HOUSE OF LORDS

Science and Technology Committee

Corrected oral evidence: Financing and scaling UK science and technology: innovation, investment, industry

Wednesday 11 June 2025

5 pm

Watch the meeting

Members present: Lord Mair (The Chair); Lord Berkeley; Lord Borwick; Lord Drayson; Lord Lucas; Baroness Neuberger; Baroness Neville-Jones; Baroness Northover; Lord Ranger of Northwood; Viscount Stansgate; Baroness Young of Old Scone.

Evidence Session No. 13 Heard in Public Questions 140 - 151

Witnesses

I: Dr Stefanie Tompkins, Provost, Colorado School of Mines, and Director of DARPA (2021-25); Dr Arati Prabhakar, Chief Science and Technology Adviser to President Biden (2022-25), Director of the Office of Science and Technology Policy (2022-25) and Director of DARPA (2012-17).

USE OF THE TRANSCRIPT

1. This is a corrected transcript of evidence taken in public and webcast on www.parliamentlive.tv.

Examination of witnesses

Dr Stefanie Tompkins and Dr Arati Prabhakar.

Q140 **The Chair:** Welcome to this session of the Science and Technology Committee. We have with us two witnesses joining online from America. We are fortunate to have Dr Arati Prabhakar, who is former chief scientific adviser to President Biden and the former director of DARPA. We also have Dr Stefanie Tompkins, provost of Colorado's School of Mines and also a former director of DARPA. You are both welcome.

As you know, our inquiry is about financing and scaling UK science and technology. In particular, we are concerned about the gap between the UK's basic research excellence and our ability to commercialise our research and scale our science and technology companies. We often look to the US with some considerable degree of envy, as you are so good at this. We would like to ask you to set out at the beginning why you think the US has been so successful in producing big technology companies and commercialising so much of your science. Indeed, have any government policies, in your view, been particularly important in allowing spin-outs and start-ups to scale up? I will ask Baroness Neuberger to start off.

Baroness Neuberger: Thank you very much indeed, and particularly for Dr Prabhakar. We have a science department in the UK, which you probably know about. It sets some of the science and technology policies, and we have a Chief Scientific Adviser and a network of advisers to provide scientific advice to the Government. In the US, the White House Office of Science and Technology Policy is completely different; it is structured differently and it combines those roles.

It would be useful for us if you could give us some insight into how it all works and how the US co-ordinates its science and technology policy across all the different areas of federal Government and its agencies. How does it co-ordinate research and development and innovation policy around federal Government? Also, how does it set strategic priorities, particularly because that is what we are so interested in, to support economic growth? We are deeply envious; you can probably see that around our committee table. Anything you can do to give us a clue as to how it is done would be helpful.

Dr Arati Prabhakar: First, thank you all for the opportunity to have this conversation and thank you very much for that specific question. You are asking some extremely important and useful questions. They are questions we wrestle with here in the United States as well.

I want to make sure I frame my comments with two caveats. One is that I read your questions and I thought to myself that this is what we wrestle with. I do not know; we do not give ourselves a high scorecard across the board. Our innovation system has had phenomenal results in many areas and in others it has not. Those might turn into useful examples to explore in this conversation, but we feel that this is a work in progress at all times and far from perfect here. We worry about the gaps; we worry about how to get from basic research to economic impact. We share a lot of your questions.

The second caveat is that we are in a time of crisis in our country, in which many of our institutions—which are not perfect, but have in fact delivered phenomenal results—are under attack. Much of what I will comment on is what has worked and some of the things that we have tried to do to improve the system but, unfortunately, that caveat is important.

You mentioned two important words. One was co-ordination and one was strategy. I will take a step back and start by describing the US public investment in R&D as one that is overwhelmingly a set of investments that are made for specific public missions. To give you a top-level framework, US federal R&D is currently at $200 billion a year. Roughly $100 billion of that $200 billion is development as opposed to research. I think of that as product development for products that only the Government needs. A lot of that is in the defence department for military systems. It is also NASA and our National Oceanic and Atmospheric Administration when they build satellites. That is an important component, but it is product development.

The "R", which is basic and applied research, is a separate $100 billion, again roughly, and that $100 billion is roughly half for health through the National Institutes of Health and then significant components are NASA for space, the Department of Energy for energy and nuclear technologies as well, and the Defense Department, of course. Included in that mix is our National Science Foundation but, for scale, it is roughly $10 billion out of the $100 billion.

The number one thing that is important is that our system is designed to make R&D investments for these national purposes. If you listened carefully, economic impact is actually not one of those explicit purposes. That leads to the interesting question of where our economic impact from public science and technology came from, and it came in many different ways. For all our information and communications and computing technologies, I point primarily

to the Defense Department, DARPA and the National Science Foundation. For technologies like clean energy, renewable energy and batteries, I point more to the Department of Energy although, again, many others participated. For pharmaceuticals, of course, I point primarily to the National Institutes of Health.

Each of those went from research investment to full commercial capabilities, some of which we have captured economic benefit from and others of which we have not. For example, solar technology started in the United States but, as it has scaled, of course, China has been extremely dominant in that particular area. Hardware in general has had a different journey. The health technologies and pharmaceuticals have their own dynamic.

