

INTERNATIONAL REVIEW OF MATHEMATICAL SCIENCES 2010

TOWN MEETING - 28 JANUARY 2011

University of London, Senate House, Malet Street, London, WC1E 7HU

INTRODUCTION AND CONTEXT

PROFESSOR SIR ADRIAN SMITH, DIRECTOR GENERAL, KNOWLEDGE AND INNOVATION, DEPARTMENT FOR BUSINESS INNOVATION AND SKILLS

The first thing I have to do is ask you to switch off your mobile phones, not only because it is discourteous but also it interferes with some magic electronic thing here which will get you into trouble, so if you do that, that will be great.

The agenda for the afternoon- I will say a very few words at the beginning, Tim who was chair of the Steering Committee will give you an overview of what has come out of...well will give you an overview of the review itself and then Margaret Wright who chaired the panel herself will give you substantive findings and recommendations. Then there will be a discussion and then Dave Delpy will tell everybody where we go from here.

Just let me put a tiny bit of context. We are probably unique in the world in not having a government department which has words like 'university', 'research' and 'science' in it but we have even more splendid words- 'business' 'innovation' and 'skills'. And within Business Innovation and Skills we are in the process of reorganisation and rather grandly one of the groups is called 'Knowledge and Innovation' and I am now the Director General of that group. That includes basically policy and budgets for higher education, science and research and pull through from knowledge and research into innovation.

For the purposes of this afternoon, obviously the big funding streams that are out there for science and research go partly through the research councils, and most of you will know there are seven of those research councils. But also a substantial amount going directly into the English universities, so research councils UK wide, HEFCE (England only). The dual support system funding for research out there under two headings to bid for in the research councils, awarded in block grants on the basis of REs or REFs to universities. But in addition there are quite substantial amounts that go into the National Academies, crudely, if there is a sort of sensible description, the money that goes into the National Academies primarily is spent on individuals rather than on projects and programmes.

We are moving from the British National Space Centre to an Executive Agency, Space Agency in April and there are various other things that are funded in terms of science and society and the support for stem ambassadors and other things that are relevant to science and in particular for mathematics.

Perhaps just worth saying, the environment in which the research councils operate in. Clearly the funding for the research councils comes through government, through spending reviews, but government in making those kinds of decisions about funding, is obviously taking onto account the global environment that we are in, competitive environment, global challenges, national challenges and in many cases working with other funding agencies in

science and general substantial flows of money through medical research charities and so on. And then, in some sense the world into which the research money goes directly into the universities, but clearly from a government point of view and also from all our points of view as citizens, there is an interest in how all that interacts with society and with the economy. So it's a many faceted environment. During the 30 years that I spent at the academic coalface, getting up in the morning with a blank sheet of paper, fill it full of Greek symbols and I would go home none the wiser at the end of the day. I don't think I spent much time during the day thinking about the wider context and my contributions to the society and the economy, but clearly if you are a government and you are dishing out loads of tax payer money you have a view on that.

I don't know whether this is readable but the science and research allocations across the spending review, I think most of you will have noticed, that the science and research resource budget got one of the best relative protections in an age of cuts to the left of us and cuts to the right of us and was basically maintained in cash terms- which isn't the same as being maintained in real terms, but is better news than most other funding streams got in government.

In terms of EPSRC the total programme expenditure profile looks like that so no disastrous, catastrophic slopes. The EPSRC, and Dave will correct me if I'm wrong, I think detailed implementation plan will be in April that will define some of the specific activities and targets for that delivery period.

Remember back in the spending review and government one has to argue the case for these budgets with the Treasury. The Treasury has certain expectations and part of the deal in getting the money for the research councils is that the research councils then publish delivery plans which are in whatever direction government has indicated it wants to go in. Those are very broad directions, not specific instructions but just very general. So the general perspective, and I think part of the reason we were able get relative protection for science and research budget, is an acknowledgment that we do have a world class science and research base. That's great in itself but I think there is also a recognition that the kind of world we are in- we are not going to be a cheap labour economy, we have got nothing left to dig up that we are allowed to dig up and so we have to be smart to survive and so science and research ideas, knowledge underpinning economic growth and societal well being is generally accepted. And that's the good news! In addition we are one of the few budgets that actually got a ring fence which means those numbers are declared for the next 4 years and nobody can raid those budgets without going back and revisiting acts in Parliament, so there really is some stability of funding over the next few years. And a recognition certainly on the part of the current Universities and Science Minister, who some of you will have come across, David Willetts, that you can't view....although its incredibly important, that we have impact on the economy and on society, you can't manipulate that in the short term like you cant be totally utilitarian about all this and so you recognise that people must have space in which to do fundamental research and the time scales in which their impacts and that research varies. So in some sense I would say compared with what some people speculated might happen in the spending review we have a relatively benign environment in terms of funding and attitude to science and research. From the department point of view obviously we need to line up behind EPSRC strategic objectives and I think Dave might say more about this later but I would like to think that there is some sense, that there are great opportunities here, there are large sums of money still available.

So why in that context do international reviews? One of the things that is part of the sell in convincing government to back this, they don't want to back second rate things so the fact that the research base is world competitive across many disciplines is really important and we need to be able to continue to demonstrate that. One way of demonstrating it is to get international teams to look at what we do, its critical friends, are there gaps, missed opportunities, that they perceive in the way we do things, what are the perspectives on a particular discipline? All the stuff that comes out of the international review, each of us individually or institutionally may or may not agree with all the conclusions and recommendations but it is a very valuable basis for all stakeholders in terms of how we go forward and what things we should be concerned about. So the way these are conducted and I won't say very much because it will come out later. All the relevant institutions and councils, and we have had a rolling programme now for over 10 years, and these can help the councils in developing programme business plans, it helps academic communities in arguing their case. If they like what the international review says they will come forward and say what terrific people and if they don't like it they will say they got that one wrong so you pick and choose, but we haven't done mathematics since 2004 - I might even have been involved in 2004- and so this one has been planned for a long time. Lots of players, all the relevant parties I hope, have been involved and the review took place- the concentrated final review week, towards the end of last year. So that's the context in which there is government, and through government, through the research councils, a lot of interest in this work and I will now go and stake my place in the audience and learn all about it.

OVERVIEW OF THE INTERNATIONAL REVIEW

PROFESSOR TIM PEDLEY, CHAIR OF THE INTERNATIONAL REVIEW STEERING COMMITTEE

Thank you Adrian. I'm here as Chairman of the Steering Committee and I'll just run through briefly what the Steering Committee did without going into very much detail. I should say...why was I Chairman of the Steering Committee – well, I was appointed to the EPSRC council early in 2009 and a few months later I was made....it was suggested that in view of that I really ought to be Chairman of the Steering Committee for the second international review of Mathematics. So I agreed to that, so that was towards the end of 2009.

So the first thing was to appoint other members of the Steering Committee and various bodies were invited to nominate members. They're listed here. The research councils on here had a sort of... the ones that weren't EPSRC, especially BBSRC and NERC, had a watching brief because of the overlaps between the work of the different research councils. But all the other institutes, Learned Societies as they all are more or less- I don't mean more or less learned I mean more or less societies... nominated somebody for the Steering Committee. The names of the Steering Committee are at the back of the report; I won't bother to go through them all.

What did then the Steering Committee have to do? Well the first thing...well this is its general role. First of all assist in the implementation of the review process. Well I'll tell you more about that in a minute. Discuss with the International Review Panel their findings and

provide advice where appropriate – that was a 1 ½ hours or 2 hour meeting at the end of the review week where we heard the preliminary findings from the Chair of the Panel, Margaret Wright, and discussed them a bit with the panel. And the last item says participate in the dissemination of the review findings to the wider stakeholder community – well that's this and this meeting and anything that comes later.

The implementation of the review process first of all involved the Steering Committee in recommending the appointment of a Chair, who should be somebody who commanded respect over both... as much of mathematical science as possible- pure, applied, statistics, operations research, and should have been on the previous panel preferably so they know a little bit about it already, although not too many of the panel members were to have been on previous panels. And we were delighted that Margaret Wright from the Courant Institute in New York accepted the nomination to be Chair of the Panel. She in future meetings joined in and we sought to fill the Panel with mathematical science experts, international experts- all outside the UK, of course, who covered the field as uniformly as possible and who were distinguished and recognised as leaders in the field and we were very pleased in the end...obviously not everybody who was invited accepted, but most did and the final Panel consisted of 15 people plus the Chair, 16 people was actually very well balanced.

Then who should the Panel...what should the Panel do? Was something we had to discuss and what information should the Panel be given and they were given a lot of information, probably more than most of them had thought they were likely to be given but anyway the main activity for the Panel was to visit various institutions and as you know they were split into three sub panels who visited a number of institutions each, and at each of those institutions a number of other institutions were invited to come along and give evidence and have discussions. More detail is of course provided in the report.

Another thing the Steering Committee had to do was to agree the so called Evidence Framework that was all these questions that the Panel had to frame its answers to. These weren't, I hasten to say, entirely the idea of the Steering Committee for this International Review. After the first few International Reviews in the early years over the last decade, EPSRC tried to get all its International Reviews to work to more or less the same framework so that...to make for continuity and ease of presentation of the results etc. to government and other things. So these basic questions were provided by EPSRC, but we modified them somewhat, and then the other thing we had to do was agree or at least approve what paperwork the Panel should get. For example we suggested topics for landscape documents which a number of you were involved in writing, which would introduce the Panel to different areas of mathematical science research in the UK, but there was a whole lot of other data that EPSRC wanted to provide and as is often the case with large scale documents produced by numbers of different individuals the first go isn't necessarily totally perfect or coherent and so the steering group had quite a bit of input to try and make it so actually some of this...those of you who will have seen these documents will know that they're still not perfect works of literature but you've only got a certain amount of time to do this sort of thing and we will hear whether the Panel found them useful or not.

The final thing that I ought to mention is the EPSRC provided the secretariat responsible for organisation and planning. Actually the people from EPSRC led by Ben Ryan and Lesley ...worked incredibly hard, actually they were present at lots of meetings and they put an awful lot of effort into providing all the documents and then into shepherding the Panel

around the country. So just from the Steering Committee's point of view we were...we would like to commend the EPSRC people who were involved in this for all the effort they put into it.

However, what we're really here for is to hear about what the Panel thought not what the Steering Committee did, so at this point it's appropriate for me to welcome Margaret Wright, the Chair of the Panel, to this meeting and invite her to present the main findings of the Panel's report.

PRESENTATION OF MAIN FINDINGS AND RECOMMENDATIONS

PROFESSOR MARGARET WRIGHT, CHAIR OF THE INTERNATIONAL REVIEW PANEL

So hello everybody and thanks for starting to listen to me. I'm looking forward to presenting these results to you and I think we'll have plenty of time at the end for a lively discussion. You heard I Chaired this Panel and it was a really very good experience. I think the Panel did a great job and we'll hear more about that as we go along. We've already heard that the planning began more than a year ago, commissioned and managed by EPSRC- as we have already heard, guided by a Steering Committee as we have already heard.

This review covers all the areas of the mathematical sciences that were covered by the previous review in 2004 and operational research. In 2004 operational research received a separate review which we called the ROR because it wasn't all international people. The members of the present Panel included people with expertise in operational research in order to extend the reach of the review. In consult with the Chair, the Steering Committee selected 15 other members, so these all had to be based outside the UK, but we tried to get people with some knowledge of the UK system, which let me just say to an outsider who knew nothing about it could be confusing. It was supposed to represent a balanced mix of international researchers with expertise spanning the mathematical sciences and relevant research council disciplines. A criterion, that Tim didn't mention but I will, was 'no doormats'. I don't know if you use that expression here – we wanted people who would actually participate, we wanted lively people. We did not want people who would just say 'whatever anybody wants us to say we'll say', we wanted people who had strong opinions. They are also sometimes referred to in the US as 'potted plants'. So we said we don't want any of them, we want people who will have strong definite views in addition to expertise, in addition to experience in this context, we all felt that was essential. So here are the 16 members of the Panel, I'm sure you can't really see them clearly- they're listed in the report. We were standing outside at this point in a very chilly garden in Taplow, we were told we could not wear our coats because it would look bad if we were all huddled together there so if there's a slightly chilly look for some of the people it's because of that. So this is the Panel, this is all 16 of us. While we were going through the hard slog of preparing the preliminary report to present to the Steering Committee.

