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Europe, and the UK, in space

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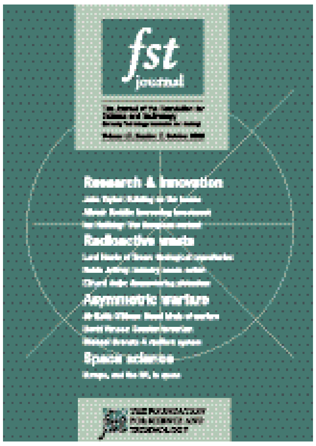

# Roots of UK underfunding

The British Treasury has now published on its website (www.HM-Treasury.gov.uk) the detailed analysis on which is based the generous allocation of public funds to spending on research in the three years beginning next April. Called the final report of the "Cross-cutting review of science and research", the remarkable document is a frank account of the imbalances in the funding system that may yet jeopardise the future of British research.

The underlying difficulty, the report says, is twofold: universities and comparable institutions fail to recover the full costs of carrying out research funded by external bodies (such as research councils) while there is an accumulated backlog of investment in the research infrastructure that will not be made good for ten years.

The report laments the lack of a clear understanding of what now constitutes the dual-support system for research. So far as universities are concerned, funds arrive by two routes: directly from research councils, charities and the like in response to research proposals and indirectly from the universities' funding councils on the basis of the periodic research assessment exercises (RAE) by means of which individual departments are graded by the stature of their research. The second stream of funds, known as QR (for 'quality-related research'), is intended to equip universities with what used to be called 'well-found laboratories'.

One graphic index of current underfunding is that QR funds have increased by 28 per cent in 17 years, while the value of project grants to the universities has increased by 65 per cent. Taking account of spending by other agencies (charities, industry, government departments and the European Union) on university research projects, the report says that the ratio of indirect to direct support of research will have halved from near equality in 1989 to roughly 50 per cent in 1999.

How have universities balanced their books? The report concludes that they have used income from fees paid by overseas students, other income (such as conferences) and by underinvesting in their 'estate'. The remedy? The report repeatedly declares that universities must assume responsibility for recovering the full costs of the research their academics carry out. In the year 2001/2, shortfall is estimated at £2,013 billion, or nearly 70 per cent of the total relevant research income.

How will universities recover full costs? The report does not offer a magic formula for defining overhead costs as a proportion of project grants, but recites the difficulties of arriving at an acceptable rule of thumb. The chief among these is the insistence of British charities, notably the Wellcome Trust, that they will not meet indirect research costs.

The report's estimate of the accumulated underinvestment in infrastructure is necessarily more sketchy. It says that, to stand still, British universities should be investing about £350 million a year in infrastructure but that, at present, they spend about a half of that. The accumulated shortfall is estimated at £2.7 million for buildings and £0.5 billion for capital equipment.

### Dogger Bank dries up?

This year's annual haggle over European fishing quotas will be even more than usually contentious. The European Commission is proposing that there should be a moratorium on fishing for cod, whiting and haddock in the North Sea for fear that there will otherwise be a collapse of stocks. Fishers' organisations and the governments of Spain and France have already protested that the plan is unworkable. Will this be the ultimate test of European Fisheries policy? (see *FST Journal* **17**(5), 3–9; 2002).

### European NAVSAT system agreed

Lord Sainsbury's caution last year about the future of the European Galileo project (see page 22) for satellite-based navigation on the surface of the Earth has since been dispelled, with the commitment of sufficient funds to the project by European governments (and the European Union). Although comparable with the existing US Global Positioning System (GPS), and interoperable with it, many of those investing in the European system appear to have been swayed by commercially strategic considerations: fears that European commercial applications of terrestrial navigation by satellite could be jeopardised by reliance on a system controlled by the US government.

Meanwhile, there has been a hiatus in the spending of the funds. Italy and Germany, the two largest contributors to the project, with more than 40 per cent of the total between them, are not yet satisfied with the proposed division of ground-based labour, in particular for sharing out the construction contracts and the location of the ground-based facilities for maintaining the system. ❐

## correspondence

### Sustainable science

**Sir** — I agree with Professor W I Montgomery (*FST Journal* 17(6), page 2) that the Foundation's discussion meeting entitled *How should governments support science and innovation in a growing economy?**, did not fully cover the field.

He points out that many university entrants with science backgrounds are opting for vocational subjects such as medicine or pharmacy, or moving outside science altogether. The question arises, why?

Scientists are increasingly finding themselves employed in the defence field. During World War II, some 70 per cent of scientists were working in that field, reasonably enough. Since then we have had Cold War arms races that were basically scientific.

But what about now? Were I a 17–18 year old in today's world, designing weapons is not what I would like to devote my skills or my life to. Nor would I want to be boosting the profits of a multinational corporation whose care for the wellbeing of either his/her fellow humans or of the globe leaves much to be desired and for whom the precautionary principle has no meaning when a quick dollar comes into view. Better to go in for medicine, and even pharmacy.

*Elizabeth Kennet*

*Discussion Meeting, Belfast, 19th March 2002, *FST Journal*, **17** (5), 9–13 (2002).

**Dear Sir…**

*FST Journal* invites correspondence from readers for possible inclusion in the journal. Preference will be given to matters arising from the Foundation's lectures and discussions. Address material for consideration to:
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# Building on the science and engineering base

Dr John Taylor OBE FRS FREng

***Priorities for Research and Innovation in the UK***

*On 15 July the Chancellor of the Exchequer announced the outcome of a comprehensive spending review which determined departmental spends for the next three years. At the FST dinner/discussion meeting held on 16 July, the priorities for research and innovation, which covers potential spend by the DTI, DfES and the devolved authorities, was debated. The general discussion that followed the three speakers is summarised by Jeff Gill.*

Dr John Taylor is Director General of the Research Councils at the Office of Science and Technology in the DTI. He was previously Director of Hewlett Packard Laboratories, Bristol

I shall begin with the science budget. The new settlement in this year's Government spending review involves a real-terms increase of 10 per cent for each of the next three years, from 2003/4 to 2005/6. That compares with an average increase of about 7 per cent a year agreed in 2000. That is a good settlement from our point of view; we are very pleased about it. It will take the science budget to about £2.9 billion by 2005/06, which is very close to doubling in less than 10 years.

There are two components of the settlement. First, there is a 5 per cent real-terms annual growth for new science, for new response-mode grants and for new programmes between the research councils – the core of their work.

The second part of the settlement funds is meant to tackle structural underfunding and over-trading in both the universities and research council institutes. It is said that Britain has 1 per cent of the world's population, 4.5 per cent of the world's funding for science, 7 per cent of publications and 8 per cent of citations. On the face of things, we punch well above our weight. The other side of the coin could be that we do science on the cheap. In reality, we do not pay the full costs of research. We must now repair the infrastructure and pay attention to operating at better than marginal costs. So we have a major uplift for the final year, to add to what we pay out for the costs of research grants that we fund.

The Science Research Infrastructure Fund (SRIF) will continue, providing capital to universities to renew infrastructure and to re-equip; the fund will increase by £50 million a year in the last two years of the settlement. Then we have another part of the settlement which relates to the funding implications of Sir Gareth Roberts' recent SET for Success Report, so that the budget for the three years is £10 million, £40 million and £100 million, respectively. We have a lot of work to do to get the details right, for this covers PhD stipends, researchers' salaries, fellowships and so on.

Finally, our knowledge-transfer work is being continued, the new round of the Higher Education Investment Fund will subsume the science enterprise challenge, university challenge and so on and be increased modestly in the second and third years, while there will be a further knowledge-transfer fund for the public sector research establishments – the first attempt at doing that seems to be working quite well. That is the settlement.

### Research Councils UK

I shall now briefly describe the Research Councils UK (RCUK) organisation that

**discussion**

**Spreading resources too thinly.** In discussion the idea of the Rutherford Appleton Laboratory pitching for the proposed electron/positron collider was compared to Manchester putting in a bid for the Olympics. The speaker saw a national vice of spreading resources too thinly and trying to cover too much instead of joining European collaborations. In some areas, such as nanotechnology, the UK could indeed go it alone, but the question was how to identify these areas. Another speaker deplored an unprofessional tendency to jump ahead into the next area without first making a success of existing work. The UK was only in aerospace because of the French and would become an anachronism unless it went with European programmes.

Another participant argued that, although the UK could not compete with the USA, Europe could, but only if it got its act together. There were not many examples of European collaboration to compare with CERN, and a European research council was a critical area for debate. In response it was observed that it was the core job of the research councils to make hard decisions whether to back particular projects, using appraisal procedures and peer review to help manage a portfolio with limited funds.

we set up this year. It is comprised of the seven research councils (and possibly the Arts and Humanities Research Council if that comes into being) that work with me on common questions such as what is going to get funded, where is science going, how do we maintain sustainability, how do we transfer knowledge, how do we relate internationally and so on. This major move forward will give us a collective identity and a collective voice when either is needed for the research councils. Its objective is to benefit science. It will try to expand the interfaces between the councils wherever the science needs it.

We decided that it would not be sensible to reorganise all the councils into a single council; what we have decided to do is to work together much more organically and much more flexibly when it makes sense to do so. I am very pleased with how things have gone so far. The organisation is already implementing the quinquennial review recommendations. It is a very important tool with which we shall work together to develop our strategies for science and the science base in coming years.

There are three fields in which I believe this organisation will add value. The first is in the strategy for the science budget and research, including postgraduate education and training; in knowledge transfer; and in the whole issue of science and society activities — dialogues, for example.

Second, it will provide a single voice for the councils when they need to talk to other major organisations as well as a single portal to the councils from outside when people want to talk to somebody but do not quite know to whom or how. The councils' potential interlocutors are legion. There are other organisations funding research, both international and from Britain, and we all affect the university community as we alter the way in which we fund or otherwise influence research. Regional influences in Britain are becoming more prominent, notably the devolved administrations. There are people in all those organisations who need to talk to the research councils about research strategy and research directions and priorities.

We also intend that RCUK will enable us to operate more efficiently and more effectively and, in particular, provide simpler interfaces to the universities and the other people that we deal with. We shall be working very hard behind the scenes to streamline what goes on there.

## discussion

**Regulation.** One obstacle to the application of research was the cost of regulation, as in the case of GM technology. Even in the EU there was a recognition that regulation could be excessive. But sometimes businesses themselves preferred to operate within the certainty of a regulated framework.

The role of the patent system in encouraging innovation was debated. On one view its effects were largely negative, and the "Cambridge phenomenon" — the growth of technology-based industry around Cambridge — was partly the result of the University resisting pressure to patent research results. Against this it was argued that patents were crucial, but that just counting them was no way to measure success. Intellectual property was a serious and subtle business, and it was no use just taking out as many patents as possible. It was regrettable that there was still no uniform European patent: without it the protection of intellectual property was a very chancy business. There were big differences between Member States on this issue and progress was difficult.

### International perspectives

To compete with and collaborate with the best in the world, we have to think internationally. (Our e-science programme is providing infrastructure that makes that much easier and better.) Each year, it seems, issues crop up where there is a need for a facility so large that you cannot have more than one on the planet. There is going to be only one Large Hadron Collider, for example. You need to collaborate internationally to get the science done.

Similar issues will arise when there is a need for an overwhelmingly large ground-based telescope or a microwave array the size of heaven knows what: there will be only one of them and we had better all get together and work out how to build them, not necessarily in the way we have functioned in the past.

The continuing need for large and expensive facilities is only part of the problem. Take the Human Genome Project. The human genome was sequenced by a major global collaboration in which British scientists played a leading role. It is important that we should understand how to stay at the leading edge of projects like these. We cannot possibly do everything, but we must continue to play a leading-edge part in projects we consider important.

That is the worldwide perspective, but there is also Europe to consider. What should be our policies towards what is happening in Europe — Framework programmes, proposals for a European Research Area, for mobility of European researchers and even ideas such as a European Research Council?

We need to make sure that we promote the most effective UK participation in the major Framework programmes as they develop. Most leading scientific countries understand, as we do, that there is global competition for the best people, who are in short supply everywhere. We have to make sure that we get more than our fair share of the best people working in our programmes. And we need to think through the implications of that as the years unfold.

The perception of European R&D is not all it might be. We are certainly seen as being behind the United States and the Japanese. Are we less good than others in transforming results into products and services? The EU Framework programmes are only a little over 5 per cent of the total public research effort in Europe. Even if you add in Eureka and CERN (European Organization for Nuclear Research), it is still well below 20 per cent, so the rest is done in national programmes. One thing that is important in the European Research Area is to make sure that national programmes collaborate and cooperate — and compete for that matter — more effectively than at present.

