the Horizon Scanning Centre<sup>32</sup>, and have been used by a number of other Government Departments<sup>33</sup>.

The clusters are not forecasts or predictions, nor are they statements of policy preference.

The clusters:

- draw on a wide range of published and expert views including the Horizon Scanning Centre's own strategic Sigma and Delta(S&T) Scans<sup>34</sup> and the government's Technology Strategy for UK wealth creation and associated Key Technology Areas;
- take account of major social, economic, environmental, and political trends;
- were initially created from these sources during a cross-Departmental workshop on 29 November 05;
- have been reviewed by senior scientists within government (the Chief Scientific Adviser's Committee, CSAC) and by members of the Council for Science and Technology (CST)<sup>35</sup>;
- were published on the Horizon Scanning Centre's website on 01 December 06.

### Characteristics

These clusters have the potential, either as enhancers or disruptors, to:

- transform the delivery of public services;
- challenge society; and/or
- affect wealth creation and the nation's security & vital interests

over the period to approximately 2015 - 2020.

### Context

In thinking about the potential development and impacts of S&T it is important to bear in mind some key contexts, including:

- all the evidence is that it is impossible accurately to predict the paths and timing of uptake of specific technologies: routes to market and to impact (and associated factors such as the timing and nature of public debates) are complex and difficult to model;
- the severe limitations of "technology push" in creating market opportunities, and the consequent need to define capability requirements better, allowing the market to develop solutions to these requirements. The "best" technological solutions, or those first to market, often do not win;
- impacts tend to occur through the combinations of old and new technologies, rather than through single breakthroughs. Technologies having an impact over the next decade are likely to have been based on scientific breakthroughs made decades earlier;
- although discussions about technology often tend to focus on the physical and the life sciences it is essential to capture the best learning from the social and economic sciences, arts and humanities.

### The "clusters"

Brief descriptions of each of the Horizon Scanning Centre's eight key area of science and technology are below. A full set of papers describing them and the process by which they were derived is published on the Horizon Scanning Centre's website<sup>36</sup>.

### Advanced materials and robotics

*Production, distribution and logistics, use, disposal and recycling of new materials. Associated developments in processing and manufacturing, including robotics.*

New, advanced, materials can reduce construction and maintenance costs of infrastructure, vehicles and machinery, and improve many aspects of their performance. Although step-changes in cost/performance are rare the cumulative impact of improvements can be major. Advances in structural and functional materials for hostile environments (temperature, stress, chemical) are at the core of much advanced high value-added manufacturing. "Smartness" refers to the way in which certain properties (structural, thermal, optical etc) of "conventional" materials change in predictable ways in response to a change in their surroundings or some other stimulus. For example, the stress within (and hence stiffness of) some materials can be varied, within limits, by changing the electrical voltage applied to them. Some sunglasses darken in bright light.

One key future trend (linked to nanotechnologies) is the embedding of sensors, computing power and communication systems within the material to make them more responsive, controllable and connected. Structures built with such smart materials will be able to indicate when they need repair, and/or maintenance – and may even be able to be self-maintaining/repairing. Trains and road vehicles built using them should be safer.

Another key trend is the extension of "smartness" from "physical" materials (metals, composites, plastics, textiles, etc and some liquids and gels) to living, biological, material.

A related field included in this cluster is robotics and some aspects of automation which have increasing applications in manufacturing, hazardous environments, and transportation systems.

## Body and mind sciences

*Tools to understand, repair and enhance physical, mental and behavioural capabilities.*

This cluster encompasses a wide range of sciences describing how the human body and mind works, both when it is functioning normally and abnormally (either as a result of an inherited condition, a disease, an injury, experience or an environmental influence). Disciplines such as medicine, surgery, and psychiatry, underpinned by knowledge in areas of science such as microbiology, pharmacology, genetics, the social sciences, and, increasingly areas such as materials science, nanotechnology and electronics can assist in prevention, cure, mitigation, adaptation or other form of management. As well as affecting individuals, such knowledge – particularly in the social sciences, and when combined with expected increases in computing power, and modelling & simulation – also offers improved decision-support tools for a wide range of policy areas.

## Energy technologies

*Technologies to meet society's energy and related environmental needs.*

Technologies linked to meeting society's energy needs and mitigating related environmental impacts, form a significant cluster. They fall into four broad areas: management of energy demand; energy supply, energy storage; transmission and distribution, and; mitigation of the environmental impacts resulting from the generation, storage, distribution and use of energy.

## Information handling & knowledge management

*Tools to store, process, collect, interpret and transmit data. Knowledge integration is defined as extracting, understanding and applying knowledge.*

Information handling and knowledge management are activities that are underpinned by a wide range of Information and Communication Technologies (ICT) which, in turn, create our ability to transform vast, complicated and complex data into information on which we can develop knowledge. Through further use of ICT including new types of user interface, this knowledge can be explored, refined and used to influence our ability to learn and to make decisions.