We had a busy schedule and that's putting it mildly! We met on December 5 at Heathrow airport, we got a preliminary briefing from EPSRC, we had a discussion among ourselves, because not everyone knew everybody else. We then went intodivided into 3 sub panels which travelled around the country during 6-8 December. I don't know if you remember that was not a good week for UK weather! EPSRC was magnificent in this case, they had made

great travel arrangements and they had to be changed adaptedly, flights were cancelled, trains were cancelled, buses were cancelled, roads were closed. It was a miracle – every night we would get a report on how the other sub panels were doing and did they make it and members of the community that came to those sessions, were delayed in traffic, had to drive on dangerous icy roads... it was really something. At different times of course we said we were just going to keep on with this but it was definitely not an optimal week to be here travelling around the country, but we did it! And without the EPSRC planning and staff who were all so cheerful and helpful we would never had made it so we're very grateful to them.

What was each site visit? Well some of you attended those site visits. So people were invited... there had been a definite guidance to try to keep on point with the evidence framework. So the people that presented talked about their work at a set of institutions. The presentations were all excellent, they were very useful. The Panel had read the landscape documents; we had read the data provided by EPSRC, which by the way was extremely helpful. We also had at every site visit a meeting with so called collaborators, meaning people from other academic disciplines and industry who had worked with mathematical sciences about different kinds of problems. Four of the eight questions in the evidence framework if you didn't notice are about collaboration; ties with industries, is the mathematical sciences contributing to the societal technological challenges of the UK, benefiting the UK economy? So this was felt to be important and it was important.

We also had a lunch meeting which was limited to early career researchers that included PhD students, post doc students and junior faculty. So we split up in each lunch- we would, say, each of us would go and talk individually with a small group of people and really grill them about some of the questions in the evidence framework and I thought that worked well. Something I wanted to stress was that with EPSRC agreement, every site visit included a segment of 30 minutes when the only people present were the panel and the participants from the community. So the EPSRC people left the room; this was because we just wanted to be sure that people felt comfortable saying things that perhaps they would not feel comfortable saying otherwise.

So then we spent the morning of December 9 and lunch in London. This was an extraordinarily good meeting; it was with industrial users so thanks to the industrial mathematics knowledge transfer network we had a lot of people from industry. We had a round table, we went around the room, each person talked about... they were all men so I can say his... his collaboration with the mathematical sciences, what his company did, how important it was and then the Panel asked questions, and then we had a big open discussion with the Panel and all those people and then we spoke individually to people at lunch time. So that was again very much directed to the questions in the evidence framework about industry. It was a productive, very stimulating session. And if you have read the report you will see we spent some time on what happened at that session.

So then we went to Taplow, where that photo was taken. We spent the rest of the time in that day going over what we wanted to do. We heard reports from the sub panels, we talked about things, we went through the evidence framework. We did the same thing the next morning, we really worked hard. And then we made a preliminary presentation on 10 December. So that's what happened and then we went back to the US and immediately after the Christmas holidays went into high gear to write the report. And that's what we've all been

doing ever since. I don't know how many email messages we have exchanged, hundreds and hundreds and hundreds of email messages about the report that you have seen.

So our charge was very broadly framed: Assess UK mathematical sciences research in comparison with the rest of the world and address a list of questions, which you have seen once and you'll see again.

There were two aspects, terms of reference and evidence framework. They are both given in the report. And the evidence framework, which as Tim described was formulated by EPSRC and the Steering Committee, consists of eight questions. Now I'm not going to show the sub questions of each of the eight questions but there are several... it's not just this question you have to answer 4 or 5 extra parts, but here they are.

- Standing on a global scale of UK mathematical sciences research in terms of research quality and the profile of researchers. That was there.
- What evidence is there to indicate the existence of creativity and adventure in UK mathematical sciences research? This is because around the world it has become a concern lately that people are doing what is called in the US despairingly incremental research. Now some of us, including me, have on occasions said it depends on how big the increment is. This is not acceptable, you can't ask that question. It means small, incremental means small and that's how it's generally interpreted so the worry is people are just doing very small perturbations of existing work, they are not being creative, they are not doing anything risky. This is bad; we want them to be bold and so on and so forth. This is a big issue in the US as you can tell and a similar question was asked here, and I think it's a valid question;
- To what extent are the best UK researchers engaged in collaborations with international researchers? I'll answer that.

Now we start the four that are about collaborations:

- Is itthe UK mathematical sciences community engaging in research opportunities to address key technological societal changes? In the report we make a point of answering this question with specific examples and I'll give you a hint...the answer to this question is 'yes'.
- Is the mathematical sciences research base interacting with other disciplines and participating in multidisciplinary research? You've heard that at every site visit we met with collaborators; we also met with people from industry. In the report we talk about this and the answer is 'yes'.
- What is the level of interaction between the research base and industries? This actually isn't in the evidence framework; I've reworded it because the question is phrased in kind of an unusual way but this was the idea that is why we had the special session with people from industry.
- And how is the UK mathematical sciences research activity benefiting the UK economy and global competitiveness? So we also addressed that.
- And finally how successful is the UK in attracting and developing talented researchers? This is the next generation, this is the pipeline, this is the future. We had to talk about that and how well are they nurtured and supported? And you will see in the report there are details about that, and today I am really going to try to

only hit the highlights because I would like us to have time for questions about the big picture.

So we'll see how it goes.

Now, I must say that in some occasions people made points and they forget to sort of say the important things again and again. In some sense saying it once should be enough, if you are writing a mathematical paper and we say we assume 'x' is real, you don't every so often say 'by the way remember 'x' is real', you just assume that it is there. But this point is very important and I want you to take it in that sense. EPSRC took a number of actions since the last review; those have greatly contributed to the invigoration of the mathematical sciences research in the UK. There's no question about this OK and I could put up this same slide every so often during the presentation just to make sure it's there. The Panel were extremely impressed by how hard EPSRC had worked, how much listening they had done, how much attention they had paid to the previous report. So please don't forget that while I go along...this is very important. I am not saying that everything is perfect, as you will see it's not perfect but a lot has improved. It has improved tremendously and we were grateful to them for that, and I believe the community expressed appreciation for that. So keep that in mind.

Now before I launch into the actual substance of the report, I am going to tell two little anecdotes about the same thing and I'm sorry for using what might be called anecdotal evidence but I think these frame things nicely.

There's a professor at Berkeley, a mathematics professor named William Kahan. He's famous as the person who single handily brought about IEEE arithmetic. I don't know how many of you compute but when you compute now and you get accurate results you can thank him. And he's a rather forceful, to put it mildly, personality. And this is a true story. So Hewlett Packard asked him to consult with them about some numerical algorithms they were going to put on their hand calculator – this is a long time ago, and they said we really want you to consult about, in particular, solving a non-numerical equation. And they had been told, I know this from my contacts at HP, they had been told they would basically pay him whatever he asked because he was the best person in the whole world to do it. So they had a meeting with him and said they we would like you to do this. And so they offered some price but they knew that they could go much higher. And he said 'I'll do it, on one condition' and they thought 'oh no, what's he going to ask for?' and he said 'I don't want you to pay me, I don't want you to pay me, I want you to promise that you will do what I tell you'. Well, now this panel was not told that anyone in this country would do what we tell you, in fact we don't actually tell you to do it, but I think that's a lovely story because it shows that sometimes the most important thing is actually to have someone pay attention. I've already mentioned that EPSRC paid a lot of attention to the last report, we make a lot comments this time and I hope something similar will happen.

Secondly part of the Kahan HP story is that when he had finally written the world's best non-linear equation solver if you don't know about it you should read about it, it's a master piece and he met with the people from the PR department and they said 'How are we going to advertise this?' and they said 'Let's say it will solve any non-linear equation' and he said 'Well actually it wont solve any non-linear equation, there are special exceptions' and they said 'What do you mean?' and he said 'It won't solve *any* non-linear equation. I'm a

mathematician, I'm precise, I cannot say it will solve any non-linear equation. Let me tell you the kinds of equations it won't solve'. He then launched into a technicaland they're sort of going 'Oh no!' he said, 'We can't have an ad where we have – 'We'll solve non-linear equations, except for ones where the function has this kind of discontinuity...' He said 'We can't do it'. So they argued and argued and argued and argued and finally it came out with something that Professor Kahn was willing to accept. Now why is this story relevant? Mathematicians are notoriously precise, many of us irritate people by being precise. We see a sign that says 'keep this door closed at all times', and we say 'does that mean you can't walk through that door ever?' But what I'm trying to say about this report is we have written it in a general way, we have not put qualifications on every sentence, when we say such and such should happen it doesn't mean that parts of it aren't happening, it doesn't mean that we think anyone's going against it, it's just that we cannot write a mathematically precise report in the sense that we would all do if we were writing papers about it. So those are my two anecdotes, now let's get to the report.

In the report, as you will notice, we begin by characterising the mathematical sciences. Now why do we do that? The evidence framework does not say will you please write some words about the mathematical sciences. We wrote those sections together, the Panel, because we feel it's very important in terms of funding and support for the mathematical sciences to have a clear statement of the nature of the mathematical sciences. So there are two sections of the report that talk about this. The mathematical sciences provide a universal language. Now here's a place where you could raise a hand and you could say 'well it's not really universal is it, I mean so and so and so.....is not'. You are going to have to not object. Let's pretend we are the PR people not the precise people. It conveys abstractions in every area, mathematical ideas, even ones that don't seem to have any practical use at all can be useful or enlightening later, sometimes decades later, sometimes a century later. I know that other fields would make similar arguments; I think it's more true in mathematics than in other areas. Based on the evidence we heard during the review week, based on what the Panel knew themselves, the mathematical sciences play a central role in solving problems from every conceivable application domain. You mention an application domain, there's going to be an application of mathematics in it. At NYU we have a programme in music composition which relies heavily on mathematical courses given at the Courant Institute and you can go on and on, so they play a key role in solving problems from every imaginable application domain and because of the unity of the mathematical sciences we try to stress this in the report. Mathematicians, statisticians and other people in the mathematical sciences community love to draw little boundaries. They love to say 'What I do is this, I'm doing algebra, you're doing geometry and they are really different and we have special features'. That is fine and there are genuine differences in methodology in the ways things operate in different fields of the mathematical sciences, but the field is united more than it is divided and we felt that point was essential to make in the report, especially when you are thinking about the mathematical sciences in the context of other fields of science, in terms of engineering, in terms of medicine. You should not be looking at the mathematical sciences as a little group of states that are all fighting with each other, you should look at it as a unity – there are real differences there is absolutely no denying that. The fact that the report is divided in sub fields and we talk about each sub field separately does not contradict the fact that the field is united. And what the unity means is that advances in any sub area advances the whole field. So I just said this – standard divisions can be really useful, we all do them, we all talk about differences in methodology but we think this has a negative effect and we

felt that it's becoming more negative in the present context which we know about - of constrained budgets and pressure. We think it's not a good idea to start drawing boundaries. In the US we joke about this, this is the mathematical sciences community in the US and it's a metaphor from our violent past – of circling the wagons and shooting in – this is not what you want to do. So we think united we stand is what the community, I'm speaking to those of you in the community, should be doing at this point.