The Framework programmes have grown a lot; they represent serious money. We need to make sure that we understand where we are going in Framework 6 and later. They will operate on different rules, with much more delegation away from Brussels.

I shall finish with a few remarks on knowledge transfer. How do you measure success? There are many different indicators but, if you choose the wrong ones, you can easily encourage the wrong kind of behaviour. If, for example, you tell people that it is patent-counts that matter, they will go and get a lot of patents but that will not necessarily transfer knowledge to the economy — it may even have the opposite effect. So we have to sustain the debate about the diversity of the missions of higher education institutions. What of the teachers in higher education institutions as the number of students in the age cohort increases along with the number in education? Will they all be doing the same kind of research? And, if not, what will be their roles in regional activities and knowledge transfer? ❒

# Innovation and increasing investment

**Dr Alistair Keddie**

Dr Alistair Keddie is Acting Director General of Innovation at the DTI. He took a leading role in establishing the new group as part of the DTI's reviews of priorities and structure.

John Taylor has talked about building on the British science and engineering base; I shall describe how we intend in the Department for Trade and Industry (DTI) to complement the increasing investment in the science and engineering base.

As many of you will know, in the middle of last year our Secretary of State initiated a major review of DTI. Several things came out of that, including the need for a much greater clarity of purpose for the department, a clearer focus on key priorities and better delivery both in policy making and in business support.

The objective of the DTI has been broadened, and is now "prosperity for all". Our agenda, in other words, is no longer exclusively a business agenda. If we seek to increase British productivity and competitiveness, that is not an end in itself, but a means to increased prosperity. To succeed, we need businesses that are successful and we need world-class science and world-class innovation. Dr Taylor has talked about the science, I shall concentrate on the innovation.

### The drive for innovation

The new organisation of DTI includes the Innovation Group, of which I am the Acting Director General. Inevitably, we work closely with the Office of Science and Technology (OST), where Professor David King, Chief Scientific Adviser, and Dr Taylor sit. The rest of DTI has been split into four new business units: business, energy, fair markets (including most but not all of regulation) and the innovation group.

I should also mention British Trade International (BTI), which is an important element in achieving DTI's goals. Increasingly, we have to think globally. BTI is no longer just about exports, but also to do with strategic international alliances. Like OST, we are building stronger bridges with BTI as part of our overall agenda.

The Innovation Group unites what were previously disparate functions and includes 1,300 or so people, including two agencies — the Patent Office and the National Weights and Measures Laboratory. This will help us build a much greater degree of complementarity between the OST and the research councils.

The Knowledge Transfer Strategy Group to which Dr Taylor referred is another organisational innovation. We regard it as a very important process, including as it does Robin Young, Permanent Secretary at DTI, Professor David King, Dr Taylor and myself, together with the Directors-General for Business and Energy. The strategy group represents another fundamental change in the way that the Department regards innovation.

What do we mean by innovation? I do not want to get hung up on definitions, but innovation is the successful exploitation of new ideas. The outcome of the process must be something that satisfies end users, whether in the NHS, business or just consumers such as you or me: the stress is on the word "successful". "New" does not necessarily mean entirely novel, but may mean something well understood and used in one sector of the economy but unfamiliar in another. This play on words is deliberate. It is meant to emphasise that innovation goes beyond science and technology, important though they are, and to emphasise that much innovation is driven by the market place. To put it another way, innovation is as much about the way we do business as it is about the ideas that are exploited. If we do not get the climate for both of these right, we shall not succeed.

> "The outcome of innovation must be something that satisfies end users."

Why is innovation important? Plainly it is linked to our goals for productivity, competitiveness and general prosperity. There is now well substantiated empirical evidence from this country and elsewhere that innovating companies grow faster than the non-innovators, are more profitable and sustain higher performance. It is important to note that this proposition appears to be the more true during periods of economic downturn. Businesses of all kinds do pretty well when the economy is doing well, but those with a record of innovation seem better able to survive the hard times. The inference that they also are the more likely to make a difference in the future is another part of the reason why we are giving innovation so much more emphasis in DTI and, indeed, at the Treasury. (In the past few months, we have been discussing with the Treasury the part that innovation in its broadest sense plays in the British economy.)

Like all creative forward-looking groups, the Innovation Group has a vision of the future. We want to see businesses in the UK achieving greater profitability through innovation, investing in innovation for long-term growth and competing successfully with the best in the world. But competition is not everything: much business success comes from partnership; we need to find ways of encouraging more businesses and organisations to form successful partnerships with the best in the world. We also want to see Britain recognised as a location for world-class innovation.

"Competition is not everything… business success comes from partnership."

You may say that is a pretty aspirational mission statement, but we are serious about it. We want everything we do to be world class, which does not mean that we will be world class in everything, rather that the things we decide to go for should be world class.

How do we go about that? I believe the key is building and sustaining an unrivalled understanding of what innovation is about, and what it means at the level of the business or the organisation. Unless we have a better understanding than at present, quite frankly I think it will be difficult to engender the know-how and credibility to stimulate innovation.

We have some specific objectives. First, we set considerable stress on faster take-up of emerging and existing technologies, of best practice and of new business models. In DTI, we interact with businesses and other organisations too slowly; so now there is stress on doing things faster.

Second, throughout British education/employment, there are major mismatches between the supply and demand for skills. It is probably better in the higher education sector than elsewhere, but it is a significant issue for the economy as a whole.

**Regulation**

Last, but by no means least, is how we go about regulation. Arguably, in the design of new regulations, we are less concerned with goals and outcomes than with prescriptions and this may inhibit innovation. There is a major agenda here that cannot be tackled in Britain alone, but which requires partnership with international organisations. That is why we are building alliances within DTI with the Fair Markets Group.

How will we know we are making progress towards our objectives? We are working on the design of key performance indicators. But we recognise that some things are more easily measured than others; it is quite difficult to measure whether we are picking up emerging technologies quickly enough.

What can we bring to the party to help deliver this strategy? We have unrivalled global knowledge of what is happening elsewhere, but we need to be much better at building networks of common interests. Benchmarking tools that allow companies and other organisations to benchmark themselves internationally against the best in the world are valuable, but they need to be improved and extended to cover the whole gambit of innovation.

On the financial side, much of the present focus of DTI financial support is on infrastructure, the national measurement system, products standards and design. Are all of these to world-class standard? If not, should we be supporting them at all? If we aim to focus our effort accurately, perhaps we should decide to do in Britain what we already do well and have partnerships with other countries, such as Germany and the United States, for other things.

The big numbers in the Spending Review that Dr Taylor mentioned in relation to the science base are a significant opportunity for business and for others who may benefit from that investment. DTI will also have some additional money — an additional £50 million in the third year of the Spending Review — to encourage greater business pull on the science base. And let us not forget that the two R&D tax credits, one directed at smaller businesses and one at larger businesses, once fully implemented, will make something like £500 million a year available to business through tax breaks. These are significant in encouraging greater business investment in R&D and collaboration with the science and engineering base.

I conclude with some remarks on what we call key disruptive technologies. As a department, we need to become much better at identifying technologies coming over the horizon that have the potential to transform products, processes or services, and whose impact is likely to be pervasive, perhaps radical, in improving performance and productivity, in creating new markets and, just as importantly, which have the capacity to destroy the competitive advantage of traditional businesses or sectors. So we need to get much better at anticipating what these challenges will be. ❐

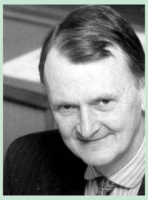
### discussion

Availability of scientists. A speaker raised the question whether enough qualified and motivated scientists would be available to support the expanded research programme which Dr Taylor outlined in his lecture. One view offered in response was that at least some areas of research would have no difficulty in attracting PhD students, provided funded posts were available for them. Part of the new science budget was to be used to implement the recommendations of Sir Gareth Roberts' SET for Success Report, for example on stipends and academic salaries. This would take time, though, and in the meanwhile there was keen international competition for good young research scientists.

It was also for consideration whether some of the new resources ought to go to addressing the shortage of appropriately qualified teachers of science and mathematics and selling science to school children. Industry too ought to support efforts to interest children in science and technology.

# Research in the European context

Professor Ian Halliday



Professor Ian Halliday is Chief Executive of the Particle Physics and Astronomy Research Council.

I will begin with some of the questions now facing the Particle Physics and Astronomy Research Council (PPARC), in the belief that many of them are relevant to other research councils. I shall then take up the question of the positioning of Britain's research in the wider European context.

What, you may ask, is a research council for? I believe a research council's main business is to make tough decisions; that is really how we earn our bread. The machinery — we use peer review, review, consultation and so on — is a means to that end, but it is the decisions that are important.

One example sitting on my desk (and, by implication, on that of RCUK) is the global future of particle physics. This is how the issue has arisen. As a result of decisions made in 1996, we are building at CERN in Geneva a big accelerator called the Large Hadron Collider (LHC). The total global cost is about SwFr 4 billion, just under £2 billion, so this is serious and global big science. The immediate question for PPARC is, "How much extra do we invest to make a success of LHC?"

Further ahead, in the next one to three years, is the need for a decision about the next big particle physics facility. It has been agreed in Europe that an electron/positron collider is the answer. The Americans, independently, have decided that this is also their goal; somewhat surprisingly, the Japanese, the Chinese and others have also decided that this is what they want. But there will be only one machine.

In Hamburg, the Germans have been doing research for 10 years, they have spent about DM 100 million and, in effect, they have bought the European site. If the machine is built in Europe, it will be in Hamburg. The Americans' preferred site is probably Chicago. The Japanese are a bit of a mystery, but insist that they are still serious players. The machine will not be working for 10 years, but the decision is upon us.

In passing, I confess that I envy the way the Germans, by investing DM100 million, have acquired a 50-50 chance of attracting a large international institute to Hamburg. In Britain, the Treasury has traditionally been sceptical of the value of big facilities, saying that they use highly qualified staff who could be employed more productively elsewhere in the economy. All I can say is that if you go to Hamburg or talk to the Canton of Geneva about the value of their big laboratories, the people concerned are absolutely unequivocal that they have a high added value. Geneva wants CERN to stay, even though the city does not have an unemployment problem.

There then arises the question of what kind of machine will follow the electron/positron collider. There is a chance — and it is only a chance — that if we play the British cards correctly, it could be at the Rutherford Laboratory. These facilities cost several billions, whatever unit of currency you care to use, which provokes a string of questions for a research council like mine: "Do we put all our money on the LHC and go for broke?" "How much do we put with our friends in Germany or Stanford, and when do we make the decision?" "How much do we put aside for a long-term gamble that Britain would win a big international facility?"

How does a research council make such decisions? Of course, we consult the particle physicists. And what do we find? The guys at the Rutherford Laboratory who want neutrinos say they want neutrinos at Rutherford. The guys who want linear colliders say they want linear colliders. And the guys who are working their socks off at CERN say, "For God's sake, give us all the money!" How do you strike a balance?

### Positive thinking

Because in Britain we are used to reducing budgets, the idea of holding an aggressive agenda for the future has hitherto been just inconceivable. One consequence of the comparative success of the last two spending reviews is that we can start thinking more positively. But you have to be careful. "How good are the scientists making the various proposals?" "How credible are the proposals?" "Will the universities or the Rutherford have the manpower to deliver this science project?" "What are the risks, and the benefits?"

My message is that it is not easy to

make these decisions, which entail a mixture of looking into the future and gambling. The whole structure of PPARC or any of the other research councils is geared to making these decisions. The real test of a research council, PPARC included, is whether it makes these strategic decisions correctly and whether they pay off.

I could make exactly the same speech about the British involvement with space – again there are short-term and longer-term opportunities and others over the horizon. Again we need dialogue with the universities about staff, about their capability and about the investment needed to build things. That is very much the area for an RCUK strategy. I believe that not only PPARC but also the other research councils must now consider how we improve our capabilities so as to seize the opportunities implicit in this extra money.

The dialogue there has to be is about strengthening the British capability to do science and to transfer knowledge. It will involve all the research councils, indeed the whole scientific community. We have come a long way, but there is still much to do. At Stanford, California, I see the impact of accelerator research on local business: it is much stronger and more tightly focused than here. We still have problems in engaging British companies in our problems. I offer no quick solutions, but PPARC will give this matter its close attention in the years ahead.