## Nanotechnologies

*Production and use of nanoscale materials and devices. Associated developments in processing and manufacturing.*

Nanotechnologies comprise a wide range of technologies derived from our growing ability to manipulate materials at a molecular level. These technologies, particularly if combined with Micro-Electro-Mechanical Systems (MEMS), computing power, and design concepts based on biological systems, may lead to the development of objects and materials which are aware of and respond to their environment. Materials manufactured at the molecular level may generate less waste. As a result of these, and other properties of nanoscale materials and manufacturing, many areas of industry and society, such as manufacturing and health-care, may be transformed.

## Network interactions

*Virtual and physical processes through networks.*

New types of network interactions are arising due to the convergence of developments such as higher bandwidth, greater and more distributed processing power, larger datasets, smaller sensors and greater understanding of the dynamics of physical, virtual and human network behaviour. This may impact on areas from the nature and capacity of early warning systems to the design of formal or informal organisations and enterprises. It may also be shaped by decreasing distinctions between physical and virtual environments (e.g. greater automation of the role of the vehicle driver, or shifting patterns in the geographical manifestation of network-enabled influencing groups). Increasingly complex networks, and systems of networks, are also more likely to show unplanned emergent behaviours.

## Security technologies

*Monitoring, tracking and detection tools plus understanding and identification of complex behavioural patterns to prevent, protect and profile security risks.*

The development of technologies that underpin our understanding of crime and security in an increasingly complex and complicated world are wide-ranging and draw upon many activities, such as detection, identification and surveillance. The potential for optimising our understanding of these issues lies both in advances in the physical sciences as well as through developments that link our understanding of the physical sciences with the human sciences.

## Sensors & tracking

*Tools to enhance our knowledge of the physical world through effective monitoring of the environment, objects and people.*

This cluster comprises a number of technologies that allow us to detect, identify and monitor aspects of the physical world. Their application has the potential for use in many different systems, for example: natural hazards, space and weather systems; changes in plants and animals and human activity, and; the movement of goods and people. Sensing and tracking technologies provide us with initial inputs that allow better monitoring, modelling and potentially management of these systems.

## Sources

31 "Long-term challenges and opportunities for the UK: analysis for the 2007 Comprehensive Spending Review." HM

Treasury. Nov 06. [http://www.hm-treasury.gov.uk/spending\\_review/spend\\_csr07/spend\\_csr07\\_longterm.cfm](http://www.hm-treasury.gov.uk/spending_review/spend_csr07/spend_csr07_longterm.cfm)

32 [http://www.foresight.gov.uk/HORIZON\\_SCANNING\\_CENTRE/Reports/S-TClusters/Clusters.html](http://www.foresight.gov.uk/HORIZON_SCANNING_CENTRE/Reports/S-TClusters/Clusters.html)

33 e.g. the Ministry of Defence in their Strategic Trends paper <http://www.dcdc-strategictrends.org.uk/>

34 The Sigma Scan – [www.sigmascan.org](http://www.sigmascan.org) - is a synthesis of future issues and trends covering the full public policy agenda drawn from a range of sources (including think tanks, academic publications, mainstream media, corporate foresight, expert/strategic thinkers, government sources, alternative journals, charities/NGOs, blog sites, minority communities, futurists).

The Delta (S&T) Scan - [www.deltascan.org](http://www.deltascan.org) - is an overview of future science and technology issues and trends, with contributions by over 200 UK and US science and technology experts from the worlds of government, business, academia and communication.

In common with much futures/foresight work, the Scans are designed to challenge current thinking and implicit assumptions. They do not to attempt to predict the future, nor are they statements of Government policy or preference.

35 The Government's senior advisory body on major science and technology issues of strategic importance to the United Kingdom

36 For the full, 51 page, cluster description see [http://www.foresight.gov.uk/HORIZON\\_SCANNING\\_CENTRE/Reports/S-TClusters/Clusters.html](http://www.foresight.gov.uk/HORIZON_SCANNING_CENTRE/Reports/S-TClusters/Clusters.html)

## Annex D: WIST workshop stimulus material

See WIST workshop workbook - separate document.

Include reference to link on HSC website where the workbook will be published.

## Annex E: Range of possible Government responses

### Descriptions of possible Government responses

Participants at the workshops were given the following text to make them aware of the range of possible responses that were open to Government, and to help participants and facilitators structure the discussions:

Government's response to new and emerging areas of science and technology<sup>37</sup> is complex, involving a range of responses (see below), and may be different at different stages of the cycle of development, manufacture, use and disposal of a technology.

The response of Government is critical to ensure that society is protected, whilst reaping all the potential benefits (including the growth of new economic sectors).