We talked about abstractions and generality and how mathematical results can provide intellectual tools and a language for expressing things which, when you look at them in their natural setting - maybe it's a global problem- seem completely different, and what this can do is it can reveal underlying similarities. We have all heard stories of a person from math going to a talk by someone claiming it's a completely different thing and saying 'Wait a minute this is just the same thing as something else that has a different name.' It can also reveal fundamental differences so it can say 'This might look the same but actually there's this key difference.' So we have a figure in our report that shows lines of fluid around alga, the internet- this is not actually of course the internet- this is a graphical depiction of the internet, the middle picture, and then traffic on some highway near Durham, I think. And we said you can explain each of these processes using similar mathematics, not the same but similar, so we thought that was good. So for those of you who are mathematicians, I had to say integration not differentiation- sorry it's a little mad joke! We thought that the point we wanted to stress was we should consider the mathematical sciences research community as a whole. In particular what this means is some researchers work some of the time on real world problems, other researchers don't spend any of their time on real world problems, they work on certain areas that are not visibly connected with the real world – that's fine they advance and strengthen the discipline and if you take the united we stand view that's very valuable as well. So this point is really important when you are thinking about mathematical sciences in the context of overall funding for science and engineering and I say this to people who control funding, I also say it to the mathematical sciences community. And the Panel felt very, very strongly about this, I can't tell you how many emails people wrote to say we must stress the unity point over and over again and remember these people are very lively and have a lot of wild opinions.

Turning now to the UK mathematical sciences research community because mathematics, statistics and operational research are done by people. Done by people, they are researchers, they're...in this context we are thinking about them at university... what about them? We've talked about the unity of the field, what about the people that exercise... do this research. We, the Panel, were struck at every one of the sub panels, every site visit, by the diversity of the UK mathematical sciences community. In three different senses –

- Area. We saw all the grey areas of the mathematical sciences.
- Size of the group. Where that often meant one person. I thought of saying group size ranging from one to 'n' to make sure you knew that one was in there. We didn't count zero as a group OK.
- And the size of the institution. So some of them were at major research universities. Other at smaller universities. We were impressed at every one of those areas by excellence, by high quality of the research, and the RAE which is done by a different agency confirms this. You could look at the ratings for certain schools which are quite small, sorry universities, in the US we say schools, and its geographically

distributed nature so it was not the case that the excellent research was all concentrated in a small number of places it was everywhere, it was all over.

So the panel grew to feel that this set of qualities, diversity in three senses and distributedness, should be preserved and honoured and protected. So we said it is essential for research funding structures to honour diversity and distributedness subject to the principle of only funding excellent research. This is not a 'Let's give everybody a little money just to be nice' this is 'We've got excellence'. We got it, there's no question about it- let's preserve it. And in terms of a more concrete idea we felt flexible funding models were needed that would allow geographically distributed researchers working in a broad area to receive adequate long term funding. I just want to say a word about this. It is not good if researchers at geographically distributed areas feel that to succeed in funding that they have to compete with each other – this is not what we want – this is not unity. We think, the Panel thinks, there should be a way to have researchers at universities that are different to get together in a broad area, and come up with a way to have that be funded. Of course that's up to other people in the room, but that's what the Panel thinks. But it takes cooperation by the universities and by the researchers as well.

One of the things that we heard about, remember at the site visits there were segments where there were no EPSRC people present, is that we felt there were some problems in communications and understanding. We know it's a time of change, people were very nervous about the announced cuts or the announced flat budget, in real terms. They were very, very nervous about it and they wanted to communicate those ideas to EPSRC and they talked to the Panel about them. The Panel was very concerned about that because we think that when things are difficult and are going to be difficult, communication and understanding are especially important – more important than ever. We, the Panel, are not from the UK. We are happy that we were invited to come here. We are happy that people asked us for our opinions. We don't work in this country, we're not the ones who should be talking to EPSRC about what to do – it's this community. So we recommend a new form? Structure? Whatever you want to call it. It would not be designed by one side, if you're going to call them sides, by one group or the other. It would be designed by the community and EPSRC working together and I hope this meeting today might start some of the process to define that kind of structure. Something new is needed and of course we had various ideas about that but it's not up to the Panel how this should be done – it's up to you.

Moving on now. As I said, four questions of the evidence framework talked about interactions and collaborations. There are many kinds of interactions and collaborations and again we wanted to stress this with the unity principle. Connections among sub fields of the mathematical sciences constitute an unending and enriching source of inspiration and new ideas. We, the Panel were very happy when we learned about areas who talked to other areas or brought in results from other areas to prove new results in their areas or took results from another area to solve a real world problem. We were very happy about this and we found that most people in the community were eager to have this kind of interaction. Now of course it's possible that the people who came to the site visits did not include people who said 'I only want to do my own area and I don't want to talk to anybody else ever'. We didn't hear that at all. We heard people say I would love to talk to other people in the mathematical sciences; I would really like to do that.

Mathematical sciences researchers participate in multi disciplinary collaborations, there's no doubt about this, involving important and complicated problems. There's evidence for this; there's anecdotal evidence for this, there's evidence from what we heard about and if we are requested we can provide more evidence- meaning examples in this case. And mathematical sciences serve as valuable partners for industry- this came up so clearly in the meeting with industrial users, it was really gratifying to hear this. Gratifying for those of us that think mathematical sciences can make a big contribution to industry. So we think that even though there are structures to help make these connections there should be more. So this is an example, I know EPSRC has had workshops, I know the institutes and Learned Societies have done this- we think there should be more, this seems to the Panel to be vitally important to the UK. Professor Smith mentioned the importance of contributing to society and we think there is complete evidence that this is happening in the mathematical sciences.

So what do we have to say about this? Now this is going from the sublime to the practical. When reviews are undertaken of Panels that are multidisciplinary that involve the mathematical sciences we think its very important for those Review Panels to have members who have experience in the mathematical sciences and have experience in multi disciplinary research, it's different. In the report we cite a report from the US from the National Research Council that talks about how difficult it is to do multidisciplinary research and there's a comment about Review Panels- it's very, very important. If Review Panels have only subject experts it's so easy to fall into the trap of someone saying 'Well I don't know about the biology but this is really not cutting edge...', whatever field of mathematical sciences your talking about, or for the mathematical scientist to say 'Well the biology sounds good to me but this isn't cutting edge research in this other area.' I think I just scrambled that up but you see what I mean –subject experts do not understand how this works and we think mathematical sciences should play a greater role; this is actually a very important point, in defining and doing the research on multidisciplinary and grand challenge projects.

Now I have here an Excel story so this is my third and final anecdote. So I was in the US on a review committee for the National Research Council which some of you may know as the National Academy of Engineering, the National Academy of Sciences Institute of Medicine if the reports that are produced are correct. It was talking about a report on energy that had been brought together that had an extraordinarily distinguished group of people who worked on different energy technologies- so it had engineers, physicists , chemists, material scientists, and they were comparing a future prospect of this whole array of technologies to do with energy which is an extraordinarily important problem. Of course none of these technologies existed so they were going to talk about the prospects and so on.....so I raised my hand and said 'How are you planning to analyse the recommendations? How are you going to bring in the type of technology, the uncertainty associated with it, the likely success, the cause?' And the answer was 'We are going to use an Excel spreadsheet'. And I said 'You don't have a statistician? You don't have a problemist? You don't have people that know about uncertainty? And they said 'Well we couldn't afford that because we had to have all these experts in the energy fields.' And I won't finish the story but let me just to say this was not happy because it seemed to me that they should absolutely, from the very beginning, have had experts that understood about collecting the data, that understood about uncertainty, that understood about weighing the options. This was a major set of

recommendations about what the government should do and Excel spreadsheets are very nice but they are not for answering that kind of question.

Connections with industry. We had great enthusiasm expressed over and over again at the Panel's meetings with the users. We think that there is a role in addition to existing programmes for more long term collaborations. The focus on basic research driven by industrial challenges, we think this should be explicitly encouraged in some way and again it's not up to the Panel to say how this should be done. We had an interesting discussion and this is mentioned in the report, where people say well industry has these short deadlines and mathematicians think in the long term and therefore they can't really communicate with each other. Some of the people from industry in this meeting said 'That's not right. If we don't have long term strategies we're not going to be here very long, we are not going to exist. It's not as though we get our new product out in a month and then we sit back and don't do anything.' So they expressed very strong support for long term connections with the mathematical sciences. There was also the very gratifying anecdote about... we happen to be talking to a mathematical scientist, we said what we were going to do, and the person said that's a bad idea. And then we realised it was a bad idea, and we're really happy with that... and so that kind of thing happens too but that's not the kind of thing we think is relevant here. So we think there should be multi-year close connections that involve academics and one or more financially committed industrial partners. If they don't make a financial commitment it's not serious. And let me just say the story about Kahan is slightly relevant here, I know what people in industry pay consultants- some of whom as far as I can tell just come in and add more jargon. So I think making a commitment to get real scientific progress, real engineering progress, is well within their means even for industries that are having constrained budgets- because it's worth it. Ok and then there are strategic relationships that companies can establish with universities. We heard from several people at the bigger companies that they already have strategic relationships with universities, about PhD programmes and about other things. We thought that was great and we thought more companies should do it and some of the little companies of course said we can't afford to do that. They should talk to the industrial mathematics knowledge transfer network because that was something...that's who got them to come there and we urge them to take full advantage of that.

Ok so now I've said thisthis is the 'x' is real thing again. Just to be clear...four of the questions in the evidence framework are written here:

- Active collaborations
- Research opportunities
- Keys and technological societal challenges
- Interactions with other disciplines
- Interactions with industry
- Benefiting the UK economy

The answers are yes, yes, yes, yes. Ok? But of course more can be done; of course more can be done. There's no doubt that more can be done. We, the Panel, would very much like it if more was done. We heard in the community, it surprised some of us occasionally, when a person who had never worked on a multidisciplinary collaboration would say 'I'd really like

to get involved in this, I'd really like to know more about the kind of big issues in that field'. So we suggested, see comments in the report, that this could be done through a variety of mechanisms including workshops to bring people together, but again it's not for us to do that. Now we were very impressed by the institutes and the learned societies, there are two sections about this in the report, in terms of visibility of UK mathematical sciences research there's no question that from an international perspective they really enhance visibility. Lots and lots of well known people from outside the UK come to workshops and programmes and institutes' programmes and institutes run by the Learned Societies. They get great benefit out of it, it really enhances the visibility of the UK. We would actually like them to do more, we would like them, possibly with EPSRC- if appropriate...we had a little joke at lunch today about the words 'if appropriate'... I'm sure it is appropriate but in any case we're leaving that open... to have workshops and gatherings where people who have interesting problems to solve can come together with mathematical scientists. Prestige does a lot here and this country is full of prestigious researchers. If you have a prestigious researcher who is going to address one of these workshops about this kind of thing, that person's visibility will attract other people to come- in particular junior researchers. It will also attract people from either industry or any of the other disciplines... whatever, to come. We heard this in one of the sub panel visits. The person said the prestige of the mathematical scientist was critical in getting this collaboration to start. People said 'Oh my goodness, we better join in. Look at this famous person who's doing this' and also I should say propose contemplated initiatives. Let's drag in the energy Excel report thing, I think if there's a major initiative that is funded, it's really good, and I know EPSRC has done this, I just think they should continue to do it and we wanted to say that.