These questions are no longer exclusively British questions. Roughly half of the PPARC budget goes into CERN, the European Space Agency and the European Southern Observatory: it is plain that we operate in a European environment.

Why has CERN been such a success? If you go there and watch who takes charge of what, you find that whether you are British or German is immaterial. It is crucial to the success of CERN that they simply ask of the people in charge of things, “Are you the best in Europe?” The EU and others are hunting for such a model.

I see Europe from a funny vantage point, I admit. *Ex officio*, I am on the governing councils of the European Science Foundation and those of CERN and ESA. Then Commissioner Philippe Busquin made me vice-chairman of the European Research Advisory Board (EURAB), which has an unusual remit. It is independent of the Commission, we are given some work to do but are allowed to take up other issues as we think fit. But we are not allowed to write proposals to the Commission longer than six pages and, in all such papers, there must be about six things that the Commission can do or cannot do “almost instantly”. That focuses the mind powerfully!

## discussion

**Applications and marketing.** A speaker wondered why the results of applied research could not be put into operation more quickly. Possible explanations were an aversion to change and the “not invented here” mentality. Another contributor saw a need to turn UK science into “working steam” for the economy. Ideas were generated and companies started in the UK, but then they tended to go abroad. Nothing would be achieved, however, unless the motivation was there, and DTI needed to find out what business was interested in and not just proselytise. Another speaker argued that research results did get applied in the UK all the time and that the science base was critically important for the competitiveness of industry. It was essential to keep investing in research, not in prescribed areas — a recipe for disaster — but in areas where there were applications. There was a history of funding very bad science and then sending it to a private sector which did not want it.

One speaker wondered what mechanism would replace Foresight in linking innovation to market demand and engaging industry in setting research priorities. In response it was observed that nanotechnology was an example of an area where a lot of research was happening in the UK but there were few marketed applications. Without a route to market there was no way to test whether ideas were sound, and there was a need for scientists who would bring their results to the market rather than apply for the next research grant. The Foresight process had become rather diffuse, and it was probably a mistake to try to cover the whole waterfront in one exercise. One approach might be to focus on a problem, such as coastal flooding, and consider what science could do about it. In that particular area there was a mixture of private and public research, but not enough interaction between the two. In a final comment, another speaker observed that there was a case for publicly funded research to go beyond responding to market demands and look at social needs. Sustainable development was one area where rapacious consumers should be able to look to science for guidance on how to enjoy life without depleting natural resources fast.

➩ A detailed summary of the discussion is available on www.foundation.org.uk

We have written one proposal about the improvement of peer review in the Commission’s own operations: the Commission said “done” to a dozen or so suggestions. We are about to write another six pages on how the university/EU interface can be improved. The basic message will be that the Commission is there and funds research; it would be very good if the Commission paid the full costs of the research it supports. Whether the Commission will say “done” on this occasion is another question.

There is a bigger question coming up. The Commission has already asked us for radical thoughts (in less than six pages) on how the future research programme Framework 7 (from 2006) should be designed so that Europe can cohere around research. CERN, where the whole of Europe gets together and competes at some level, has evidently fired the Commission’s imagination, but it has no idea how this could be done.

EURAB membership is half industrialists and half academics, My fellow vice-chairman is an industrialist from Mercedes Benz; and 17 per cent of the total R&D spending in Germany passes through their hands. He tells me that what the Commission does in the Framework programmes is utterly irrelevant to Mercedes. If they need to do anything, they do it. They would like the other money to be used for blue skies research — exciting things that most of the time will lead nowhere but once in a while will lead to something really worthwhile. So, totally to my astonishment, I find that I and the man from Mercedes make identical speeches to EURAB about the future of European research.

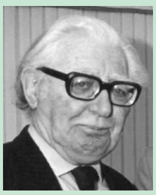
I believe that there are many changes afoot in the spending of European Framework money. The Commission seems to be flexible, certainly the current Research Commissioner is open-minded. There is an opportunity here for RCUK, DTI or whoever to put together a coherent British picture of what we would like to happen. My fear is that Britain will not organise itself to take advantage of these circumstances. I mentioned earlier that we have just joined the European Southern Observatory: arguably, we have done this 30 years too late. ❐

# Why the House of Lords backs geological repositories

The Lord Howie of Troon

***How should radioactive waste be managed?***

*With a quarter of the United Kingdom's electricity produced by nuclear power and with Government environment policy backing continued use of this non-$CO_2$ producing power source, radioactive waste disposal is high on the political agenda. At the FST discussion meeting on 12 March 2002, Lord Howie of Troon, Dr Robin Jeffrey from British Energy, Professor Salje, Programme Director of Research at MIT Institute Cambridge and The Rt Hon Micheal Meacher MP led a discussion on how radioactive waste should be managed. The discussion was summarised by Jeff Gill.*



Lord Howie was a member of the Science and Technology Committee.

It is three years since our Select Committee reported on the issue of nuclear waste and its disposal. We had hoped that the Government would have moved into action by now. Our report appeared in March 1999, and we were promised the Government's response that Spring; we got it in October. We were then told that the Government's proposals would appear in early 2000; they appeared in late 2000. The minister then came to meet the committee. Many of us were disappointed. This may be a long-term problem, stretching over many thousands of years, but that does not mean that you can put off making a start on the problem indefinitely.

On the contrary, we believe that to deal with the vast amount of radioactive material that already exists, we should be thinking very seriously about dealing with it permanently; I believe we need a solution in the next 20 years or so. But the subject is highly political and will be dealt with only by the Government persuading the people to let it do what it eventually decides to do. Of course, there will be scientific and technical arguments to back up the decision. The immediate question is what to do with the stuff that already exists. There is a sizeable amount.

The Committee considered various means of disposal, of which the two most likely were: (1) deep disposal in geological formations thought to be suitable and for which engineering could be devised to make them safe; and (2) indefinite surface or near-surface storage. Various other proposals such as dumping waste in the sea or firing it into space were considered not to be feasible. We considered that geological disposal was the best feasible way of dealing with this material for as far ahead as we could reasonably see.

That raises philosophical questions. Our recommendation of geological disposal has a crucial caveat: the material disposed of should be retrievable, at least for a while. Our reasoning was that the engineering might not last long, while it is also possible that clever engineers in the future will devise better means of dealing with waste.

Not everybody agreed with us. Greenpeace and the Friends of the Earth were particularly anxious that we should adopt surface or near-surface storage. Some of us (myself included) found these arguments unconvincing. Really what these organisations believe is that we should not use nuclear power and that, if a means of safe disposal could be devised, nuclear power might again be used to make electricity. The inference is, of course, correct.

In case you think I am being unfair to Greenpeace, I proffer this interesting anecdote (which is a matter of public record). When our committee was taking oral evidence, Greenpeace offered Lord Melchett (then its chairman) and Dr Helen Wallace as witnesses. Lady Platt asked them, "If society were to decide, by whatever process, that disposal is the best option, would Greenpeace be prepared to contribute to the debate on taking this concept forward and select a location for a site in the United Kingdom? If so, what features would you like to see in any future site exercise?"

Lord Melchett's reply was, "The short answer to that is no". This did not surprise me; at an earlier enquiry on GM matters I had chaired, I had asked Dr Wallace a very similar question about GM matters and she gave the same very short, succinct, and very precise reply.

So we recommended that deep storage was the best answer we could think of. We proposed that there should be a nuclear waste management commission to develop a comprehensive strategy and a radioactive waste disposal company to design, construct, operate and eventually seal the installation. We proposed a timetable in which the Government and Parliament, the Commission, the company and regulators would carry the project through over a period that we thought might be 24 years, but which could be 25, or 30 or even 50 years — still short in comparison with the length of time over which the storage was to take place.

We were emphatic that there should be a full consultation period; the Government, I know, agrees. We also said that the policy should win a large measure of public acceptance and that it should be explicitly endorsed by Parliament at the outset and then at regular intervals during implementation. In other words, consultation through the parliamentary system would be a continuing element in the life of the installation.

Our final recommendation was that the Government should act without delay. When we met the Minister in October, he told us that doing nothing was not an option. So I await his contribution this evening with interest mounting, perhaps, to excitement.

I shall end by dealing with the question, "If waste lasts for thousands or even hundreds of thousands of years, are we not creating a risk for posterity?" The idea is that people will be living in a condition of constant risk, measurable though it may be, and that we should not land risk and fear on our grandchildren, great grandchildren and their descendants as well. But a large part of the world lives in a condition of constant risk. Take the risk of devastating floods in Bangladesh and the certainty that, at some point, there will be a serious earthquake on the San Andreas Fault. I believe that posterity will be able to accommodate itself to the kinds of proposals we have made, that the Government will adopt them and will then be able to persuade the public that this is the right thing to do. ❐

# Industry needs action on waste

**Dr Robin Jeffrey FREng**

Robin Jeffrey is Executive Chairman of British Energy.

The question of what to do with nuclear waste is seen by many to be immensely complex, but I put it to you that the technology is straightforward. I say that as someone who spent much of his working life on the design, construction and operation of nuclear power stations.

First, I shall say a little about British Energy. We were privatised about six years ago and we operate the 15 most modern nuclear reactors in the United Kingdom. We have also some coal and gas capacity in this country, which makes us the largest UK producer of electricity. In addition, we have major nuclear investments in the United States and also in Canada. By operating in these three regulatory regimes, we have a global perspective on nuclear waste.

As you know, many UK nuclear power stations will reach retirement age over the next decade or so and there are no plans to replace them. At British Energy, we take the view that the United Kingdom needs a mixed energy policy and we propose that the 25 per cent of the country's electricity that comes from nuclear today should come from nuclear in the future. What to do with nuclear waste is therefore central to that debate. It is an issue that can no longer be ducked.

Nuclear power produces electricity without dumping global warming gases into the atmosphere. Britain is committed to substantial reductions of $CO_2$ emissions in coming decades. To bring in renewables and to phase out nuclear will not affect the *status quo*. If we are to bring down our global warming emissions, we shall need both renewables and nuclear energy — a mixed energy policy. That is why we should replace nuclear with nuclear.

I should explain what nuclear fuel and nuclear waste look like. The fuel for our Advanced Gas-Cooled Reactors (AGRs) consists of spherical pellets made of uranium or plutonium oxide: they are about a centimetre across. Yet each pellet can produce enough electricity for a typical UK household for one year. And the waste? Imagine a piece of a black glassy material about the size and shape of an ice-hockey puck; that is what vitrified waste looks like. A single such object would contain the waste from the fuel needed to generate a whole lifetime's supply of electricity for one person. [*At this point in his presentation, the author displayed simulated fuel pellets and vitrified waste.*]

If you believe what you read in the newspapers, Britain has no policy on nuclear waste. That is totally false. There is a licensed safety case to load these pellets into the reactor and a licensed safety case to take them out and store them. Then there is a licensed safety case to transport the spent fuel in hugely robust flasks to Sellafield and then another safety case to reprocess the spent fuel into vitrified glass blocks.

When we ask, "How should radioactive waste be managed?" (as in the title of this evening's discussion), we imply that we are still at square one. We are not. All but the last piece of the jigsaw is in place. What remains is how to take blocks of vitrified glass and place them safely and permanently (but retrievably) deep underground.

You may remark that conventional power stations do not produce dangerous waste, but they do. The carbon-based gases they produce are choking our planet to death, yet conventional power stations pump them out as if there were no tomorrow; if they carry on like that, there will not be a tomorrow.

To rub salt in this wound, the Government is proposing to make the nuclear industry pay the climate-change levy even though our wastes do not affect the climate and the costs of disposing of them are fully internalised anyway. What we need is a *skyfill* tax, analogous to the landfill tax, to be paid by those who dump polluting gases into the skies. It should be the polluter, not the innocent party, who pays. If the conventional generators were required to remove the $CO_2$ pollutant from their exhausts, perhaps to store it in depleted oil reservoirs, that would double the cost of electricity from coal and increase by half again the cost of electricity from gas. Nuclear power, by contrast, already internalises the cost of managing its waste. Adopting the "polluter pays" principle would make nuclear head and shoulders the cheapest source of electricity.

On radioactive waste, there is at present no final disposal route for intermediate or high-level waste. Why? A few years back, Government cancelled the plans to develop such a repository and at present there is still no Government commitment. The consensus of scientific opinion is that permanent geological disposal in deep custom-built repositories is the most sensible solution and I agree with this. It would be unfair to say that Government is inactive on the question, even though we sometimes seem to be in suspended animation. Since the plan to build a facility at Sellafield fell through in 1997, there was little action until the Department for Environment, Food and Rural Affairs published a consultation paper last year.