The range of Government's possible policy responses includes<sup>38</sup>:

I **Legislative/Regulatory** either in order to protect individuals, society and the environment from harm, or to encourage research and innovation by establishing a framework within which they can flourish. The various types are:

- a. *Primary Legislation*: where action is required by Government, but existing legislation does not cover the circumstances arising from the development in science and technology, e.g. a breakthrough creating an entirely new domain of medical intervention and scientific research – the “test-tube baby” born in 1978 – led to the Human Fertilisation and Embryology Act (1990), which was introduced to make provisions to license and monitor the performance of fertility treatment clinics, and any research using human embryos. Also provides a clear legal framework within which further research and innovation (eg Stem Cells) can take place.
- b. *Changes to Regulation under existing legislation*: for example, advances in knowledge about the susceptibility of workers to noise-induced hearing loss, coupled with society's increasing concerns about the harm done to individuals and the costs to society, and the rise of the “compensation culture”<sup>39</sup>, led to a policy response to require employers and employees to take various actions at lower noise exposures than previously required. This was done by issuing new Regulations stemming from European Health & Safety Directives.
- c. *No change to existing Regulations etc as existing ones are adequate*: eg an assessment of the risks associated with the introduction of a new chemical into an industrial process is already required under the Control of Substances Hazardous to Health (COSHH) Regulations, so, unless that assessment identifies a new hazard (which is improbable given the deliberately broad definition of hazard used in the existing Regulations), the development and introduction of a new material or chemical is unlikely to require any additional regulatory response related to health & safety (although other aspects may require new regulation). Similarly, any new product or device (a RFID tag, a new type of computer storage device, a pharmaceutical drug) is going to be influenced by a range of existing legislation or regulation (eg H&S, consumer protection) as it moves into the market.

2. **Policy change:** a change of policy that does not require legislative or regulatory changes.
3. **Advisory:** The provision, by Government, of information and advice:
- E.g. for employers e.g. the Scottish Executive issues advice on protecting the health of poultry workers from Avian flu.
  - E.g. for the public e.g. the Food Standards Agency states that "Adults should eat no more than 6g salt a day".
  - E.g. for both the public and business e.g. the government and leading businesses have together created a website - [www.getsafeonline.org](http://www.getsafeonline.org) - to help individuals and small businesses protect themselves against internet security problems.
4. **Investment** to meet some other, existing, policy goal (eg economic growth):
- E.g. investment in public infrastructure and other procurements. In response to the development of the motor car, central Government funded building of the national motorway network.
  - E.g. investment in research to better understand issues associated with a new development, either directly through its own research programmes (e.g. DEFRA funding of field-trials of GM crops), or indirectly by seeking to influence industry's R&D expenditure (e.g. the Technology Strategy Board's investment in "Innovation Platforms" on e.g. Network Security and Intelligent Transport Systems.)
  - E.g. investment in skills.
5. **Enable/Convene:** create and stimulate desirable activity to seize opportunities and manage risks e.g. Knowledge Transfer Networks (KTNs) whose aim is to improve the UK's innovation performance by increasing the breadth and depth of the knowledge transfer of technology into UK-based businesses and by accelerating the rate at which this process occurs.
6. **Consultative or deliberative** in order to get more information, or views of relevant stakeholders (including the public), in order to inform policy development:
- E.g. The Independent Expert Group on Mobile Phones (IEGMP), also referred to as the Stewart Group (it was chaired by Sir William Stewart), was set up in 1999 at the request of the Minister for Public Health to examine the possible effects from the use of mobile phones, base stations and transmitters on health.
  - Public Engagement e.g. "GM Nation" or DTI Sciencewise programme of public engagement on stem cell research announced 02 Mar 07. (NB a purpose of the WIST programme is to identify areas where Government-sponsored public engagement would be beneficial to society and policy-making.)
7. **Participate in international debate** in order to further UK interests (for which it needs to develop a viewpoint first).
- E.g. influence European Directives on recycling of materials in cars and consumer electronics.

8. **Laissez-faire:** Government takes a conscious decision not to respond, but to leave development, introduction, take-up, spread, use and disposal entirely to social and market forces. Hard to think of any examples of anything being developed and introduced that isn't covered by some aspect of existing regulation: the key question, therefore, is "Is existing regulation adequate?"

9. **Engage with the public:** Mis-interpret the significance of the development, or fail to spot it entirely. This is what the WIST programme is intended to help prevent!

### Sources

37 "science and technology" is used here to mean far more than "widgets": as well as products and devices, it includes ideas, knowledge, materials, and processes.

38 This is not an exclusive "choose-one-from-the-following" list: many S&T developments will provoke multiple responses. For example, the Government's response to the motor car includes investment in infrastructure and regulation (including a regime of standard-setting, testing, compliance-monitoring and punishments for infringement) associated with the licencing of both drivers and vehicles to use that infrastructure.

39 The relative impact of these factors is, of course debatable – but that debate is not relevant to the discussions within the WIST programme. It does, however, provide an example of multiple causes – not just a single development - leading to a particular policy response.