Ok, now let's get to the part that actually worried us a lot. PhD education and training. And again when you talk about evidence what does evidence consist of here? There's some data about the percentage of junior faculty who are hired who did not receive their PhD in the UK. The Panel met with groups of PhD students and post docs and junior faculty, it was striking how few of the post docs and junior faculty had received their PhDs in the UK. And the PhD students kept saying we're very worried about getting a job in a UK academic establishment and that's what we wanted to do. Now EPSRC has been great since 2004 in this regard because the previous international review mentioned this- so there are Taught Course Centres and there are centres for doctoral training, they've been very helpful. People were 100% enthusiastic about the Taught Course Centres, they really felt this was helpful- especially when they could be from a geographically distributed set of universities, so that if you were in a unit... if a PhD student was in a small university, that person could join into the Taught Course Centres programme somewhere else. So there was no doubt that this was enthusiastically received. But there's no hard data about those because getting a PhD doesn't happen in a year or two, it takes a long time. So we don't know whether the long term effect will be to change things in a good way. We think, the Panel thinks that effective strategies are likely to require supporting PhDs for a longer period of training than 3 ½ years which is what it has gone to now after three. It says in our report we heard mixed comments about this; some people said we really should have four years of funding, other people said if you give us the 3 ½ we will find the extra half. It was very unclear what the actual situation was and it varied a lot, so we just make this statement about provision of funding during an adequate period. We suggested a one year research masters followed by three years of

PhD studies. This is because, and this is a problem in the US, some people who start on a PhD end up not liking to do research or they are not very good at doing research. If you have a research masters where you get a real taste of research you're much more likely to know whether you are ready to go on or not. Under the old system, I guess it's called the traditional system of three years undergraduate, three years PhD on a topic you have already picked out; of course you had to know that you wanted to do research on that topic with a certain person. If you started broadening it and making it more flexible there's a danger that people may think they want to get a PhD and actually they don't. So you need some way to work with that. And then we think strong effort should be continued to ensure that UK PhD training meets the highest international standard. We talked to people who had made hires- they would say 'the PhDs trained in the UK don't have the mathematical breadth, they don't have the richness in their training'. So this is not really a problem for any one segment of the community, EPSRC or universities. Universities should be concerned about this too and we hope they are because if, and this is an if, if the UK cares about home-grown talent, and if you can attract talent from overseas and this is- let me just say - a view in the US too- you think 'Well we don't have to worry so much about this, we'll just skim the cream off the rest of the world'. That may not be possible for a long time to come; other countries are interested in having the cream of international talent as well. So the Panel felt that this was something that attention needed to be paid to this point.

OK so this is similar to what I said looking to the future early career researchers. Hardly any of the post docs and junior faculty that we met had got their PhD education in the UK. Now I don't know how these people were chosen; maybe it wasn't a random sample but it was really striking. I'd say where did you get your PhD? - Italy, Iran, Turkey, France, Germany ... I mean you'd start thinking 'Oh where's some of you guys from the UK?' And I don't think they were deliberately chosen for that reason, I think that's the way it is and I think the data is showing that. So UK positions are attractive, that's one of the questions in the evidence framework- is the UK an attractive place for the mathematical sciences research? And the answer seems to be yes. When we talked to these people they'd say 'It's much better here than in my country', so in a sense that's good but what does it say about UK PhDs? I think this situation is fragile and the Panel thinks this situation is fragile and it needs continual attention and it needs some kind of consistent policy - either we have outstanding PhD training in this country which is not cheap or we count on getting people from overseas and we don't worry about it. That's very stark, that's an exaggeration of what the Panel would say but I think it's really true that someone has got to think very clearly about this.

OK, women in mathematical sciences research, this was a sub part of question H. The panel unanimously wanted to make this a recommendation. So we had data about this, we had attendance at the site visits and compared to similar meetings that would happen in other countries the proportion of women was strikingly small. We asked people about this we'd say 'We notice there are not many women here' and the attitude seemed to be 'It's really too bad that there aren't more women in the UK mathematics industry...' and people want to tell... everybody would say 'Well do you think something should be done about this' and they would kind of say 'Well there just aren't very many women'. So again this is a case where Panel members are unanimous in thinking that a lack of attention to this issue will be damaging in the long term to the UK. There have got to be many women in the UK who would love to study the mathematical sciences and become mathematical sciences researchers and for various reasons it's not happening. They have a lot of options now as

you know, the days when women couldn't go into science and engineering are gone and if there are careers where they are perceived to be more attractive that's where they will go. So again this is not a decision for the Panel- this is our feeling, lack of attention to this issue will be damaging in the long term, significant changes will happen only when the issue is taken seriously. Now some people will say if we wait long enough it will take care of itself- I don't happen to think that's enough butnot my decision. OK so if it is decided that action is appropriate, this is not a decision to be made by the Panel, then I think the Learned Societies and the institutes have a lot to contribute- OK?. And finally the previous panel in 2004 wrote a special section about statistics and I think Professor Smith you had some input into that discussion. The people who were on that panel for statistics feel the situation is still bad in statistics- despite, let me say again EPSRC has made great effort to improve the situation for statistics. Its not 100% clear what the problem is but there is no doubt that attention has been paid to this, I want to be clear about that. And so there are forms of action that could be taken, could be considered- this is not a decision for the Panel. A more flexible grant structure was one idea that the members of the Panel in statistics thought was appropriate; an in depth study what exactly is this situation, is another. This is an instance of a Panel thought that is up to the rest of you to take action on.

Now, this may be the part that people care about the most and it's the one I am going to say the least about. We did a sub field by sub field analysis of each of several areas and here they are listed in a funny format because I had to use a smaller font- I don't know if you can read it? So as you will know from looking at the Panel, each person is expert in one or more sub fields but no one is expert in all of them so obviously the sections about sub fields were written by specific Panel members or a sub set of Panel members. So here are the fields we commented about. It turns out- I learned this morning, by email - there should have been a section on logic and fundamentals which somehow in the hundreds of emails about this report did not appear in the report, so it will appear in the report. And if there is some mechanism for me to let people see that before it's in the report we'll do that. I don't know how this happened, I really don't! But given the crazed pace of these emails and so on and so forth...an area that has been asked about is dynamical systems and complex systems- there is no sub field report on that. This does not mean this is not an extremely important area- there was a very, very good landscape report in this area. It listed a lot of interesting research that was being done. However, I have asked the Panel members in the past week does any of you feel confident to write an assessment of this area and no-one has said yes. It doesn't mean that it isn't important, of course it is important and if only EPSRC had let us have 50 people on the Panel we would have covered it and other areas too. But we didn't do that, we don't have a Panel member who is expert enough- because remember this involves going beyond the landscape. It certainly ...there's no point in saying we read the landscape report and we agree with every word of it, you have to know something about the report. So I'm sorry about that, I'm really sorry about that but if someone can think of a way to resolve it besides adding two more people to the Panel- after the fact... which I don't think we'll be allowed... we're not going to be able to deal with it. If anyone has detailed comments about any of these areas- you think there's a screaming mistake in one of the sections or in several of the sections, then they can write to me, email me and send me their thoughtful, well considered comments about this. And I don't mean just 'You didn't mention my work!' That is not a well considered comment. We're happy to get them and we're happy to incorporate them. As you can tell this was a very intense week, we were working under tremendous time pressure and similarly for doing the report so it wasn't possible, but we have some time now

after this meeting and really the Panel wants the report to be as complete as we can possibly make it.

Final thoughts, so now this is what members of the Panel have asked me to do although not perhaps exactly the way I'm going to do it. So they have said it seems clear that mathematical sciences research in the UK achieves a high standard of excellence on an international scale. I mean different fields are different and not everybody has world leaders but it's really, really excellent. As was commented earlier. And in response to the four questions in the evidence framework, that involved interactions with other areas- its absolutely clear mathematical scientists interact productively with each other, with other disciplines and with other industry. And they help to solve major problems in science, engineering, commerce and medicine. There is really no doubt about that.

But despite the enormous importance of the mathematical sciences their role is often invisible or disguised, and this is true in many other countries. Now, what's a possible reason? Let's take when you're trying to convince someone at a high level how important your field is – you use powerful images – right? Ok, astronomy – in the US they just walk in, they show these pictures and everyone says 'Give them what they want' – great? We love it... astronomy... look this is from the Hubble's space survey – they're wonderful! Now of course we could argue about the mathematics, it's leading to the size of data, to detect the things to show this but people love it. So astronomy gets a cake walk- they just get what they want! Another thing you can do is be really cute – I'm not sure what fields would go with a kitten or a puppy, but people just say 'Awww!'. We have to say stuff like that- whatever it is. Now I'm not saying - I'm trying to be a mathematician here - I'm not saying that some of my colleagues are not as impressive as a picture of a galaxy or as cute as a kitten or a puppy, it may be that they are and we should find them if that's the case. But here's the kind of thing we have - I have never known anyone to show an equation and have people go 'wow!' or 'So cute! What a cute equation'. So this is what we have to offer. So what that means is we need people who understand how important mathematics is to make the case for us.

So the Panel members have asked me to urge those of you in powerful and influencing positions, I won't say which of you that is- probably every one of you - who understand the importance of research in the mathematical sciences to argue on behalf of and make every possible effort to enhance the outstanding UK mathematical sciences research enterprise because it's very impressive and we really think...this is theyou don't have to do what we say but we want you to think about this. Thank you.

Tim Pedley: Now we have over an hour, an hour and a quarter for discussion. It's not going to be entirely easy for this to be a totally coherent process, I'm sure there are many people here with things they want to say. Maybe, I would like to suggest we divide the comments into three different categories which we might do in order. First of all, particular questions or comments, questions to Margaret or comments on the report itself and the conclusions the Panel came to. I think they should come first, then the rest of it is a bit more difficult to separate out but I think there are some findings and recommendations which have greatest implication for us in the mathematical sciences community- universities, institutes, Learned Societies, whatever it is, sort of more or less independently over the funding situation. Then there will be other comments which will be... for which the funding implications are going to

be central and which will be directed, lightly I hope, towards the EPSRC. And I would like to suggest, if you are in the last category which says 'I think EPSRC must do the following' please wait till we get there rather than jumping up straight away. Having said that the one other thing I'd like to say is when you make a comment, please stand up so more people can hear you- although there's some ladies with microphones- say who you are, where you come from and if appropriate who you represent. But at this point I'm just going to be the chairman or referee and invite questions aimed at Margaret.

QUESTION AND ANSWER DISCUSSION

David Delpy CEO EPSRC: Just before we throw it open to the audience can I just emphasise Tim's first point. The EPSRC are going to be around for... well hopefully the rest of the decade or more!...and there are a lot of staff here. Margaret is only here today. I mean obviously she is, and she and the rest of the Panel continue to respond to queries by email and so on but this is your one chance to really get...ask questions of Margaret of how she felt the Panel's ...what the Panel's views were on things so ...I'm quite happy to answer questions for as long as you like that are difficult ones for EPSRC but you will get me tomorrow and the week after and the week after that....Margaret, you've only got today.

Jim Moffat; Defence Science and Technology Lab part of MoD, Senior Fellow: There's about a handful of us in an organisation of about 3,800 so I'm at the vanguard of the innovative research that we do, or at least that's what I'm told anyway!

I've got three points to make- all of which are in and around the report itself, I think. The first one is that maths isn't just about producing products. I am a mathematician by background, I did a PhD in quantum physics, I now do operational research so I have seen both the applied and pure aspects of the subject. But the other thing that it produces apart from all that, it produces people who are useful to us in 'industry' in the sense that we supply evidence for ministers and high level decision makers. So that's our product as an industry if you like within DSTL. The kind of people we are looking for...we recruit a large number of mathematicians and what we are really looking for are not narrow people that can just solve problems, we are looking for systems people that can think broadly in an interdisciplinary way. So I very much support your emphasis on thinking across boundaries because that's what we're looking for when we sift people.

Second point is that you mention the unity of the subject. I think very much a strength; there's been a sort of healing of the division between the pure and the applied aspects of mathematics, that's my view. I think that working across that division is one of the main springs of innovation in mathematics now, so problems in industry give rise to stimulating and innovative pure mathematical research and vice versa. And some of the work we've done recently was drawn from very pure areas of maths, for example.

And finally, I was surprised by the statistic about women in maths. In my own area- operational analysis -we have about 400 people in the lab, all doing operational analysis across the lab and roughly half of them are women so...that's a real fact.

Margaret: So what are you doing to make this happen?