That consultation process set a timetable stretching out to 2007 for reaching agreement on policy. Our submission made it plain that the existing policy vacuum on the issue of long long-term storage is damaging our industry and the country. In particular, I suggest that we have much to learn from the experience and achievement of other countries in this matter. For example, Finland already has a fully operational underground repository for intermediate-level waste and is pressing ahead with a high-level waste repository. The United States has taken a major step with the announcement last month that the Yucca Mountain site in Nevada will be the location for a long long-term geological repository.

We should not underestimate the likelihood of "not in my back yard" protests at the building of a repository. Any such project will need the support of local communities, while their anxieties are understandable. But a repository will be safe, will involve considerable investment and lead to employment. It is also incumbent on the Government to do its democratic duty and to make an impartial decision based not on the wishes of individual pressure groups but on technical advice, best practice and the interests of the UK as a whole. ❐

# Gemstones for sequestering plutonium

**Professor Ekhard Salje FRS**

Professor Salje is Programme Director for Research, Cambridge-MIT Institute. He is also Head of Earth Sciences at Cambridge University.

To produce anything, including energy, you need three components: raw material, a production mechanism and a means of disposing of the waste. Historically, raw materials are good old nineteenth century stuff, production belongs to the twentieth century and both those centuries largely ignored the third component, waste. The twenty-first century will certainly focus on that. What we are learning is that whatever we produce, we have to put something back into the geological environment. There is no way around that; it is as true for hydrocarbons as for nuclear waste.

So far as hydrocarbons are concerned, the timescale is important. Reliable forecast models that tell us about climate change are only a few years old, sufficiently good data on which policy can be based is very recent.

The real question now is not so much how will the climate change, but what can we do about it? That question was asked only 6 months ago through collaboration between the United States and the United Kingdom through CMI, the Cambridge-MIT Institute, on possible ways to increase the uptake of $CO_2$ in the oceans. There are several means by which $CO_2$ could be removed from the atmosphere, for example by sequestration in the oceans or in certain geological formations. But these are not yet technologically and economically viable because the technological development has simply not been done yet.

The historic timescale is totally different for nuclear waste. I shall focus on high-level waste, in particular on plutonium, because that is by far the worst material we can think of. In Britain we have something like 60 tonnes, which is a very large quantity when the critical mass for a simple nuclear device is about 15 kilograms.

Plutonium is extremely toxic. Some time ago, before the events of September 11, there was a think-tank meeting at the Department of the Environment (DoE) about likely terrorist targets: we came up with New York, with London as a second choice. We did not think of aeroplanes, but we did think of a dirty plutonium bomb. The Americans have that very much in their minds still.

In the golden years of nuclear power construction, it was clear that nuclear waste would be produced if the reactors functioned as planned. But the constructors took the view that waste was an engineering problem, to be solved when the plants were up and running. That is more or less what happened. It led to the solution we have heard about this evening —

## discussion

**The how and where of disposal.** The invited speakers had identified two major issues: how radioactive waste should be disposed of and where. In discussion some thought the second question should be addressed now. Although 40 per cent of the land area of the UK had been said to be potentially suitable for deep disposal, that might be very optimistic. Finding and characterising optimal rock masses would be a major undertaking; research ought to start at once.

Against that it was argued that it was not practical politics to start geological surveys or publish a list of potentially suitable areas: the Government would inevitably be accused of plotting. Nothing could or should be done secretly. The form of disposal should be settled before location was considered.

Another speaker confirmed that NIMBY – not in my back yard – was still very much alive, witness the reactions to a proposed wind farm on the Isle of Skye. On nuclear waste, consultation was necessary, but none of the options would get strong public support; ultimately, the Government would have to decide.

Another suggestion was that siting issues should be considered throughout the debate, first in general and then in more specific terms. There could be a discussion, up front, of how the question of location should be addressed. Elsewhere, the resistance of local communities had been dealt with by compensation. Some called this bribery, but it was necessary to be realistic.

Others argued that siting could not be considered independently of what was to be deposited; the more successfully waste was encapsulated, the more sites would be suitable. One speaker thought it a mistake to lump intermediate and high level waste together, as the latter was much more difficult to deal with. Different solutions might be needed for different parts of the problem.

glass encapsulation contained in an engineered metallic case, which in turn goes into a geological repository.

I am a geologist and I know a little bit about the Yucca Mountain Project. I have also talked to the Swedes and the Finns. I believe that finding a politically and technically acceptable site in Western Europe for geological disposal will be extremely difficult, if not impossible in the near future for the UK.

By contrast, the Yucca Mountain Project has a relatively good site. The Yucca mountain was expected to be a very dry site, although this expectation is probably wrong. The difficulty with currently used glass pellets containing plutonium is that they leach such that the plutonium in particular may get into the groundwater – which is bad news in itself. Furthermore, plutonium might even be chemically retrieved by terrorists. As it happens, even in the Nevada Desert, the design of the Yucca Mountain Project had to be revised several times to reduce the humidity. Even so, the site is too small to hold the nuclear waste already produced in the United States.

So what can we do to make nuclear waste as safe as possible, both environmentally and in respect of terrorism? The big question is whether we can encapsulate the material much more effectively than is now possible in glass. Geological deposition would then become a secondary issue: the political problems of finding acceptable sites would be much diminished.

To achieve such a goal, we have to understand how waste material is contained in glass and other materials. Amazingly, in the 1960s and 1970s, Britain was clearly leading in this field of science, but today we have a much reduced relevant science base. The United States is now in the lead, there is work in France and very recently, with the availability of European money, research on alternative encapsulation methods has begun again in Britain.

The big questions are how does leaching work, how does water interact with these pellets? And if the pellets are not acceptable in all cases, as I believe, are there alternatives? Here's something pretty after all this gloom: zircon crystals, which were very popular, particularly in Victorian times, when people who could not afford diamonds bought them to use as amulets hung round women's necks.

Some of these crystals are highly radioactive, they are very strong alpha emitters, although people did not know about that when they started using them as gemstones. Most of them have survived the entire geological history of the Earth; they were created when the Earth's crust was first generated. Because of their chemical structure, they incorporated uranium and other heavy elements from the outset, and they have survived everything — water, the 600°C of metamorphic processes and so on.

We are beginning to understand the reasons why these materials are orders of magnitude better than glass in their leaching properties. In terms of atomic structure, atoms of plutonium or uranium are contained in oxide cages and are surrounded by silicate molecules, which is a very stable chemical configuration. This stuff is extremely stable; the melting point is very high. There is virtually no leaching.

What happens if one of these radioactive atoms inside a cage explodes in a radioactive decay? An alpha particle goes out, is pushed back and the ordered arrangements of the atoms of the cage is totally shattered. It becomes chemically extremely active; the same sort of thing happens in the glasses. But outside the shattered region in a zircon crystal, the silicate network remains intact. That is what protects this material from leaching.

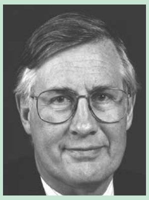
So here is a potentially much safer route to the long-term storage of materials such as plutonium: learn how to synthesise zircon crystals (or something similar) on an industrial scale, and sequester the plutonium in them. The leaching properties of these crystals could be several orders of magnitude superior to those of glass. Of course, there would be limitations: putting too much plutonium in a crystal would cause the shattered regions of the crystals to overlap, creating pathways for water to infiltrate and cause the whole structure of the crystal to disintegrate. But otherwise, zircon crystals are a promising new route to the safe long-term sequestration of high-level waste and we may learn to make even better materials for specific purposes of encapsulation of nuclear waste.

Improved methodologies have been developed in Britain and they are now cheerfully being discussed in France and the United States. As things are, NERC, BNFL, the Americans, the French, the Japanese are all putting small amounts of money into research to tell whether the exploitation of such a technology would really have advantages over glass encapsulation and would truly minimise the importance of the geological context of repositories.

Britain, after many years where really very little was happening because of various political circumstances, in the past five years has started to do very respectable research in this area; it is fully recognised internationally. Some encouragement should be given to the groups who brought funding into the country to explore these methodologies. They may well embody some of the solutions we shall need in the future. ❐

# Winning a public consensus

The Rt Hon Michael Meacher MP



The Rt Hon Michael Meacher MP is Minister for the Environment, Department for Environment, Food and Rural Affairs.

Lord Howie articulated a perception that the Government does not want to take difficult decisions about radioactive waste and that it prefers talking to doing. I do not believe that; I will say what the situation is.

I want this Government to be remembered as the one that took the right decision on radioactive waste. I want people to say that "it was scientifically and technically the right decision and they could prove it because they listened to people and involved them in the decision-making process."

What we are trying to achieve is a broad measure of opinion — not necessarily unanimity — that the decision we take is right and should be implemented. (Let no-one underestimate the difficulty of achieving that given the history of the past 20 years.) I believe a government's duty is to protect people and also the environment on a timescale of thousands of years. If we make a hash of it, the consequences could be no less than catastrophic.

Lord Howie castigated the Government for being slow. He explained that there are two main solutions — deep-level disposal and indefinite long-term surface storage. But look at what has happened in this country in the past 20 years. The previous government, properly and in good faith, tried to find an answer. In the mid-1980s, they selected a dozen sites believed to be geologically appropriate; unfortunately, they did it secretly; inevitably it got into the media, there was a terrible furore and the scheme was dropped like a hot potato.

With motives that I also respect, the Government tried again, proposing a deep repository at Sellafield, the site of Britain's main nuclear installation. Then, just before the 1997 election, John Gummer, then the Secretary of State at the Department of the Environment, judged that the project had failed on grounds of safety. That is what happened.

The other option is surface storage. It is perfectly possible, certainly for tens or hundreds of years. But after September 11, we regard that with considerable unease. It is not ruled out. The Government is doing everything it can to ensure the protection of Sellafield, but nuclear installations remain targets for terrorists.

So what is the answer? Lord Howie suggested that engineering and technology will improve and he is right. When he suggested that we should allow time for that to happen, he was giving precisely the reasons why the Government is right not to rush into this. That is essential when you are talking about the environment for thousands of generations.

I ask you to consider the timescales we are talking about. Nuclear waste will remain dangerous for tens if not hundreds of thousands of years. Compare that with the history of the most recent ice age, which ended about 11,000 years ago. An ice sheet about 2 to 3 miles thick covered the North American continent, Northern Europe down to London or thereabouts and over the Siberian plain, pushing the ground downwards by hundreds of metres in a gigantic compression. That is the perspective in which we must face this issue.

## discussion

**Research and nuclear power.** There was concern over the erosion of the British nuclear science and technology base; the skills needed if it were ever decided to build a new nuclear power station were no longer available in the United Kingdom. It was also suggested that it might make sense to look for a European or global solution. In response, it was acknowledged that there were geologically suitable disposal sites in other countries, but transporting the waste would be problematic and it would be hard to persuade other countries to accept British nuclear waste. It was noted that a substantial part of the existing accumulation of radioactive waste was of military origin, and was accordingly the responsibility of the taxpayer.

It was argued, indeed, that existing nuclear power stations needed to be replaced as they reached the ends of their working lives, because there was no realistic prospect of replacing them with renewable sources of energy. One participant, indeed, suggested that the quantity of radioactive waste now held was modest, and that it would be worth making arrangements for long-term storage only if nuclear power generation came back with renewed capacity.

I say that to take a decision of such gravity and of such momentous long-term significance hurriedly, before we have examined every option, including the key requirement of public acceptability, would be irresponsible.

This is how I see the problem. There are more than 10,000 tonnes of intermediate and high-level solid waste in Britain at present. The amount is growing by more than 5,000 tonnes a year. The total will be 250,000 tonnes when nuclear materials now in use are converted into waste. It will increase to half a million tonnes as existing nuclear plants are shut and dismantled. Some part of this will still be radioactive and dangerous several hundred thousand years from now. We should arrange to dispose of it only if we are absolutely sure that we have got it right and that the public is behind us.

Why is the Government now seeking people's views? This is one of the questions raised when I visited the Select Committee; underneath their customary courtesy, their Lordships were asking in utter exasperation, "Why don't you get on with it?"

The failure in 1997 to win planning permission for the proposed Sellafield repository was an important lesson for us all. It made us realise that we could not simply assume that disposal is best — it *may* be, but we can no longer defend it at all costs.

Second, we have to look at all the options before deciding which is the right one. For example, some argue that waste should be stored on the surface for several hundred years, if need be. I think that is pretty risky, but the argument is that we should follow such a course until we know more about the risks of radioactivity and have better ways of protecting against them. Advocates of surface storage point out, not unfairly, that safety limits have had to be revised in the past few years, and ask whether we are yet ready to take a decision that may turn out to be wrong and which then cannot be reversed. That is an argument for being extremely cautious.

Third, we realised that this question could not be left to experts. We need a public debate. On a host of issues such as landfill sites, nuclear dumps, GM crops and chemicals, all of which have great value to society, the opposition is intense and NIMBYism is rife. I accept that governments must deal with this. But if we make the wrong decision, many people may suffer; all citizens have a stake in the decision.

We therefore need to involve on a massive scale ordinary people who do not pretend to know much about the nuclear issue, using the media and public meetings up and down the country. We also need critical involvement to ensure that we have looked at all the key issues and asked the right questions. We have also to listen to what people tell us. That is why we agreed with the House of Lords inquiry in 1999 on the need to build a strong consensus. I was disappointed by Lord Howie's statement in that he seemed to go back on that, but he may have simply underestimated the difficulties of building a consensus.

What we are proposing is a programme of research to identify the best way to manage nuclear waste. It will identify as best we can all the gaps in our knowledge and it will take account of international experience. For what it is worth, the Finns took 18 years to reach the decision they have finally taken. We should take the same care. Recognising that we shall not be able to eliminate every uncertainty, the process should take perhaps 2 or 3 years, but if we can do it faster, we shall. Our priority is to reach the right decision.

For the research, we shall need a single set of tests against which each option will be judged, so that we can decide objectively between them. For example, a very important consideration is whether we can retrieve the waste if we need to, which is one of the arguments against deep-level disposal. The research programme obviously has to be rigorous and objective so that people will be confident of the outcome. So we plan to set up a strong, independent and authoritative body to advise on what information is needed, how it should be gathered and, when there is enough information, to advise on the best option.

Only when we have considered that shall we launch the next debate on how and where we implement the decision. That, of course, will be a very sensitive political issue. Our consultation paper raises a number of other cognate issues such as how we deal with the plutonium already separated from spent fuel – should that be treated as fuel or as waste?

I do not want the House of Lords to think that we have done nothing except hope that no-one will notice. We and our colleagues in the devolved administrations have begun the groundwork for the research project, We shall now consider the responses to the consultation paper and the two Select Committee reports that appeared during the consultation period and will publish a summary of the responses. We hope this can be done in time for us to launch the second stage of our programme before the end of the year. That is not inaction by any stretch of the imagination. ❐

## discussion

**What kind of debate?** One speaker urged the need for a more balanced debate. The protagonists tended to distort the issues. Thus the tonnage of existing radioactive waste was quoted without comparison with other forms of waste. Yet cadmium, mercury and lead remained toxic for ever while the dangers from $CO_2$ emissions were immediate. Different radioactive elements tended also to be lumped together without regard to their different decay rates.

Other speakers agreed. There had as yet been little success in communicating with the public about relative risk. The risks to health from landfill sites were reported only in the medical press, whereas radioactive waste and genetically modified organisms made the daily papers. The public did not know what to trust in the strongly polarised debate. But one speaker saw a danger of underrating the public. People had a better understanding of risk and risk avoidance than they were given credit for, and would take a risk if they saw advantage in doing so. People used mobile telephones, in spite of uncertainty over their effects on health, because they offered benefits. By contrast, genetically modified foods had not been accepted because consumers did not see what advantage they might offer. The public was quite capable of deciding whether it was better to continue dumping $CO_2$ into the atmosphere or take the risk of nuclear power generation.

A number of speakers had stressed the long-term consequences of decisions made now, and the responsibility which present decision-makers bore toward their descendants. In discussion it was questioned whether many people really cared about what would happen even 100 years ahead. Nevertheless there was a clear duty to consider posterity, and any decisions should be capable of being reversed in the light of experience.

⇨ A detailed summary of the discussion is available on www.foundation.org.uk

# Towards novel kinds of warfare

Sir Keith O'Nions FRS

***Asymmetric Warfare: how science and technology can support the defence of the UK against terrorist attack and other forms of unconventional warfare.*** *This was the brief of a dinner/discussion meeting held at The Royal Society on 1 May this year. Three speakers opened the evening: Sir Keith O'Nions, David Veness and Mike Granatt. The discussion that followed is summarised by Sir Geoffrey Chipperfield.*

Sir Keith O'Nions is Chief Scientific Adviser at the Ministry of Defence. His responsibilities include managing the MOD's annual £450 million research programme and chairing the Investment Approvals Committee. He is also responsible for key links with the USA.

After September 11, we all have a vivid impression of "asymmetric warfare". I will not discuss the taxonomy or classification of asymmetry, but I will say how that event has changed our view of future conflicts. Since September 11, people (and the media) have been particularly concerned about certain forms of asymmetric threat — attacks with chemical, biological, radio-nuclear dispersal devices (CBRN in MOD-speak). I shall try to deal with possible responses to them, but I am mostly interested in future asymmetric threats other than our current preoccupations. I shall also raise the question of how citizens and, specifically, scientists and technologists should respond.

What is an asymmetric attack? It happens when an instigator gains a disproportionate advantage by exploiting something different. It may be a different capability (a weapon, say), a different strategy or organisation or even a difference of philosophical values between the instigator and a target population. That helps to bring September 11 into focus: an asymmetric attack capitalises on perceived weaknesses in individuals, societies or infrastructures.

There are examples of chemical or biological (CB) attacks that go back certainly to 600 BC. One of those often cited is the siege of Caphir in AD 1346, when the Mongols catapulted the remains of plague victims into the city of Caphir and started a plague epidemic among the defending Genoese. The anthrax attack in the USA last year was of that ilk.

Many chemical agents are now potential threats: two of them, mustard gas and Sarin, have been around since the First World War. They are still a threat, possibly more immediate than more sophisticated agents, not least because they have at least been used. The list of biological agents is also long, but I can make my point by mentioning anthrax, plague and smallpox. And few people realise how easily such agents can be made.

The first element of an effective response must be intelligence: Who is out there? What weapons have they got? What do they intend? Are they prepared to act? We in the United Kingdom are fortunate in having a chemical biological defence organisation at Porton Down that has been asking such questions for a very long time. It is a truly world-class establishment. What it does is to make assessments of the threats and consider what defensive measures — vaccines, protective clothing or home-security measures — might counter them.

We cannot escape the fact that September 11 changed the way we think about these matters. Certainly the world has changed, but the change began much earlier – perhaps a decade earlier. The attacks of September 11 were unconventional and struck at the heart of a technologically advanced society. Those were the ingredients of asymmetry.

> "Who is out there? What weapons have they got? Are they prepared to act?"

Responses to asymmetric attacks are likely to include elements not hitherto regarded as components of military operations. When Lord Robinson became Secretary of State for Defence in 1997, he commissioned a Strategic Defence Review, the public version of which remains a good read. Its chief purpose was to shift defence away from the Cold War era towards a more complex world in which smaller scale operations might be necessary. That forecast has proved correct. Even before Afghanistan, there were operations in the Balkans, Sierra Leone and elsewhere. Yet the Strategic Defence Review was silent on what we now call asymmetric warfare. After September 11, the present Secretary of State instructed the department to produce a new chapter or an addendum to the earlier review. We are in the thick of that just now.

Afghanistan illustrates how novel components of the response to an attack can arise. Stabilisation operations in Afghanistan have been an essential part of the approach from the beginning. I make that point to emphasise that there is new thinking about. Military action in the conventional sense of destroying something is no longer sufficient. The other side of that coin entails the stabilisation of populations, infrastructure, schools, education, health and so on.

The response to asymmetric threats must therefore cover a broad domain. I have given you a canvas of the kinds of things we need to think about and I invite you, in discussion, to put some paint on that canvas.

Faced with asymmetric threats, the first need is to locate their sources through intelligence, but there will necessarily be gaps in our capability to locate something precisely (especially if it is mobile). So part of the response must also be diplomatic under the rubric of coercion (which may take many forms), prevention and stabilisation. I have given you a flavour of stabilisation in connection with Afghanistan. But another element of the response is likely to be military, with the objective of destroying the threat. Last is civil contingency which Mike Granatt will talk about.

Our vulnerability to chemical and biological attack has been well rehearsed, but we are vulnerable in other ways. Take information technology. For the past 40 years, the density of transistors on a silicon chip, or the processing power of the chip, has been doubling every 18 months. That is called Moore's Law, which dramatises not only our present dependence on information technology but our future increased dependence. We have not fully understood our vulnerability on this score nor are we fully prepared for it.

Here is another example, chosen from the many I could use: commercial satellite imagery. It is now possible to buy on the open market images that show the positions of aircraft on the ground. And this stuff is getting better and better and will become more readily available. The implications for domestic security are obvious. Images of this quality coupled with precise locations down to metres or less with the Global Positioning System, mean that vital parts of domestic infrastructures will become generally available, not just to the defence and security worlds. The implications bear thinking about.

Emerging technologies will bring other novel threats: biotechnology is one such. Advances in genomics and in medical science offer immense advantages to poor as well as rich societies, so that their risk analysis will probably go in favour of better health care and longevity rather than the avoidance of the obvious novel asymmetric threats from the eventual products of these technologies. Those who believe that it will be possible to control biomedical advances because of the security threats they pose are probably mistaken.

Another example is that of ballistic missiles. This is a contentious subject about which the world is trying to make up its mind. (The USA has decided, and is withdrawing from the Anti-Ballistic Missile Treaty in June.) Simple ballistic missiles are readily proliferated, the range of those now being acquired is ever increasing and they represent the ideal spending for countries seeking to operate on the big stage with a low budget. Inevitably there are concerns about tipping these things with CBRN devices. The threat is real, but we cannot yet accurately assess the risk.

These circumstances provoke the questions of what science should do, what society should do and what we, as individual scientists, should do. Remember that technological advance is rapid and that experience suggests that many such advances will engender novel asymmetric threats. The simple response is to accept that we obviously have a continuing need to identify threats posed by new technologies. With awareness still heightened by September 11, that is all very well for the time being. The challenge will come when the public perception of threat decreases. How can we maintain over the long haul a comprehensive identification of the emerging threats? ❒

## discussion

**Counter-terrorism and political processes.** A major theme in the discussion was the nature, the causes and the definition of terrorism, and concern that action taken by the Western world to counter what it perceived as terrorism might lead to embattled attitudes on the part both of the West and of Islamic societies.

On the one hand, terrorism could be seen as merely the justifiable and rational response of deprived, alienated, and helpless people to the greed and rapacity of dominant powers; on the other it was a horrific assault on innocent people who had no responsibility for the misfortunes, or misguided ideals, of the perpetrators.

Labelling terrorists as either evil or martyrs did not help. One must recognise the evolution of terrorists through freedom fighters to participants in accepted governments; and the political constraints of elected governments in dealing with, and condoning, violence in their own countries.

The control of terrorism cannot be solely through military solutions — as recognised by the emphasis on the stabilisation of countries where terrorism found hosts — and it would be a start if it were recognised that terrorism cannot be "defeated", it can only be managed (largely through political processes) to tolerable levels (as with British experience with the IRA).

We should also remember that a passionate believer in a cause will be insulted to be called a terrorist; defining him as such will appear self-righteous and may well make subsequent reconciliation more difficult. The long-term effects of counter-terrorism policies need to be most carefully watched; they may embed terrorism rather than make it more manageable.

Other speakers, however, while not denying the crucial need for political processes in managing terrorism, stressed that counter-terrorism policies needed to be vigorously pursued at the same time. Counter-terrorism could be seen as holding the ring while politicians worked at solutions; it was a two-track process — eliminate the causes and stop the results. The intentional slaughter of innocent civilians was murder; you cannot condone murder, you must stop at "the threshold of blood".

# Counter-terrorism for tomorrow

David Veness CBE QPM

David Veness is Assistant Commissioner for Specialist Operations at the Metropolitan Police. He joined the Metropolitan Police in 1964 as a cadet. During his service he read law at Trinity College, Cambridge .