Jim: I guess we are offering... I'm not quite sure actually we did kind of positively address that agenda maybe 15 years ago. I mean defence is seen as quite a serious area, it used to be the preserve of perhaps older middle aged men, if you like. We've swung the balance maybe because the global dynamics of defence it's an international community, it's an interesting area, you can work and really make a big impact on things. Perhaps these appeal more to the kind of people that we are recruiting now. But it's certainly a fact that out of those 400, roughly half of them are women. So that's my piece.

Professor Paul Glendinning, The University of Manchester/IMA Vice President; I think there's a lot of good stuff in the report and I'm very pleased that you've done it. Just a couple of points that I wanted to make that are really about... not quite nit picking, but sort of ambiguity that I felt when reading it and wondered whether you could do something about it. One was you talked about the unity of maths but then you break maths up into three sections- the mathematical sciences, but then the connected to which is where mathematical biology and things are and the industrial. For example when you talk about your findings, and the evidential things in 2.1 and 18 you refer only to section 5 which is the mathematical science bit and not the connectedness and the industrial and I felt you therefore lost some of the unity you were talking about and it just...it may well have been an oversight...but I'd quite like to see that if you felt that was appropriate- I believe that's the right way of saying it!

The second thing is I think there are some 300 plus applied mathematicians who probably come in under the analysis heading in the way that you have grouped things together and they weren't very visible and I felt that in particular...within that analysis it was talking about... that it is under represented in the UK. Well they were using the old analysis, the pure mathematical PDE thing I think which you were referring to as being under represented whereas analysis as a whole including what I believe you meant by analysis is obviously one of the biggest sections, probably the biggest section in those groupings. So it felt to me like an ambiguity and I think it's important to know where different people were that's all I'm... I don't think there's anything fundamental there it's just I like these things clean – I'm a mathematician.

Margaret: Analysis is one of the things that we thought a lot about because it ranges.... I think it says in the section it ranges from the purest to the most applied. We felt that in that broad context it was under represented it was mentioned as being under represented the last time; we still think it is under represented.

Paul: Could you emphasise that then as being the general feeling ... I think the problem is when you see that number under represented it's nearly always interpreted as in the context in the pure PE analysis so there's a sort of sense that actually you're talking about the whole group...

Margaret: Ok I've got it, I've taken a note and as I said getting the wording right...I'm waiting for the first person to say here's an inappropriate question but anyway the appropriate wording about analysis was some effort and I think we will revisit that so I have made a note of that point.

Dr Jonathan Dawes, University of Bath; I wanted to pick up slightly on the previous comment and broaden it a little. The Panel have had access to huge amounts of information that normally we don't, and one thing that comes across to me in the report is actually lack of numerical values for things. Something that I would find very interesting and instructive is just to have some numbers of researchers in different areas for example, some broad totals. I think this would help illustrate how the report is grounded in the activities of real people in these institutions and also I think you could show very clearly the diversity of the distribution of activities that we have. I think that would also help in grounding the report when it goes to EPSRC and possibly higher up. There will be numbers to attach to things.

Tim: I think I can comment a bit; at least some of the landscape documents have done that. They are to be made public any minute?

David: Yes, in fact if they are not on the website they will be there at the same time as the report. So all of the evidence that was provided to the Panel, which was in fact largely supplied in collaboration with the Learned Societies, is all going to be available.

Jonathan: That's very gratifying to hear. People are only going to read the report though, so could we have them in the report as well, where appropriate?

Margaret: So, can I just make a comment about that? So the Panel... it's already been hinted to the Panel that this report is too long. We of course think every word is riveting and people will want to read it and there was a discussion about should we say in each section- the RAE reported blah, blah, blah, researchers in this area and so on and so forth... and we just thought it's in the landscape documents, it's in the RAE. I mean it was an editing decision because of course if we do it for one area we have to do it for all of them and that adds up to a lot. So it wasn't a... 100% it wasn't a random omission, we just felt that wasn't the case. Now that I have your comment, again none of this is done by me alone- except to find the pictures of the kitten and puppy... I mean we'll have a discussion with the Panel, they're all waiting for my comments on this meeting and I'll mention that.

Professor Gordon Blower, Lancaster University; The question is, was the Panel provided with any information about the demographic profile of the mathematical sciences community particularly with regard to the qualifications and number of PhD students?

David: The demographic distribution of students, of fellows, post docs and staff. Yes it was all there.

Margaret: Do you mean demographic like from Scotland or do you mean demographic in gender or...?

Graham: Age profile and qualification.

Margaret: Age profile. I think we have that, I mean I almost brought the document with me on my flight but I decided it would weigh down my luggage. It's this huge document I believe all of it pretty much is going to be available- so we had that data, yes.

Ken Brown, University of Glasgow/LMS Vice President. It's mainly in that last capacity that I want to speak- the last few questions from Jonathan and Graham refer to data. What the data must emphasise is it's EPSRC data and refers to EPSRC figures, EPSRC students, EPSRC post docs. There is no reliable, as far as I know where, demographic data about staff in UK universities, PhD students in UK universities there should be...

David: The panel was supplied with all of the data that came through the HESA statistics which the universities report....

Ken: Then that's not reliable...as we've found...

David: Adrian's just left unfortunately- since he's responsible for HEFCE.

Ken: We found when we were preparing the documents that the LMS submitted, which the Panel used quite extensively; we didn't have time to get reliable data. For instance prepared on employment statistics for new staff which would be very useful and deals with quite a lot of what Margaret has said. And I think we would be working on that and gender imbalances; again I'm not aware of reliable HESA data on that sort thing.

David: And the RAE data that you returned in your ...during that process...are equally unreliable?

Ken: It's true Dave that within the RAE data there may well be possible to extract information on gender balance on... even on where PhD students came from but its not easy to do that and its not in a form where you can just access it from the RAE data you need to work at it and its out of date.....

Margaret: Let me just say having more data would be good, having reliable data I think is always good! In the US I mean, I'm speaking now about the NSF, they try to prepare data about this. The trouble is it's not always reported correctly. In particular when they ask people for their gender you don't have to answer. So they tend to judge by first name which isn't really reliable, especially for people from other countries and so there's always a big question about is this really accurate? That's why, I think it's mentioned in the report, we had a small sample of data with the early career people that we met, which of course is a small sample and it could be that everybody else is different. But the impression we had was very strong.

Professor Keith Ball, ICMS/Edinburgh University: Since it combines several things that have just been said, it seems to me possible that the issue of the uncompetitiveness of the UK PhD vs. the influx of people from abroad may in part have to do not so much with the quality of the training, but just the numbers of UK PhDs. If you can cream off the rest of the world and you are not producing so many of your own, you're going to cream off the rest of the world regardless of how good the ones are that we are producing. And if you don't have accurate data on that, I think one should treat that issue a little bit carefully. I agree that the situation may be fragile, although of course it's nice that we have sort of been rescued by having all these wonderful people come from further east to work here. But it may simply be that if you've got a lot of very good people coming in they will get jobs because they're very good not because we are producing bad people or less good people.

Margaret: Ok, so at the meeting with the industrial users- now that the industrial users, we didn't have a meeting with heads of department to talk about their hiring. Several of the industrial users said in the open meeting and privately at lunch that they found many PhDs trained in the UK to be too narrow. It was as in the same sense described here – they wanted to work on the thing they had done their thesis on, they didn't want to work on any one else. Now in industry unless you happen to be the worlds leading expert in the product they're about to produce next week that's not acceptable....

Ken Brown: That's true...

Margaret: That was a clear message about UK PhDs...

Ken Brown: But the hiring of people in the departments is a very different question...

Margaret: Correct, but we didn't have access to meetings with heads of departments and maybe it would be useful to have that. Several of the people we met, and again this is anecdotal- I know that *break in recording* ...lately has a PhD from the UK and they've just said the ones from overseas are better; they have stronger training, they have richer training. These are not recorded in data....

Ken: I'm not saying that fact is wrong. I'm saying one of the explanations may simply be that there is a much larger pool so of course the best ones will be better. We get lots and lots of applications from people overseas, every time we have a job we have 200 applications, 70% of them from overseas. And most of those overseas ones are absolutely unemployable as well as some of the British ones, but we don't employ so you don't see them. We employ the best! Of course!

Margaret: So as to how to resolve this I don't know because we did hear comments that were critical of UK PhD training compared to other countries. But there is certainly not enough of them that I could credibly go before a body that was going to execute me if I didn't make a strong case and argue that it is a clear case. It was a strong impression and all the sub panels got it. Now does that prove anything? I think it proves something but it certainly doesn't make an overwhelming case. And if this is decided by people of power and influence that it is an important issue, then this should be looked into very carefully in the way that you have described. Departments could be asked to comment on their assessment of junior hiring.

David Delpy: Can I comment here? This comment about the weakness of the UK PhD is something that if you look at our previous International Reviews across the whole of the EPSRC landscape came through consistently in our first round of International Reviews. And it was a consequence of that EPSRC made the very specific decision to first of all extend the period of funding that we provided and the question was whether it was 3 or 4 years so we compromised on 3 ½ years and in most instances people can find that additional 6 months where it is needed. But also we explicitly introduced the cohort training through Centres of Doctoral Training, the engineering doctorates, the life sciences. And in the International Reviews of those areas where we started that and we did start it in engineering- we rolled it out elsewhere, we did it in life sciences, those international reviews that have been done in those areas where historically we have got a bit of evidence is that in fact that has made a significant difference to the quality of the UK PhD. And the panels have mentioned that in their second round. So its not that this Panel is unique in identifying

that, it was a consistent message early on and the interventions that we have made were in response to what was a consistent message.

Professor Colin Sparrow, University of Warwick: Can I ask you about your comments and recommendations on PhD training because on the one hand the report speaks well of what's been done in the years since the last review- the doctoral training centres and the TCCs and so forth... on the other hand the recommendations, such as it is, there's the extension of the plan which probably most of us would agree with, but the recommendations, such as it is, for this research masters plus 3 years which you could say was in contradiction to the way things have been developing so far. I just wondered if you felt, not like changing the report, saying why you were here informally more of the thinking that went into recommending that rather than more taught courses or some extension of the doctoral training centres or something like that.

Margaret: Let me broadly try to address that. And I'm from the US, whereas I think all of you know a few PhD students come to the PhD programme knowing exactly what they want to work on and the person with whom they wish to work, most of them don't. So most of them have to take a year typically or a year and a half to prepare for qualifying exams that are broad and then they spend.... a 5 year PhD is typical in the US. We could have said you need a 5 year PhD. We sort of thought that would be impossible here, maybe we should have been bold and just figured 5. So the research masters, the idea of that is in a sense to provide a year of background training. We thought that for some people who are interested in industrial problems they could do some research connected with industry, we also thought, and again it depends on the structure, that lets say a PhD student at a small university where there's an excellent person to advise the students PhD could take benefit from the Taught Course Centre and could get the broadening there. So in a way its more mimicking the system in other countries, that's why we did it that way...of the...at least some time to get some breadth. The thing is if we said...I don't know...we think PhDs should be 5 years, we'd still want to get in the message of 'broaden it, broaden it, broaden it' because it really...everything we heard...and by the way all the people on the Panel had experience on other panels in other countries, and they all said these days its not enough to have a PhD in a narrow area and a plan on working on that area your entire career. So that's the reason, so I don't really think it's a contradiction, we were trying to be a little practical.

Tim Pedley: But you...if I may add, you also recommend that the first year should be a masters degree. I thought for the benefit of those who get going on a bit of a research project in that time and realise it isn't really for them and also to give research experience to the new PhD students who otherwise might not have had any.

Margaret: Of course, Tim's mentioned points I should have mentioned because, again in the US and other countries, sometimes people start a PhD and realise very early that they don't want to get a PhD and we don't want them to waste their time. And the thing that normally, at least at my institution, stops people from going on is they realise they don't like doing research. It's too imprecise, it's too fuzzy, it's too ill defined and so a research masters is perfect for them. They have a degree they can make use of it, they've learned something, they haven't wasted everyone's time, it's been valuable, so that's right. That was an important element- thank you.