The current threat operates on three tiers, the first of which is the Al Qaeda network, which has links to other groups such as Egyptian Islamic Jihad. There is then a middle tier of groups based in a broad swathe of the Earth's surface reaching from the Magreb through Egypt and the Lebanon to the Philippines and Indonesia, with the Kashmiri conflict as a prominent focal point. The third tier includes small groups and individuals. There is some movement between these tiers.

Al Qaeda itself does not appear to be disposed towards negotiation, but in any case its agenda is hardly negotiable. The issues include the US presence in the Arabian Peninsula, US support for Israel, the Palestinian problem, the oppressed bombed people of Iraq and oppressive regimes everywhere. None of these agenda items appears immediately susceptible to root cause solution or peace process. At the same time, this new dimension has brought a new breadth of attack measures exemplified by September 11.

In the seven months since then, the variety of possible attacks has been further broadened. The anthrax attacks in the USA last autumn illustrated the impact of bio-terrorism — and that will not have been missed. Indeed, we have learned in the past seven months of Al Qaeda research in CBRN that has been proved more determined than we expected.

## Pluses and minuses

What have been the pluses in the past seven months? There is a new government in Afghanistan, and one logistical base has been neutralised. Then many planned attacks around the world have been disrupted. We have a grand alliance of political will, military action, diplomacy, intelligence, law-enforcement and financial investigation. In the UK, counter-terrorism has been strengthened and crisis management improved. We have new laws, the Anti-Terrorism and Security Act enacted late in 2001, together with new structures and policies.

There have also been minuses. Al Qaeda has undoubtedly exfiltrated across thousand-kilometre borders into Pakistan and Iran, often into lawless zones. All Al Qaeda operations have entailed long periods of preparation. Preparations for the twin embassy bombings in August 1998, for example, began in 1993. The attack on the *USS Cole* was two years in preparation. And we now know that detailed training for September 11 on the eastern seaboard of the USA began a year before the events. It is important that Al Qaeda is not a corporate hierarchy, but capable of devolved initiatives, either by fragments of the organisation or, as we are now seeing, by regenerated units. So the threat at the top tier remains.

The linkages between the various groups of the middle tier that I described appear to be closer. There are recurrent indications of intended attacks. The groups concerned have not been damaged by the military successes in Afghanistan, but small groups and individuals have been given impetus by events unfolding in Palestine. So much is clear from the truck-borne gas-container attack on 11 April outside a synagogue on the island of Jerba off Tunisia that killed 16 people.

## Targets

From both these tiers, we face novel kinds of attacks. Their distinctive features include the production of mass casualties, simultaneous and concurrent incidents, deliberate suicide by the perpetrators (which, by definition, excludes warning) and, finally, CBRN. With sufficient long-term planning, all these features can be combined. The natural targets of such attacks will be not only symbolic but also significant in themselves. World cities are obvious targets. We are in one, for London is symbolic of the links between the USA and the UK as well as being a seat of government, military security and political power and of some economic significance. Yet cities such as London are vulnerable in several ways, even fragile.

Our current review of the counter-terrorism regime in the UK has raised several issues. Enhancement of transport security (land, sea and air) has become a major goal. Our planning caters for CBRN terrorism, suicide attacks, macro-casualty attacks and spectacular and concurrent attacks. We acknowledge that we must pay attention to crisis and incident management, the management of the consequences of an attack (not the same thing), the legal frameworks in which we act, policy and decision structures and public information mechanisms. We are concerned with terrorist use — and abuse — of IT and with threat perception, or how people feel about the threat.

The items I have listed add up to an unmistakable message to traditional counter-terrorism: we are now in the business of creating deeper partnerships. Just before Christmas, we had to confront the issue of the ship *Nisha*, supposedly laden with bulk sugar but possibly carrying more sinister cargo. Quickly, it was necessary to forge a relationship with the sugar-refining business. That illustrates how counter-terrorism must now rely on more radical and imaginative public/private alliances. If there lingers a belief that a single counter-terrorism agency can deliver a response, the briefing has not been understood.

The most immediate problem is the inadequate perception of the reality of the threat. Sadly, there will be further attacks. We are between events. We face a long-term menace and a whole range of dangers, from traditional terrorism to macro-casualty events. We need to enhance prevention and response mechanisms, which

"... there will be further attacks. We are between events. We face a long-term menace."

calls for the management of complacency. That was almost palpable here in London over Christmas: there had been no further attacks, the war in Afghanistan seemed to be going remarkably well, so that people were tempted to suppose that September 11 was a one-off that would not affect the rest of our lives. But it will. The need is to balance public understanding and to encourage defence without unnecessary paranoia.

What, in these circumstances, can we ask of the scientific community? I refer to two broad opportunities: the detection of hazard and the reduction of harm. We would, of course, give all our Christmases for one reliable street-level detector of bio-threats. We would also like an infallible method of detecting suicide bombers in unsecured locations such as shopping centres; we are optimistic that such a device will emerge. We have been talking with the Israelis and our Sri Lankan colleagues to develop tactics and devices to deal with this problem.

On the reduction of harm, the overwhelming objective is to protect the public, which entails enhanced protection (including escape) for emergency services staff. We also need equipment that is capable of long periods of operation. Above all, we need to find a more constructive dialogue with the public and, indeed, all of the component elements of the organisations involved in defence. I regret to say that these are long-term needs. ❐

# Building a resilient civil system

**Michael Granatt CB**

Mike Granatt, Head, Civil Contingencies Secretariat, Cabinet Office. He is also Head of Profession for the Government Information and Communication Service. Mike started his career as a journalist before he joined the civil service in 1979.

The Cabinet Secretariat generally is meant to coordinate what Government does. The achievements we boast about are often only partial successes. The role of my part of the Secretariat is to build resilience of the Government system and even of the United Kingdom. I too believe that the world has changed since September 11, and in ways that bear directly on the problems we now face. Nobody has quite solved them yet.

Asymmetric relationships are not quite cricket. Cost and technical barriers to innovation have been lowered. In 1997, the Swedish cabinet received a report from an official committee that a single person with a computer could seriously damage the country's IT network. Much has happened since then. The networks we now have affect the whole of society. It is widely accepted that daily life is sustained by transnational networks of unprecedented complexity and largely uncharted mutual dependence. Whether crises are triggered by accident or by terrorism, the problem we expect to face in crises is that of working out what has happened and where.

Crises can arise that are not connected with terrorism. I cite the example of the protest about fuel prices two years ago. It was heralded by months of weak signals -- protesters boycotting petrol stations and distribution depots. The protest was dispersed, involved a small number of people and was self-organised. Yet at the peak, there were 21 separate protests going on across Europe. The effectiveness of the protest surprised government, industry and even the protesters themselves.

The protest had effects we had never thought about. For example, there are 90,000 people in the UK who make sandwiches for retail sale. They are not a conspicuous group, but they worry like the rest of us about their livelihoods. So, as petrol stations (which sell sandwiches), schools and hospitals shut down, a large industry was itself threatened with shutdown. At the same time, the NHS began to grind to a halt -- not for obvious reasons, but because nurses and others found that they could not get their chil-

## discussion

**Rules of engagement.** A number of points were raised about the effectiveness of counter-terrorism strategy and tactics. What, for example, were the Rules of Engagement in dealing with suspected terrorists? In war, the rules were precise and every soldier knew when to act or not; but dealing with terrorists in a civilian context was much more difficult.

Not only were you were governed by the rules of criminal law but media and public reaction was crucial. Issues such as invading privacy and sharing information when the threat was not clear and physical violence on suspicion that a terrorist act may be planned required flexible response and good training.

Questions of the censorship of scientific or technical information which might be of value to terrorists were raised. Should academics and researchers be subject to some constraints? The answer was probably that such constraints would be futile — knowledge cannot be sequestered. There was a strong argument that it was undesirable in principle to constrain publication of such information; but there could always be specific problems.

Much more important was to encourage means of countering any misuse of such information or limiting its uses — there had been success in the past on nuclear issues. It was also suggested that there had been too much emphasis in defence spending on high technology equipment when better value would have been achieved if terrorist-type threats had been seen to be significant. Perhaps; but like the proverbial tanker, it took a long time to turn defence strategies away from Cold War concerns to present dangers.

dren to school and had to stay at home with them: the NHS began to lose staff in a big way. The lesson to be drawn is that networks are vulnerable in unexpected ways.

I turn now to the important question of people's differing perceptions of loss – a more relevant concept than that of risk. People at large are loss-averse rather than risk averse (witness that they will often run substantial risks to keep what they have). The loss-averse span a broad spectrum. At one extreme are those whom psychological research dubs "wild empiricists" who can afford loss, can displace it or even replace it. Generally speaking, they do not have much to lose. At the other extreme are the "extreme rationalists" who seek precision in everything and who are far too secure to have nothing to lose.

My contention is that people need to switch between these extremes to deal with some of the circumstances we now confront. In crises, the best may well be the enemy of the good. The wild empiricist (perhaps your adversary) has one priority: to stay ahead of the game. If you are an extreme rationalist, meaning that all your decisions entail waiting for the very best information to arrive, you may lose everything. If our goal is to support decision-makers, we must give them good and salient information quickly. The recipients must then be prepared to take risks in using it.

What are civil risks and how resilient are we? We define risk as uncertainty of outcome; it is the combination of events and their consequences. Risk is therefore, in itself, neither good nor bad, but just something we must manage. Resilience is the ability to anticipate, pre-empt and resolve disruptive challenges into healthy outcomes. It does not reside at a particular level in the system, but at every level. It is not simply a matter of dealing with consequences — anticipation and pre-emption are crucial.

The most serious implications of the change there has been since September 11 affect the networks on which we depend. The internet was invented in the USA in the 1960s in the guise of "ARPAnet", as a means of wartime emergency communications. It had the effect that scientists were suddenly able to communicate with each other at low cost and with unprecedented speed and convenience. Resilience was built into ARPAnet: it specified that there should be at least six channels connecting each two points in the network. In the internet now, there are at least 150 alternative paths between any two points.

Network risks are very complex; they are not easily described by statistics and are full of cryptic combinations. In the estimation of risk, the judgements required may not comply with the model of accumulated experience that seems to mark much of what we do in government, but may instead be counter-intuitive. Moreover, the conventional response may be inappropriate when the circumstances themselves are no longer conventional, while counter-measures against previously anticipated threats may be made nugatory by the changed circumstances.

We should remember that a crisis is not just a very big emergency. The police, broadcasters, all sorts of people, deal with big emergencies all the time. A crisis in the sense in which I use the term involves some element of breakdown, either caused deliberately or by some organisational failure. Crises also have dynamic properties. Things move quickly but always through a network (often imperceptibly), so that an organisation can be overwhelmed before it knows what has happened, isolated before it appreciates that danger.

My key point is that, whatever the technology, what really matters is the extent to which decision-makers are disabled (or, otherwise, enabled) in a crisis. We may be vulnerable to asymmetric attack in many ways, and must do what we can to understand what these are. We also need to understand our capability to respond, both generically and in particular – and must anticipate that planned responses may not always be effective. We need decision-makers who are agile, who can make decisions quickly.

> "response to a crisis may consist of disconnected tactics, not an integrated strategy."

We can anticipate that decision-makers may be disabled by things such as a deluge of data arriving in a form that cannot be absorbed or even processed. What can science do to help? Or a system may be so tightly optimised for normal operations that a small disruption will cause deep trouble. Remote micro-management is a perennial tendency of organisations. There is a temptation to enquire exactly

## discussion

**Winning public support.** Speakers also raised the question of risk, and the attitudes of the public and the influence of the media. A principal concern was how to persuade people that terrible possibilities — such as September 11 — would be with us for a long time and that people must learn to live with this. People had lived for many years lived with the prospect of nuclear war, but that was always more remote, and the consequences so cataclysmic that they may more easily have been shrugged off and, in any case, there was nothing that could be done.

But the possibility of a bomb in the supermarket is different; it is easily imagined and individuals, if they failed to be aware, could feel themselves responsible for disasters. There was a tendency, particularly in the USA, to think that scientific advances could eliminate these risks. That was unrealistic, and such expectations must be managed down.

What was important was that science and technology worked with policy implementation to help the political process. Creating a public understanding of risks must be a major government aim; it must start with willingness on the part of ministers to confront questions about risk, and not to allow public clamour, as in the case of railways, to displace reasoned argument.

The media were often blamed for sensationalism over risk issues, but competitive pressures and the paucity of knowledgeable scientific journalists would always lead to hype unless reputable scientists, who could speak to them in terms that the media could understand, took a proactive part in leading debates.