Ben Aston, Independent: I'm interested in the relationship between mathematical sciences activity and the national well being. Can I refer to item D of the structure that was offered to the Panel. Just to remind you it reads...'is the UK mathematical sciences community actively engaged in new research opportunities to address key technological and societal challenges'...could you just remind us of what conclusions you came to on that matter?

Margaret: Well that's one of the questions I put up and dramatically said yes, yes, yes to. The examples we give in I'm going to have to look at what section it is ...where we said here are examples of collaborationsI mean of course what do we define as beneficial to society? In the opinion of the Panel all the rather remarkable work in mathematical biology and bio-medicine is clearly benefiting society in a direct way. We heard from this person, its one of the examples about the infectious diseases and how the mathematical models help with that. I think everyone would say that preventing infectious diseases from spreading is benefiting society. Now do we think ink jet printers benefit society? I think many people do especially the people that use them all the time- think they benefit society and we have a start up company...so the list here we have is:

- Manufacturing
- Energy
- Health and healthcare
- Economic efficiency

We tried to pick those deliberately because those seemed to be the definition of societal technological challenges and we felt...there were other examples let me say. We had a wide selection to choose from but we limited the report to try to cover ...how shall I say...geographic diversity and diversity of area and so on and so forth... and the fact that ...you know now again do people regard finance as a societally beneficial area? Well I do! And the Scottish Finance Risk Academy appears to benefit society at least from the viewpoint of the organisations in Scotland that rely on that. So I think the answer is it is benefiting through key societal technological challenges which by the way is not a phrasing I would ever use in a million years, but is the phrasing that was given to us- so we tried to respond to it.

Professor Kenneth Falconer, University St Andrews: Going back a moment and looking at what you were talking about from a slightly different perspective. I have a niece within her final year of a mathematics undergraduate degree at a fairly reputable university. It looks as if she is going to do quite well and she is wondering whether to go into a PhD in mathematics, perhaps leading on to an academic career, or whether perhaps she should go in a different direction and look for something where the money is perhaps more immediate. She is very well aware of a number of the issues that have been mentioned in the report and so I was wondering given what the panel has seen of the mathematical environment in the UK at the moment if they had any suggestions as to how I should advise her?

Margaret: I don't think I can speak on behalf of the Panel here because they're not here. I mean in a way you're asking the wrong person because I got an undergraduate degree in mathematics and then I got a masters, then I worked in industry for a while and then I went back and got a PhD, and then I did research, and then I went to Bell Lab and now I'm at NYU. And every bit of it has been good! And I think, now this is totally personal, this is not the Panel speaking. I think when you look at careers and I've known many friends who are

lawyers who have gone into business, they've gone into lucrative professions, and 20/30 years later you ask them- are they happy? And the answer is 'No'. You ask people that do what I do- are you happy? And they say 'Yes, it's frustrating at times but I love what I do'. So when I talk to young women which I do pretty often, I say 'This field is so exciting and if you love it that's what you should do and you will get a good job and you will enjoy it even if you don't make tons of money because in the long run what counts is your love for your profession and how much good you will accomplish'. And see, to me working in mathematical sciences is a profession that leads to benefits to society. So you know you're doing something intellectually interesting and you're benefiting society. I think mathematicians, mathematical scientists, have an underserved bad reputation as not contributing to society. It's something that frustrates me because they do – I think that's why there are 4 questions in the evidence framework about 'Are you doing this? Are you doing this? What is the evidence?'- They are. So I would tell your niece to study mathematics, or statistics or operational research any of those things- they are different but I would encourage her. That's speaking totally to the side of the report; we don't have a section on advice for young people.

Dr Beatrice Pelloni, University of Reading: One of the foreigners that work in this country! I have two points to make...two things. One has to do with women in mathematics and one that links to the other topic which is the education, mathematical education in this country.

I wonder whether in your report you could incorporate the idea of flexible... both funding and flexibility in general in the model in which mathematics is supported by allowing PhDs to be slightly longer maybe not unfunded but longer because in this country unless you finish your PhD in 4 years you're out without appeal. For women in particular this is quite difficult, sometimes they just drop out of the sideways because of that at PhD stage, I think.

And the other issue is again to do with PhD training and how it is done here. There was one thing that was discussed in the panel meeting I attended and that was about MSc courses and there are very many, very focussed MSc degrees that were funded by EPSRC until last year in mathematics. Is your recommendation that these are subsumed into a 4 year sort of broader scheme of education or is there any recommendation specific to this degree study in any case now or not funded any more by EPSRC will be useful perhaps to say a word or two about this in the report?

Margaret: We talked about making a recommendation about that but we decided since they are not funded anymore, it wasn't really... I won't say appropriate ...it didn't seem worth it to make a recommendation.

I think the big picture of our recommendations is very clear. I personally think, again this is me, investing in young people is one of the best investments you can make...I don't think there is much argument about this. So I never understand when tough decisions have to be made that they say they're cutting the money for this important thing it seems to me it's vital. And I think more flexibility- in the US, you have heard about me, I worked in industry for a while and then I went back and got my PhD and in some countries in the world that is not possible you must get on the treadmill as they say, and you have to stay on the treadmill

and I think that's bad. I don't think every 19 year old knows exactly what he or she wants to do for the rest of his or her life and I think we should have some flexibility there. And it does particularly affect women I believe and there's some data to support that. So we'll think about that comment.

David: Can I comment because I suspect there's a reporter in the audience and I just want to correct something that you said. EPSRC, in the funding that it provides to the universities through the doctoral training grant and so on, makes no specification about how long that funding should be for, how long the PhD should be. The university has the flexibility to extend it from 3 years, which is usually their own minimum internal requirement, to whatever time is appropriate. Similarly for career breaks, those are automatically built in. The university doesn't even have to come back to EPSRC to ask for permission on that. The comments you made are not unique to you. There seems to be a common perception that somehow we provide 3 ½ years funding and therefore you must do your work in 3 ½ years and that is therefore a restriction. It is the university who in fact are given that impression; it is not EPSRC who are imposing it as a regulation.

Beatrice: I know it's the university and if I gave you the impression that I thought it was EPSRC putting this barrier it was wrong. It's a general perception in this country- certainly PhD students think...

David: Absolutely. And it's a perception we have got to get rid of because it isn't reality, it is a perception.

Professor Bill Moreton, retired: I would like to bring things back to more general issues. I commend the report actually, its brilliant- very perceptive, it's got a lot good recommendations and I'd like to highlight two in particular.

One is the need for better communication between the mathematics community and the funding agencies. Some of us are old enough to have worked with the old maths committee; it was a tremendous conduit between the universities and funding agencies. We don't have anything like that now, its crucial that we have something like it now. It's only then we can argue these sorts of issues, these general issues about how important are structures for degree courses and so on and so forth. So that point I think is one which needs to be followed up in the next 4 years.

And secondly I would like to comment on the 3 + 1 + 3. I think it's a minimum structure that we should have. I would prefer 3 + 2 + 3 because in the two you do have the breadth which would enable students at the end of that 2 to go in many different directions and to explore different relationships between mathematics and other subjects like engineering, like biology and so on. You can't do that in a 3 + 1 + 3 but you could in a 3 + 2 + 3.

So I commend the report for highlighting the need for this communication between the universities and the funding agencies and secondly for a structure along the Bologna framework of three distinct steps.

Tim Pedley: I think we are clearly merging into the latter part of the ...that I had outlined and I think we just carry on taking the discussion where we will. Bill's comments are I am sure extremely well taken. I've found the two liner in the report supporting Bill's first point...'There should be some continuity to provide institutional memory, allowing members

to 'learn the ropes' while avoiding a self-perpetuating and potentially self serving body;' which was the excuse for abolishing the maths committee in the first place. More comments?

Professor Jonathan Dawes, University of Bath: I just wanted to be brief on the structure of the report again. Section 17 is headed 'International Connections' page 38, it's rather brief given this is sort of the rest of the world. It's the only section that addresses part C of the evidence framework and even within the brevity of section 17 not every part of part C of the evidence framework could be said to be addressed wholesomely. Particularly, I wanted to ask if somewhere in their notes the Panel collectively could expand on section 17, perhaps in the final version of the report, particularly around the word 'effectiveness' - are the interactions effective. For example one might look to see whether citation counts were significantly higher on work done in collaboration with overseas partners. That kind of measure is used in other contexts I believe.

And I thought for future IRMs could we have perhaps more emphasis on, including representatives on the Panel, from these particular countries picked out in developing parts of the world. At the moment the representation out of the 16 Panel members is rather thin, there's one Chinese representative, or one individual who has a Chinese affiliation listed in the details and the 16 panel members are heavily weighted in the US and Western Europe and I think there could be more variety perhaps there.

Professor Ken Brown, Univeristy of Glasgow: I think this is the last International Review, so in fact that point can't be taken.

Tim: The last one of this cycle- there may be future cycles!

Ken: Ok, so I have two points relating to the general discussion about PhDs and training. First going back to Colin, I thought it was very ironic that he was querying the 1 + 3 structure because I'm actually a product of Warwick's 1 + 2- as it then was- with a research masters ...so if it worked for me....But I think, seriously, my reading of why the Panel were keen on 1 + 3 is because you have to go from where you are now and we already have the beginnings of such a structure with the Taught Course Centress albeit 6 months probably rather than a year. But you can imagine with a certain amount of more funding it wouldn't take that much of a push to get us to 1 + 3 from a ½ + 3 which is roughly where we are at the moment. So that's the first point.

The second point is Keith's very valid point about actually if you are employing somebody you take the best you can and with international market to choose from, you get where we are now. Which brings out the point which isn't addressed in the report as far as I could see which is the career path issue for early career researchers. It's all very well improving the PhD structure but you still hit the buffers at the end of your PhD because there are very, very few post doc or research assistant opportunities available and that is going down, it's been going down for 2 years and it's going to get worse presumably and there's not discussion about what we are going to do about it. And that's the real problem for people looking for academic careers.

Professor John Greenlees, University of Sheffield and LMS: Ken has just asked my question which was about ...we've talked about....how there may be a problem with the

level of UK PhDs but imagine we'd solved it. Is there a career structure...and Ken just asked that question but I think it bears asking twice.

Margaret: I want to make a comment about that vis a vis what happened in the US, I forget when...at some point... where universities were in a pinch and they stopped hiring tenure track faculty, as we call them. They started hiring temporary faculty and so many people getting PhDs in the mathematical sciences were given these jobs which were pathetic. I mean you had to look for another job immediately, you had a huge teaching load. I mean universities are not always the noble structure as one would like to believe they are. There were stories about your taxi driver in New York having a PhD in mathematics and that kind of thing. And there was a lot of anguish about career paths then and to some extent there still is.

The view was, Ok... PhDs in the mathematical sciences are supposed to be intelligent, they will look at the small number of jobs open to them and they won't get PhDs in the mathematical sciences, they will go to law school or they'll get MBAs. But in fact that's not what happened because things have got much better since then and the difficulty was that people who were driving taxis in New York, if there were any, were not competitive with people who were just getting their PhDs. So everyone said well what we need are more post docs so that those people can get a lot of publications and become competitive again. And to some extent that's what happened and its because the people at the National Science Foundation were paying a lot of attention to the home grown talent – do we want to waste these people in some sense – you know driving a taxi in New York is interesting but its not quite what most of them had in mind.

So it seems to me in this country there should be- and it fits in with what people have said about data- you know if there are UK PhDs who cant get academic jobs, but could have post docs, who could then become competitive that's a good way to spend your money. You've invested in their educations, you don't want to waste it, but it has to be seen in that sense of this is an investment in young people and we want to make sure that it pays off. So, if there are never going to be enough junior faculty positions for PhDs in the mathematical sciences then there should be fewer. But I happen to think there will always be a need for it for reasons that have come out in the report. It is very, very, very important to have excellent people in the mathematical sciences at all these universities.