The UK had the advantage that the population reacted sensibly to official warnings about risk, as when there were IRA threats to the London Underground and they became more aware of possible dangers and did not panic. It would greatly help understanding of risk if the Government concentrated more on the active part the public had to play in averting risk.

➩ A detailed summary of the discussion is available on www.foundation.org.uk

what is being done by the Borough Council or the City Council when the decision-makers should be declaring their intentions and letting their local counterparts get on with implementation. The big danger in the response to a crisis is that it will consist of disconnected tactics, not an integrated strategy.

One of the challenges for science and technology is to help enable decision-makers in a crisis. Helping them anticipate the consequences of an attack is a first need. My secretariat runs an assessment operation, and during a crisis provide a consensus opinion of the consequences. We know from recent experience that differences in the terminology used by different agencies can be an impediment. During the fuel crisis, arguments between some organisations became a real problem but often boiled down to different meanings attached to the same words. Simple things can cause confusion: "bodies", for example, can mean "police officers free for duty" to policemen, but something entirely different to ambulance-men. If you multiply this kind of miscommunication greatly, you have a real problem in getting accurately assessed information in front of decision-makers quickly.

There is also a need to try to coordinate responses ahead of crisis. During last year's epidemic of foot-and-mouth disease, the Minister for Agriculture had to move quickly to reinforce his veterinary resources ahead of the disease spread. Network effects quickly came to light. In 1967, when the report on the previous FMD outbreak appeared, Britain had no motorway network, but in 2001 it was possible (and commonplace) to transport sheep from the North of England to Devon in only a few hours: that changed the entire nature of the spread of the disease. As a result, it is difficult to see how the 1967 White Paper could have helped in every respect in 2001, but there is a need to make sure that we learn and that the learning is kept up to date.

There is also a need to distribute the risk so that decisions are spread to where they can be best managed. A large number of communities is involved, from leaders at national level to citizens all over the place. They have different and often conflicting interests and include commercial companies that ordinarily are in competition with each other. How do we secure cooperation in the face of inevitable rivalries? That is a conundrum we must now solve. In the handling of the "Millennium Bug" problem some years ago, we did persuade competitive industries to talk to each other about their common problem.

We are all in this together and have several un-met needs. What can science do to help us spot some of the dangers ahead? How do we make this knowledge accessible to the whole of society? It is very easy to put all your information in one place, but the real need is to make sure that a lot of people can tap into it and also contribute to it. What do we need to have in place to comprehend the supporting decisions? Do we single out obvious targets, for example, attacks on nuclear power stations, or try to enhance the resilience of the entire system? That could be very expensive indeed, but it may be the only way when we do not know how and where the network will be attacked.

That uncertainty is a part of our present difficulty. Another is that we can be sure that the threats will change with time and that the menu will be enlarged. How rapidly? We do not know, but one obvious conclusion is that we need a technology watch in place to look for novel dangers but also for innovations that may provide opportunities to protect ourselves.

Dwight D. Eisenhower once said that he always found that plans were useless but planning was nevertheless indispensable. The great committee factory in which I am a humble toiler has produced, in my area alone, several new Cabinet committees and, since September 11, a great many new papers on various worries prompted by the events of that day. Most of these have proved useful and have prompted a lot of work that has improved our capacity to protect ourselves. We need planning if only to keep knowledge alive and to keep talking to each other.

We also need a culture change. In 1962, C. P. Snow wrote about the two cultures — the gulf between the arts-based policy maker and the science-based contributor to policy. I believe that culture barrier is still out there alive and well in all our systems. One of the challenges for society and government is to try to make sure that the barrier comes down more quickly than hitherto. ❐

# Using space science for the public good

**Three speakers were invited to give their views on how space science might benefit the public. They aired their views at an FST discussion meeting on 17 October 2001.**

## *Space science in Europe and the UK*

**Professor David Southwood**
*Research Director, European Space Agency*

The question I am addressing is, why does Europe, why do we in the United Kingdom, do space science? I have spent my career in space science, and I hope I have been working for the public good. Clearly, I believe that space science can be used for the public good.

There seem to me to be four reasons for Europe to be part of the global space effort. First, space is a strategic asset, to ensure our technological independence. Second, in order to safeguard our European cultural identity we need to work together. Third, excellence in space science is a demonstration of capability and vision. The iconic power of space exploration was demonstrated by the US Moon landing. We do not need to go to the Moon, of course, but excellence in space science can have the same effect now as the Moon landings did in the 1970s. And fourth, space science fulfils an important role in supporting scientific education.

**Why does Europe need a space agency?** Its purpose is not just to do science in space, but also to enhance European capability in space science and in its application, and it is the applications that contribute most to the public good. To build European industrial and technical capacity we need to be competitive with the USA, where space science is supported by considerable military spending from the public purse. In Europe, investment from the public purse in civil projects can serve the same purpose. The success of the European Space Agency (ESA) shows that Europe can achieve more collectively.

The EU heads of government in Lisbon in 2001 made a remarkable statement, that Europe should become the most competitive and dynamic knowledge-based economy in the world. Knowledge in today's world means science, and a healthy economy requires the application of that science to practical purposes. There are many examples in space of how pure science can have unforeseen practical applications.

Satellite navigation is now an every-day fact of life. But its roots are in pure science. In 1950 the first International Geophysical Year took place — a worldwide effort to understand our planet. Russia's contribution to the geophysical year in 1957 was the launch of Sputnik 1. A worldwide race to find ways of determining the orbit of Sputnik followed. The race was won by two US scientists using equipment on loan from the US Navy. The orbital determination was a scientific breakthrough, the result of some lateral thinking. Within six months the US Navy was using Sputnik to locate their own Polaris submarines. Frank McClure, who had to justify loaning them the equipment, had realised that once they solved the orbit problem, if they knew where the spacecraft was, they could work out where they were standing on the ground. From there it was a short step to solving the problem of locating Polaris submarines.

McClure also recognised that there would also be an enormous number of potential commercial uses for such a system.By 1967 it was available for commercial use, but the receiver cost around US $30,000, which effectively limited the market. But 30 years later the Global Positioning System (GPS) is used by scientists the world over and in practical applications by hikers, sailors and airline pilots.

The history of the GPS demonstrates that advances in science and technology and the development of practical applications are inextricably linked. Basic science and technology applications are closely coupled, applied science and basic science are, in my view, symbiotic. Applied research facilitates basic research and *vice versa*.

The close relationships between science and technology, and science and the public good, are very evident in the field of Earth Sciences. Launched in 1991 and 1995, the ERS-1 and ERS-2 satellites for Earth observation were an ESA success. They paved the way for semi-commercial applications of space science like Radarsat 1 and 2, the Canadian follow-ups. They led indirectly to the release of classified data by the USSR and in the United States, and in applications such as monitoring polar ice and volcanic activity, the public benefits are clear.

**How will ESA pursue this role in the next decades?** In July 2004 NASA's Cassini mission, launched in 1997, arrives at Saturn, and with it ESA's Huygens probe, due to land on Titan to examine its atmosphere and surface. In June 2003 Mars Express will set off on its six-month journey from the Baikonur launch pad in Kazakhstan on board a Soyuz Fregat launcher. Mars Express will do a global survey of Mars and Beagle II, a British project, will search for life on the surface of Mars.

The International Rosetta Mission is to rendezvous with comet 46 P/Wirtanen. On its eight-year journey to the comet, the spacecraft will pass close to two asteroids, Otawara and Siwa.

Further into the future, in 2009 or 2010, BepiColombo will set off on a three-year journey to Mercury. BepiColombo, an ESA mission in cooperation with Japan, will explore Mercury. This ambitious project consists of two European spacecraft, one to land, one to orbit along with another Japanese spacecraft to orbit.

We also look beyond the Solar System: next year another one of my tasks is the launch of the International Gamma Ray Astronomy Lab, the first joint Russian/European mission.

Herschel and Planck are the projects that will dominate my directorship because we are building those now. Both projects look back to the beginning of the Universe and are due to launch as part of a single payload in 2007. The Herschel Space Observatory (formerly called Far Infrared and Submillimetre Telescope or FIRST) will be bigger and better than any of its predecessors, an infrared telescope located 1.5 million kilometres away from Earth. Infrared astronomy looks at cold objects — other planetary systems and galaxies as they are born.

We will also cooperate with the USA on the Next Generation Space Telescope, the successor to the remarkabe Hubble Space Telescope. We will take a 15 per cent share in this grand venture.

Then we have a mission to look more deeply in our own Galaxy with Gaia. A purely European idea, Gaia is a single spacecraft, consisting of three telescopes that will constantly sweep the sky, recording every visible celestial object that crosses its lines of sight. Like Herschel and Planck, Gaia will be placed in an orbit around the Sun, at a distance of 1.5 million kilometres further out than Earth. Spacecraft placed in this special location, known as the second Lagrangian point or L2, keep pace with the orbit of the Earth. Gaia will map the stars from here.

Finally my favourite mission. Arthur Eddington wanted to see inside stars about 80 years ago. Some time after 2008, ESA will make his wish come true with the Eddington space probe, basically a precision photometer to measure small changes in the brightness of a celestial objects, allowing astronomers to relate them to the internal condition of the star. This

## discussion

Participants in the discussion raised the issue of the balance between European and UK programmes, particularly in relation to small satellites — one speaker said that resources should go into major collaborative projects rather than “little nuggets”. It was asked how much weight ESA gave to benefits for industry when making decisions on programmes. The Agency pursued a number of objects, including the development of European technology, but a comment from industry was that European space projects tended to expect a big commercial investment, and this would not happen unless investors saw a prospect of making profits.

One participant expressed concern about broad programmes which lacked central organisation and central expertise in data management. Some past projects had been weak in handling vast quantities of data, though ESA had done well in the meteorological area. An influential member of the US Congress had asked why the UK bothered to gather data about the Earth, since the US already had more than enough.

One participant complained that the speakers had not mentioned life sciences when talking about the benefits from space science. The International Space Station could be exploited for this purpose.

⇨ A detailed summary of the discussion is available on www.foundation.org.uk

technique is known as asteroseismology.

The last mission I want to mention is LISA. This will expand the horizons of physical science by hopefully allowing us to see the Universe through gravitational waves as opposed to light and electromagnetic waves.

UK and European space programmes are contributing knowledge and developing new technologies. We also help industry in a variety of ways. All in all, an important contribution to the public good in this country. ❐

## *The UK’s role in space science*

**The Lord Sainsbury of Turville**
*Minister for Science and Innovation, DTI*

I believe that there are exciting opportunities to use space to do world-class science, to create jobs and wealth, and to improve the quality of our lives. But is also easy to spend money in space to no good purpose, and if we are to get value for money we need to be clear about our objectives.

Today UK space policy has three clear objectives: scientific excellence, commercial profitability, and the effective achievement of social objectives — by which I mean activities such as the collection of environmental data. In the UK we believe that every programme we participate in must fulfil or be part of a process of fulfilling our objectives. This is why there are some types of programme that currently we do not invest in.

One of these programmes is the International Space Station (ISS). The latest estimate of the total cost over the 30-year period of construction and operation is 100 billion euros. Europe has an 8 per cent share of this, investing 500 million euros per annum. We chose not to participate in the building of the ISS. However, with the ISS in orbit, the opportunity exists for all nations to make use of it. We now have to decide whether UK researchers would benefit from using it and whether to support some limited experiments.

We also do not intend actively to participate in manned exploration of the Solar System. This is because we are not convinced that the benefits of human exploration go beyond the political and cultural into the scientific and commercial.

In my capacity as Chairman of the ESA Ministerial Council over the past two years, I have seen fundamental changes in European space policy. In institutional terms, the most important change was the development of the European Strategy for Space. Its goal is to bring space, and more particularly satellite applications, into the heart of the development and implementation of a range of European policies. The reverse is also true: the Strategy brings a range of European policies into the heart of the European space programme.

I would now like to look at how we are doing against the first of our objectives, scientific excellence. We are now benefiting tremendously from the past national investment that has allowed our scientists to secure lead activities in the ESA Cornerstone missions SOHO/Cluster and XMM-Newton, now successfully operating in space. The UK achieved well above its pro rata share of Principal Investigators for those missions. Those activities cover the areas of solar physics, space weather and X-ray astronomy.

The next five years will see the UK playing strong scientific roles in the exploration of the Moon, Mars and Saturn. We are backing the Beagle II Mars lander because of the world-beating science that its aims achieve.

The UK will also play major parts in the infrared telescope, Herschel, and the cosmic microwave background mission, Planck. We have welcomed the recent changes in the ESA Science programme, which have enabled an exciting programme of new missions, such as the LISA and Gaia missions.

Turning to our second primary objective, the commercial exploitation of space, the first area to consider is telecommunications. The satellite communications industry is already large and, with the rise of internet traffic, broadband, multimedia, mobile and digital broadcasting, it is set to grow much larger. With the development of digital and interactive multimedia technologies, broadcasting represents a major market for UK industry. Two years ago the UK confirmed subscription to ESA’s ARTES [Advanced Research in Telecommunications Systems] programmes 1 and 3, which respectively address technology studies and multimedia developments. The work undertaken during the second phase of ARTES 3 will place the UK in an excellent position to command future contracts in this field.

A second important commercial area is global positioning systems. Galileo is an independent European satellite navigation system currently being developed through the European Commission and ESA. It is designed purely for civilian use and will be interoperable with the US GPS. The UK and some other Member States have been cautious about committing to this project but discussions continue with a view to establishing whether the system meets the need of users and provides real benefits to the public. [See Diary, page 2, for the latest on the Galileo project.]

Finally, a word about some projects that address social objectives. Space can help us define and monitor the environmental challenges that currently face us, such as understanding climate change and weather forecasting.

Knowledge about the state of the environment is an essential basis for establishing and enforcing policy as well as for reacting to disaster situations. The joint EC/ESA Global Monitoring for Environment and Security project, GMES, is being designed to meet this need. The EC’s outline action plan for GMES is starting from the needs of users, establishing the customer base on which to build sustainable services for the public sector that are not funded from research budgets. I look forward to seeing a detailed action plan later in the year. [See Diary, page 2.]

Earth observation is finding increasingly broader applications in the environmental sciences, and is being supported through the Natural Environment Research Council’s Centres of Excellence programme. I am extremely pleased to announce the establishment of two new centres under this programme. The Centre for Terrestrial Carbon Dynamics joins the expertise of ecologists, mathematical modellers, forest specialists, Earth observation scientists and statisticians. Together they will harness information from space to achieve greater understanding of the Earth's carbon cycle and global warming. Earth observation data will be used to help resolve the current scientific debate about the way in which carbon dioxide emissions from soils and vegetation affect the Earth's carbon balance. This input is vital if we are to address current global warming trends.

The Centre for the Observation and Modelling of Earthquakes and Tectonics will identify the mechanics of earthquake faulting and of continental deformation. Tectonic activity has affected society in many dramatic ways, most recently in northwest India. The need for a greater understanding of how we might mitigate some of the disastrous consequences of tectonic activity is without question. Satellite observations are an important resource in meeting that need as they provide measurements over the time and the spatial scales required to investigate tectonic activity.

UK space policy is also committed to developing new technology throughout the space industry. The British National Space Centre has created a National Technology Programme, which aims to stimulate the leading edge generic technology that will enable the space industry to move forward and increase its capability. This programme has focused on areas such as small satellites, key enabling technologies for telecoms satellites, satellite power systems, and the software used in satellites and their control.

The UK is a world leader in small satellite technologies. One of the ways in which we actively promote this technology is through the British National Space Centre's funding programme for small satellite projects: MOSAIC (Micro Satellite Applications in Collaboration). The aim of this programme is to stimulate industry to invest in small satellite missions. In 2000, I announced three projects that would receive funding under the MOSAIC programme.

This is an exciting time for space exploration. The UK gets excellent value for its investment in space, in terms of both scientific and commercial returns. It is vital to maintain clear objectives in the future, but equally important that we are not blinkered by them. We do not want to miss exciting opportunities because we do not have the vision to see what contribution they can make to our lives.

I have spoken about our three primary objectives in space activity, scientific excellence, commercial profitability, and the achievement of social benefits. Linking through all of these is the common aim of enhancing the quality of life. I firmly believe that space is a vital tool for achieving this. Alongside this, we need to have the political and economic will that fosters a vision of the future.

Space already serves European citizens in many diverse ways. The challenge before us is not merely to keep up with their changing needs, but to provide an infrastructure that can respond to an unimaginable diversity of future needs. This is our aim. To make space truly serve the European citizen. ❐

## UK Space programme

**Michael Storey**
*President and Chief Executive Officer, Inmarsat Ventures plc*

I am concerned with the use of technology to create commercial opportunities around the world. I believe that economic development and economic opportunities contribute to social welfare and development.

I would like to put into perspective the way that we as a commercial organisation think about commercial opportunities. Inmarsat is probably the least acknowledged but most successful body involved in the exploitation of satellite technology in the UK — an untold secret. I therefore welcome this opportunity to explain what we are doing and what we might do in the future.

Inmarsat's commercial success in exploiting space technology originated from a suggestion made by Arthur C. Clarke. In 1946 he was an employee in the War Office when he wrote a document in which he described the opportunities for using geostationary spacecraft to act effectively as a mirror in space from which communication services could be reflected back to the Earth's surface. He concluded that spacecraft flying at an altitude of 36,000 km and at a speed of 6,600 miles per hour could maintain a relative position to the Earth's rotation and provide a footprint over the Earth. It would then be possible for this mirror effect to be directed and exploited commercially.

Some 20 years later Inmarsat latched onto that idea and looked at providing a commercial proposition. We now have in space nine geostationary spacecraft providing communications services relevant to a large number of vertical markets. They provide communication services effectively, at any latitude, any longitude and any altitude so they cover all air space and virtually the whole of the Earth's land surface. Therefore they are an essential commercial extension of the geographical limitations of our terrestrial communications system, such that it is possible, anywhere in the world to communicate effectively with anywhere else in the world.

So we operate on a worldwide basis, providing at least an extension to the terrestrial networks in order to provide a ubiquitous telecommunication services across the world. And something like 80 per cent of the world's air surface and 100 per cent of the world's air space is not adequately, or indeed in some cases probably never will be, served by terrestrial communications. We are contributing to the needs of a world that is increasingly driven by the requirements for more data and the requirements for more broadband capability to deliver that data. Inmarsat is playing a pivotal role in supporting disaster initiatives and supporting communications to the world in serving those areas that are not readily accessible by communication services. We do this in numerous vertical industrial market segments, the obvious one being the maritime industry. Our services are provided to global mobile situations, including the aircraft industry, governments, global manufacturers, media organisations, and to disaster and relief agencies.

Today we have the capability to deliver 64 kilobits of bandwidth to virtually every part of the world and every part of the world's air space. In comparison, I was logging on to my computer at home this week in central London where I could get 56 kilobits connectivity; the Inmarsat system is obviously faster.

We have invested US $ 1.7 billion in moving towards the next generation of satellites. And that next generation of satellites will move from 64 kilobits up to 432 kilobits, a factor of about 7 in terms of increasing the speed of connectivity. Our mission for the future is to continue down that path, to continue to serve these vertical markets that I mentioned earlier on a global basis in a way that is relevant to the business requirements and the social requirements of those enterprises operating globally.

Inmarsat is a formidable organisation in that it has been economically successful since the day it was born. We have managed to create a commercial business out of the initiatives that have been taken in space technology. We have demonstrated that those investments create enormous returns and we have demonstrated that, by a clear commercial focus on exploiting technology rather than playing with technology, you can deliver a viable business. If you can deliver a viable business, you can deliver a viable justification for investment, for further research and development for space technology. ❐

**Recent lectures and dinner/discussions organised by the Foundation are listed below. Sponsors, to whom we are very grateful for their support, are shown in italics below each event. Summaries of these and other events are available on the web at www.foundation.org.uk**

12 March 2002

**How should radioactive waste be managed?**

Lord Howie of Troon, House of Lords
Dr Robin Jeffrey FREng, Executive Chairman, British Energy
Professor Ekhard Salje FRS, Programme Director for Research, Cambridge-MIT Institute
The Rt Hon Michael Meacher MP, Minister for the Environment, Department for Environment, Food and Rural Affairs
*UK NIREX Ltd*

19 March 2002

**How should governments support innovation and science in a growing economy?**

Mr Leslie Morrison, Chief Executive, Invest Northern Ireland
Professor Gerry McKenna, Vice-Chancellor, University of Ulster
Mr Noel Treacy TD, Minister for Science, Technology & Commerce, Dublin
*Department for Employment and Learning, Engineering Employees Federation, Engineering Training Council in Northern Ireland*

26 March 2002

**Crossing the discipline boundaries — integration of the UK science, arts and humanities base**

Dr John Taylor OBE FRS FREng, Director General of the Research Councils, Office of Science and Technology, Department of Trade and Industry
Sir Brian Follett FRS, Department of Zoology, University of Oxford
Sir Christopher Frayling, Rector, Royal College of Art
*Arts and Humanities Research Board, The Wellcome Trust*

23 April 2002

**Pathological specimens and data — what controls should be in place?**

Professor Nick Wright FMedSci, Warden, Barts Hospital and The London School of Medicine and Dentistry
Mr Steve Catling, Chief Executive, The Retained Organs Commission
Dr Robert Coleman, Chief Scientific Officer, Pharmagene Laboratories Ltd
*Cancer Research UK, Department of Health, Medical Research Council, The Wellcome Trust*

1 May 2002

**Asymmetric warfare**

Sir Keith O'Nions FRS, Chief Scientific Adviser, Ministry of Defence
Mr David Veness CBE QPM, Assistant Commissioner, Specialist Operations, Metropolitan Police
Mr Mike Granatt CB, Head of Civil Contingencies Secretariat, Cabinet Office
*QinetiQ, Ministry of Defence, Science Systems Limited*

22 May 2002

**Science, Technology and Sustainability**

Professor David King FRS, Chief Scientific Adviser to the UK Government and Head, Office of Science and Technology, DTI
Professor Sir Brian Heap CBE ScD FRS, Master, St Edmund's College, Cambridge
Ms Sarah Roberts, Manager, Global Environment and Risk, Arthur D Little
*EMTA, Department for Environment, Food and Rural Affairs, Department for Transport, Local Government and the Regions*

25 June 2002

**Science and Engineering**

The Lord May of Oxford AC PRS, President, The Royal Society
Sir Peter Williams CBE FRS FREng, Chairman, The Engineering Technology Board
Sir Alec Broers FRS FREng, President, The Royal Academy of Engineering
*The Royal Commission for the Exhibition of 1851*

9 July 2002

**Beyond Moore's Law — does the UK have the research expertise to take a lead in the next generation of microprocessors?**

Professor John Enderby CBE FRS, Physical Secretary and Vice-President, The Royal Society
Sir Alec Broers FRS FREng, Vice-Chancellor, University of Cambridge
Professor John Kay FBA, Economist and Writer
*ARM, British Computer Society, The Insitution of Electrical Engineers, The Institute of Physics*

16 July 2002

**Priorities for Research and Innovation in the UK**

Dr John Taylor OBE FRS FREng, Director General of the Research Councils, Office of Science and Technology
Dr Alastair Keddie, Acting Director General Innovation, DTI
Professor Ian Halliday, Chief Executive, PPARC
*Office of Science and Technology, DTI*

25 July 2002

**Energy policy**

Mr Tony Meggs, Group Vice President Technology, BP
Mr Rob Wright, Director Energy Policy, DTI
Professor David Fisk FREng, Imperial College
*Office of the Deputy Prime Minister, Department of Transport, NERC, Science Systems Limited*

2 October, 2002

**The Lord Lloyd of Kilgerran Prize Lecture**

Professor John Burland FREng FRS, Imperial College
*Comino Foundation*

22 October 2002

**Productivity, R&D and the supply of scientists and engineers**

Sir Gareth Roberts FRS, President, Wolfson College, Oxford
Mr Harry Bush CB, Deputy Director, Finance Regulation & Industry Directorate, HM Treasury
Mr Bill Parsons, Executive Vice President, Human Resourses,ARM
*Particle Physics and Astronomy Research Council*

24 October 2002

**A science strategy for Scotland (in Edinburgh)**

Sir Muir Russell KCB FRSE, Permanent Secretary, Scottish Executive
Professor Wilson Sibbett FRS FRSE, Chairman, Scottish Science Advisory Committee
Dr Chris Henshall, Group Director, Office of Science and Technology, DTI
*EMTA Scotland*

31 October 2002

**The 2002 Zuckerman Lecture**

Professor David King FRS, Chief Scientific Advisor to the UK Government and Head of Office of Science and Techology, DTI
*Schlumberger*

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