David: Can I just comment on this? Obviously the.... pretty much all the conversation about career path is about the academic career path. The greatest benefit to the UK is in fact in those individuals who have been trained, who then go out in fact provide everything we need within the broader part of society. So it ...so a PhD who does not finish up in the academic world is not as far as I'm concerned a waste if they are in fact using those talents and skills in other areas.

Now I would agree there is a specific question that we can talk about in terms of academic career paths, but the training we provide through both the PhD...undergrad PhD and the post docs who again will not then go on to get an academic career- that is a training that is a benefit to society as a whole and it is not a waste of training.

Margaret: Right but maybe driving a taxicab in New York is...

David: Well there's always an anecdote....the taxi driver.... a pretty well trained mathematician I would have thought could find a job in industry. Most of the industries that come to us say they want more.

Professor James Vickers, University of Southampton: I just wanted to make a small comment about career development, which is I think...our PhDs are currently not in the job market, even for the post docs because that's an international market. Many of our post docs are hired from overseas. But actually EPSRC does have a very good scheme which is called PhD Plus. It ran it for 2 years and I think that the extra year that PhD students had actually does prepare them, not just for post doc market in the UK but internationally and that means that the amount of money EPSRC invests in training these people does not go to waste. And I think it was an excellent scheme and I just hope it carries on. I'm not sure mathematics made as much use of it as they could have done. It was administered at university level, I know in my university I had to fight really hard to get any kind of share of it. But if you had a scheme like that, maybe ring fenced for mathematics, it would be very good.

David: I can comment on that. It was a pilot that we ran and it was excellently received. I approved the wording of a letter yesterday which your research PVCs will be getting on Monday, which indicates that the PhD Plus scheme as it is in fact being extended across the whole of the doctoral training grant scheme. It is intended for 10% of the PhD students so this is not a broad extension of the PhD. For those who really feel they are likely to have an academic career it's providing that additional source. I am not going to ring fence...in any area. This is an internationally competitive market that the UK research universities play in- that you within your own universities play in. You have got to fight your corner, we are giving you the tool, you've got total flexibility or your research PVC will have that flexibility ...go out there and win out. So it is going to happen.

Professor Colin Sparrow, University of Warwick; I completely take the point that you made today and in the report that you don't want to tell either us or EPSRC how we should communicate better, it's for us to work out. But on the other hand you did spend quite a lot of time with quite a lot of us and with quite a lot of EPSRC and I wondered if... not in the report and sort of off the record in so far as .. if you have any advice for either us or EPSRC about to how do it in a way which is useful and effective, perhaps from your experience elsewhere.

Margaret: Well this isn't exactly off the record is it?...

Tim: But it's off the cuff!

Margaret: Off the cuff. So let me say two things. One, the points in the report about unity, abstraction, generality etc. about how when the mathematical sciences is viewed in the context of other fields of science and engineering, it's important to recognise those properties. All fields think they're different, you ask a chemist, you ask a physicist ...'Are you the same?' and they say 'No, no, we are completely different'. Mathematical sciences are the same. We think we're different and we try to articulate that.

So I think in terms of what EPSRC should do, that is an important point to keep in mind. They're keeping it in mind; we just think they should really keep it in mind especially when...

as they say tough decisions, no-one ever talks about easy decisions, tough decisions have to be made.

For the mathematical sciences community, I would say the unity idea is important. I think people should work together. All the people on the Panel had experience basically saying to their colleagues and their own countries, 'don't complain so much, be more constructive. Try to do something that's constructive'. We felt that the UK mathematical sciences community could do that, that they could not necessarily compete with each other that they could say lets work together that's why we thought this mechanism for communication was important. That it would be a way to sit down constructively and talk about things. And the reason in the report we said talk about them in advance, is because even though people in government are sometimes sworn to secrecy, they can float ideas and they can get reactions to them.

And our Panel members cannot really say what the best way to implement something is in the UK. We have our ideas about it, but it's up to this community. So I would take that as a very serious responsibility. People who are concerned about the future of the research in this country should take that as a responsibility and they should talk to the people in government, be forceful...you don't have to march through London... but be forceful and make your points and I think if they are well founded people will listen. Maybe that's naive, but that's what I think.

Professor David Abrahams, The University of Manchester/IMA/International Review Steering Committee Member: But I want to speak in terms of unity and the great support of us working together rather than separately. Could I just say thank you to you and all the Panel for your hard work in addressing some of our issues, we are very, very pleased that you have addressed it for very little remuneration or reward I am sure. But we greatly appreciate it and we hope it will be beneficial to us as a community- not least in discussing many of the issues you have raised. And I think I'm pleased that Bill is pleased with the report because I think it does address many of the issues which are very long standing within our community.

One of the points which seems to be slightly missing from your report is an idea of identifying some of the threats we are facing. You are very positive about many of the things we do but with small perturbations they could easily cause us problems or difficult decisions. I have been banging on for many years that we really are a big subject, we have got lots of PhD students, we have large numbers of academic staff yet financially we get little reward or substance for the funding from various sources. And so threats from cutting through our money and other areas of funding will have large repercussions. So I wondered whether the report...you discussed whether to identify upcoming threats or decisions that need to made and so particularly say for point B of the excellence of our community, because we could easily shrink in size very, very rapidly. Or whether you felt it best to leave that out of the report?

Margaret: Well, as I said, when EPSRC asked all of us to do this we didn't ask as Kahn did, that they would promise to do what we say. I believe they will pay attention to what we say and we've made, I think, our opinions clear. The report does say in a couple of places this is an issue that hasn't really been addressed, that the mathematical sciences play a huge role in educating undergraduates, even ones that don't go into the mathematical sciences. And

this was about mathematical sciences research, but I think having excellent mathematical sciences researchers and a geographical distributed set of universities means that there is an opportunity for students from all around the country to learn about the mathematical sciences, to get excited about mathematical sciences research.

Let me just say a word about that. In US and Canada undergraduate research is a huge emphasis of funding agencies. They want you to do it. Some people say 'Well under graduates can't really do research'. Well you have to define research don't you? But I mean I think it's very important for that to happen and I think having excellent people at a lot of universities allows that to happen. So to me a threat would be if there stopped being excellent people at these geographically distributed institutions, we say that in the report, then I think that's a real blow to undergraduate education in the UK.

People have to learn how to be mathematically well educated. They have to know about statistics, they have to know about how to read charts that appear in the newspapers and things like that that are totally elementary to us but not elementary to them.

We didn't specifically address threats directly, that didn't seem to be as constructive as we wanted to be, we wanted to be constructive. And I think there are implications in some of our statements. I, by the way, don't like reports that say 'Here are the following threats and if you don't do this everything is going to fall apart'. I think they've lost their credibility. There are too many reports like that in the US, 'You must increase funding for high energy physics or else this terrible thing will happen...you must increase funding for blah, blah, blah,'. No, I mean we want... as I said at the end... that this excellence should be recognised and honoured and the maths sciences community should work with the funding agencies to try to figure out how to make things better, and preserve the great system that you have. Probably not an answer to your question..but anyway...

Tim: The level of questions is...I mean... the volume of questions is...I actually have a couple of questions... I have a couple of questions of David Delpy which will begin to cover the third area...what is his reaction to two of the main recommendations which appear to go somewhat against current trends in EPSRC?

Number one- the encouragement and honouring of the geographical diversity, an acknowledgement that there is very good mathematics done in relatively small departments as well as very big ones.

And number two- the point raised by Bill Moreton. The recommendation that there should be some sort of new communication or committee structure with a memory, with longer term membership, so that members of the EPSRC and members of the mathematical sciences community can be involved at an early stage, not only in particular intellectual challenges but also in modes of funding.

There is a recommendation in the report that if there's a choice between having a managed programme...I mean they didn't use these words...but a managed programme and a sort of free for all of responsive mode proposals and that this new committee or communication structure would discuss that at an early stage and go on discussing it which to me sounds very close to what EPSRC is currently keen on. Which is to transform itself from being, and I quote 'from being a mere funder of research to being a sponsor of research' which it gets

involved through that. So these are a couple of questions. I mean David might have been going to talk about them anyway in his winding up, but I ask them now.

David: To an extent I will, part of the answer is not going to come out today because the whole idea of today is to let the community see the report, comment on it to make sure factual inaccuracies and so on are corrected and to try to address elements that are missing. So we will wait until we've actually got the final version of the report. But I can answer; I'll try and answer the two questions that Tim has put to me.

The first one, in a simplistic way...the question of geographical diversity. I'm very thorough in responding to ministers about this. EPSRC does not have a remit which involves social engineering and of getting appropriate and equal balance of research excellence across the UK. Our charter tells us we should ensure that the research base in the UK is internationally competitive and works to the benefit of the UK economy. And if that results in a non-uniform geographical distribution then so be it. If the government wishes to balance things on a geographical basis, then they can either change my remit or provide, through alternative agencies, ways of redressing that imbalance. We are not into social engineering. We will fund the excellence wherever it is.

So that's a simplistic answer to that. Now linked to that of course is this question of concentration. What is true is...by taking that remit that we don't address things geographically. We have a system which has evolved as a result of peer review of the choices you, the community, have made through peer review of applications that have come in which results in 22 universities taking about 83% of our funding and 12 universities taking about 55% of our funding. That's fact. It has come about as a result of academic peer review processes. Either you believe the peer review processes are incorrect and bias, or if they are working, that is where the excellence is. So we already have a highly concentrated research base anyhow. That's across the whole of the EPSRC remit. Where I think the UK doesn't get maximum benefit from that concentration is that on larger scale programmes, this is tackling the major societal challenges and so on...we finish up with 12 or 22 universities all competing to try to be the group, the university, the institution that solves our energy problem or our digital economy programme. Whereas in reality we need to get appropriate groups, of the best experts in sub disciplines together for those large interdisciplinary programmes. So in terms of concentration, I think there will inevitably be a further concentration within the academic research base and it won't only be driven by us, it will arise from other changes that are happening, in student fees, in the other things that are affecting the whole of the research base. So...there's nothing...you know EPSRC only plays in one part of that very complex landscape.

Final one, or the question you asked was about this standing panels and committee memberships. We do have SATS, we do have strategic advisory teams- we have a mathematics one which does have that continuity, we don't change everybody overnight. We have a rolling replacement of those, so there is a degree of memory in the advice that we are currently getting. We don't have standing panels for grant awards, we got rid of them across the whole of our remit and that was in response to pressures from the academic community who said this is in fact leading to a stultification of where funding was going. It was leading to- it was perceived by the academic base- a continuation of funding for those individuals and those groups and those institutions that were represented on the panel. So as a result of considerable feedback EPSRC went to a panel....a college structure and

floating panels. And that, I would say, has actually worked extremely well across our remit. I would need to be persuaded why maths is different.

Tim: Wouldn't the view of the strategic advisory team- that mathematics should have a somewhat different structure wouldI mean that's the community that the maths programme would be serving. Presumably if the strategic advisory team was consistent in its advice, would there be anything to stop EPSRC doing things differently for maths than for say, engineering? I mean ...

David; You're right. I mean there is nothing and I would hope that EPSRC is and always has been sufficiently flexible that it will put in place an appropriate mechanism...

Margaret: I want to make a comment...the term 'social engineering' is not, it's totally diametrically opposite to what we had in mind. You'll notice we said repeatedly, excellent research is what should be supported. The report does not say take all these little universities who don't have excellent research and please give them funding. Absolutely not. What we are saying is there is a system in this country which has grown up where excellent research is located in many different places. If the goal is to support excellent research, that should be continued. I don't think there is any evidence at all that getting rid of the support for excellent people at small universities that are geographically distributed would improve excellence; the Panels' goal was excellence not spreading the wealth. I just want that to be clear because I don't agree with that at all. If someone had said 'Oh this poor university it has a really mediocre person, but lets give them some money'. Forget it! No way! We would not support that. What we saw was here is a really excellent person, at this small university which is geographically separated from others. That person should be supported. So that's what we said, its not social engineering.

Professor Paul Glendinning, The University of Manchester/IMA: Well you have already said most of what I wanted to say but I will say one thing. Nobody I think is arguing that there won't be concentrations; I mean that's the nature of the way that things work. However, EPSRC has put in place things which enhance that effect, and we have seen that enormously so in statistics, although not intended I admit. But now there are intentional things through platform grants and things and I think one of the things the report, which I thought was absolutely a fabulous thought, was to have distributed platform grants. So where there is excellence in an area, a sub discipline, and you have got people who are excellent in geographically distributed locations, that they can come together and say 'We want to do, broadly speaking, a project in this area. We're all fantastic, give us some money. We'll visit each other; we'll talk to each other. We will do our research we'll have post docs, and post docs maybe will move around a bit'. That's not pandering to some strange regionalism, that's just saying unless you put all your eggs in a few baskets that's naturally happening. And it's accepting that and doing something about it.

So there are two things... I guess what I am saying is if politically there is a decision that you want to create large excellence and let the rest disappear, then fine, say that. You are allowed to say that, that's what governments can do. That's what governments do! But don't try to justify it by pseudo academic arguments which I don't believe hold. And I think the

report actually makes a very good case for a very sensible programme that would undo some of that.

David...The report specifically talks about funding excellence in small institutions or wherever it is and that's not what I disagree with. It does actually talk about a geographical distribution; it actually states a geographical distribution that happens to be a consequence of where the individuals are. It's not something that we are aiming to do to provide a geographical distribution; we are funding excellence, wherever the excellence is. And it should stop at that point, and I have no problem with that.

The question of the sort of programme that you're talking about, we already have mechanisms for doing that. They are called Programme Grants. If a group of individuals want to come together to tackle a programme of research to tackle a problem, then they can do it....

Tim:The thought was

David: The mechanisms are there ready...

Tim: I thought what David was going to say there was that the main obstacle is often in the universities not in EPSRC, which I think actually is true.

Professor Uwe Grimm, Open University: I think thatits not just a question of....I mean the diversity here is not just a question of the geographical distribution, it's also a question of the size of groups working in mathematics which I think makes it quite different from many other disciplines in the EPSRC remit. And I was wondering with this issue of concentration, how do you preserve funding for small groups working on fields that maybe are not the ones that necessarily done better in the large collaboration.

David: I think the relevant question there is both the excellence of the research and the national capability and whether in fact given the size of the UK, the research base, we can actually afford to cover and fund research at an internationally competitive level across the whole of our remit. Historically we have never done it, I don't think we have been as open and explicit about saying that we don't, but the reality is we never have anyhow, and with a budget that is going to reduce by 3% in cash, take whatever inflation figure you want – 10% the Treasury is predicting – so 12% down by the end of the next spending round. If I want those internationally excellent groups to continue to play internationally excellently, which I do, then it's a fixed pot- what goes out in order for us to continue that. So I don't think to be honest we can't afford to play at an internationally competitive level in every single area of EPSRCs remit.

Tim: And what you will support will be determined by mutual communication and discussion as recommended.

David: Absolutely. Yes I mean the decisions on that need really careful input from the whole of the academic base and from the user base and obviously the views of an international, an external International Panel are extremely useful in helping us to do that. However, it would be nice to be honest if there was more of an indication of prioritisation. We didn't ask the Panel the question so they haven't answered it, but if we had asked the question...if we have to cut our...the budget in maths by two thirds, how should we do it? What should we

save and what shouldn't we? We didn't ask that Panel that question and a third is...we were looking at a third at the time when the Panel came but that's the sort of question we really need advice on. What are the relative priorities of some areas compared to others? And that applies maths vs. engineering, vs. chemistry, vs. physics – the rest of EPSRC remit.

Professor Malcolm MacCullum, Helibronn Institute for Mathematical Research: I just wanted to make more explicit what is behind some of the previous discussion, which is EPSRC not only in the last few years, but under your predecessors, has moved more towards offering grants in large amounts. That's inevitably going to produce larger concentration. What mathematicians generally believe is we need lots of smaller grants. In other words we need more money in responsive mode and less in platform grants and programme grants in mathematics. In fact, things have been going in the opposite direction, and that will damage mathematics. I think there's no doubt about it.

I'd like to pick up two other points in the discussion. One was about undergraduate research and we may all be sceptical of the extent to which this is possible. I'm of course, because the nature of the work the Helibronn does internally, not allowed to tell you what they did, but I can tell you that last summer we had five students; two undergraduates and three PhD students working with us. And they contributed by far the most significant result we have had in the last five years. It was a splendid example of what for many years has been my favourite bumper sticker from my days in California, which said 'Hire a teenager while they still know everything'.

The last thing I would like to make a point about is there is an implied question in the report about GCHQ's experience with recruiting PhDs. I don't think they have had a shortage of PhDs to recruit as far as I know, but I will double check with my colleagues. However, I do think we are very conscious of the problems of lack of breadth since much of what we want to do in that area does involve a knowledge of different areas of mathematics working together and we are particularly aware of it when we come to picking the research fellows at the Heilbronn Institute- where of course we have to pick those that are eligible by nationality to work with us. But we are very aware that they don't have the breadth that we would like and in some cases we can't take people in certain areas because they would not be up to the standards that Bristol University, our associated partners, would consider appropriate for the research area they would be working in their external work. So I think this is a very serious matter which does need to be addressed. We are also in that same connection, conscious of some of the points that are made in the report about the lack of PhD students and young people coming through in particular subject areas, for example I would loved to have been able to recruit somebody new in probability but I couldn't.

Margaret: I just want to make...I'm going to say the same thing again, hoping that repetition will make it clearer. I was on the last review Panel- I didn't chair it- and two things that both Peter Hall and I, he was on the last one, observed this time, and other Panel members commented on two things. One, the international standing of UK mathematical sciences research is better now than it was the last time. Its noticeably better in many areas and much of the credit for that is due to EPSRC but its also due to possibly the RAE, there are many factors and I don't like to identify them. So we thought this is really good, if what you care about is how well you are doing on an international scale you are doing really well.

The second thing, and the reason we made the recommendation about the communication and about retaining the excellent system you've got, is there's more unhappiness in the community than there was. This came out very clearly in the segments where EPSRC people were not there. People talked about feeling excluded, they talked about why do they have these big grants when we have all this interesting research we would like to do. The Panel then jumped in and said 'Well how can this be done?' They said well we could have distributed groups to work on an area. This seemed to me and to the Panel to be a good idea but those were two striking features since the last report- increased quality and greater unease, discomfort and concern about communication. And those really are why our top two recommendations are what they are. And so that's an explanation. You didn't ask us to prioritise our recommendations but the ones you put first tend to be the ones that you think are big. And I think if we were asked, if all 16 of us were sitting here, that's what we would say.

Tim: We have reached the time in the programme where the discussion has come to an end. And the final 5 to 10 minutes are for Dave Delpy to talk to us about next steps, so next steps it is followed by tea. But while he's walking over there let me just reiterate our collective thanks to Margaret and through her the rest of the Panel for the enormous effort they put in.

NEXT STEPS – PROFESSOR DAVID DELPY, CEO, EPSRC

David Delpy: Thank you. The first thing I want to do is to contradict Tim, the questions have not ended, the whole reason for me being brief is that I am going to tell you largely about the process that is going to happen now and then allow us to quickly get away to coffee, some biscuits possibly, if that's an appropriate use of EPSRC funding, and informal questions both to other members of the Panel, of the team, Tim, myself and my staff. So next steps. You've had your opportunity now and also over the next few days to make your comments on the report. We do obviously need the factual errors to be corrected, you've highlighted some things you feel are missing or perhaps aren't given an appropriate weight in the report and Margaret will feed those back to the Panel and it's up to them to decide how they wish to respond to that. I suspect as soon as you walk out you'll think 'Oh god, why didn't I ask this' so I suspect that Margaret will be prepared to take some more emails but whether they should go to you Margaret or through EPSRC- through Ben, I don't know which would you prefer?

Margaret: It's probably easier if they come to me but if they go to Ben it's fine. I should mention tomorrow night I am going to the theatre, you've read the report, you'll know that and then I am going home on Sunday! So not much is going to happen before then.

David: This is not going to be a long additional reworking of the report. What we want to do now is get it firmed up and then obviously EPSRC can use it together with the other International Reviews that we have undertaken across the whole of our remit, the feedback which we have had from our meetings with the Learned Societies, the SATS, our other panels TOP and UP, to decide what we do in order to respond to the points that are raised. And the funding decisions in the end that are going to have to be made over the next 4 years.

When the Panel visited we hadn't actually got a budget, half way through the week they were here I was told informally what my budget was likely to be but wasn't allowed to mention it in full at the final meeting on the Friday. We do actually know now what our overall budget is - many of you, or some of you, would have looked at our delivery plan which at a high level explains what we are going to do. We are now going to be preparing...we are in the process of preparing a detailed implementation plan which will be published by March and which will set out what we're going to be doing over the next 4 years. In reasonable detail over the first year and to a degree the second year and in far less detail over the following 2 years. This is a report, an implementation plan which is updated on an annual basis so it doesn't set in stone what we are going to be doing because the landscape within which we are working is changing.

Just to re-emphasise what the budget is. Adrian put up some numbers there. The reality in simplistic terms is that the grants line, the resource budget as it's called for EPSRC and pretty much all the other councils except MRC, is down by 3% in cash terms by the end of the 4 years. So if you add on to that whatever your particular estimate for inflation is- the Treasury estimate is 9%, 8.9% I think they say. So the Treasury estimate is we will be down by 12% in real terms on resource. However, the capital line, the capital budget is now outside that ring fenced amount that was allocated to the research base and that is allocated to BIS, they have now split it out into allocations to research councils and that is down approximately 50%. And its 50% not spread across the 4 years but 50% from 1st April, so it's a straight drop of 50% in our capital allocation. Now we are not a particular capital intensive research council, we typically spend about £50m but about half of that is committed to large programmes- like fusion programme at JET and to some of the other large scale equipment and so the reality is I would estimate that I am going to have to take about £25m out of the resource line, out of the grant line, in order that the research we fund will have the necessary equipment in order to carry out the research. So although we have an overall in theory drop of 3% in the grant line in order to ensure I've got enough equipment I am going to take £25m out. Now that's £25m out of £800mish but it is another hit. So we are in a period of diminishing resource and I think the academic community needs to be aware of that. However we have got some really strong recommendations in this report, the comments about the...particularly about the perception of... between the community and EPSRC about not working together or certainly not understanding one another, is one that we really do take on board and we have to make sure we do find a way of solving that, hopefully with a single mathematical community and not four different mathematical communities or six or whatever the current number is...I don't know. So that one I think we have really got to take on board because whatever we do we have got to do it with the academic base. EPSRC is only one player in the health of the university base in the UK.

So we will be working up some specific responses to every one of the recommendations, we'll accept some we probably won't accept others. That will go to Council, Council will look at that and agree or not with the recommendations that we put to them and following Council's agreement overall that will then obviously be published and we will be implementing it. If you look at our previous International Reviews not just of maths but of all the other areas of our activity you will see that in fact we have always responded to the points that have been raised by the International Reviews, sometimes in ways that the community are happy with, sometimes not, but we have always made a response.

These are a significant effort, the Panel put a fantastic bit of work into that as did the community in providing them with the information on which they made those judgements and we are not going to waste that effort, we will really act upon it. So the detailed response will be published and the report itself will be published together with all that background data that people talked about at the start of the question time. So you will see all the data that was collated from the sources that were available.

Tea and refreshments are waiting outside! There are a lot of EPSRC staff here, some of the people who were on the Steering Committee and obviously Margaret, although I suspect Margaret at some point would like to get back to her hotel. But thank you for attending and thank you again Margaret for everything that you've done.