In the cases where it has worked for us economically, it is because of a combination of that rich publicly funded research, but then that moving into an environment with robust capital markets, with clusters of innovation, with a university research system that in the course of a few decades went from ivory tower and hostile to commercialisation to embracing commercialisation. That culture shift was a result of policies that started shifting behaviours in the universities.And huge domestic markets, in all cases, because we are a large country, and, in some cases but not all cases, government procurement. Again, each story is somewhat different. I will stop with that as some introductory comments. I hope that was useful.

The Chair: Before we move on to some more questions, Dr Tompkins, would you like to add to anything you have heard Dr Prabhakar say and of course, to introduce yourself?

Dr Stefanie Tompkins: Absolutely. Arati covered it well and eloquently. I am happy to dig in a little bit more specifically on the high-risk, high pay-off side, but some of the other questions might be better suited for me to address those topics.

Q141 **Baroness Northover:** That was fascinating. That was a wide-ranging introduction. We may dig into some elements there, like the universities' culture shift, but I will pursue those points about co-ordination. Co-ordinating science and technology policy across Government is hard when it is spread across different agencies and you have outlined some of the different ones that you have in the States. Our Department for Science is fairly new and it split from previous departments in 2023, so this convening role for science and technology is a new role for it. Of course, cross-government co-ordination is difficult. We are seeking your advice on how this is best done and what is essential to co-ordinate this successfully.

Dr Arati Prabhakar: I will start by simply saying that you cannot co-ordinate your way to impact. Co-ordination is helpful to introduce people who may have components of the answer for hard challenges or big opportunities, but impact comes from within the individual agencies.

When the National Science Foundation funds basic research in an area that leads to a vibrant research community and people running to the conferences with a lot of excitement, that is research impact. That happens because the agency focuses and does its mission. When DARPA builds on top of that research foundation and says, "Let us build a prototype of something that seems impossible but will change the world"—and that could be a military system, a vaccine or new electronics capabilities; there is such a wide range—in pursuit of its mission, that is where impact comes from.

To me, co-ordination has always been ancillary to structuring agencies to have the right mission and then enabling them to pursue those missions. Those are not easy to do, but that is how you build an ecosystem where the components together can achieve some significant advances.

Dr Stefanie Tompkins: If I may add to that, I want to point out that it is not always moving in the same direction. There have been plenty of examples where DARPA has invested in early-stage breakthrough technologies where the next step was for the National Science Foundation to turn it into a much broader discipline and to incentivise the universities to grow this technical area. Sometimes things will go in unpredictable directions.

Part of what we do is to pay attention to what we learn as we are making new discoveries and constantly to think about the best transition path for that particular new set of knowledge or that new discovery might be.

Dr Arati Prabhakar: I will take this opportunity to say thank you all for getting me and Stef back together again, because we loved working together when we were both at DARPA a number of years ago.

To concretise her comment, the internet of course started at DARPA with the ARPANET and then the TCP/IP internet protocols, but then NSF expanded it to the wider research community and launched it into the commercial world. Similarly, for vaccines, DARPA did the first ever mRNA vaccines that went into humans. When we finally convinced the vaccine community, which was extremely sceptical, that mRNA vaccines could induce immune

response in patients, in human beings, NIH and many other actors took it forward. This linear model that always starts with research and then DARPA takes the next step is not necessarily always the way it works; you have to allow for that wonderful fluidity among the ideas and the people in the agencies.

Q142 **Lord Drayson:** Further building on the comments that you have made specifically about DARPA, you will probably know it is an agency that is held in high esteem here in the United Kingdom. Could you go a little further into what gives DARPA the secret sauce to have that track record that you just summarised, Dr Prabhakar? How do you judge in which areas to fund research? Who does DARPA partner with to make sure that the research is done in partnership with the right partners? How do you balance the consideration of risk within the science and the commercial potential or the potential relating to DARPA missions? If you could, start with summarising the description of DARPA's mission and then to what you attribute its success.

Dr Arati Prabhakar: I will start. Stef will have a lot to say about this. I will start with mission, which is the first answer to why DARPA has been successful. It has a different mission than other agencies. Of course, it was started in the wake of Sputnik when we realised that we needed a place with a mission to focus on technological surprises and breakthroughs, not just the things that the Army, the Navy and the Air Force already knew that they needed.

That mission of breakthrough technologies and capabilities for national security is DARPA's mission. From that mission comes a set of business practices and processes within the agency. From that, comes the kind of people who are brought in. From mission, process, and people comes culture, which is ultimately what allows DARPA to do the big things that it has done over several decades now. That is the top-level picture.

The way it decides which areas to focus on, I see as a combination of strategy. When Stef and I were DARPA director, we were each in a role that thought about the broad landscape of national security and the broad landscape of scientific and technological possibilities, where new things were becoming possible.

Those top-down views drove hiring. Which kinds of programme managers did we hire? Notably, Stef was the first person to bring in an anthropology PhD as a DARPA programme manager because she saw—and we very much agreed on this—what was happening with the social sciences as a place for phenomenal new capabilities. Even when social scientists did not see that, Stef started seeing

that. That informed which kind of person was brought in as a programme manager. That is the top-down part.

Then, critically at that point, the script flips and it is a bottoms-up process because we very much look to those programme managers to decide which specific programmes would be bold enough and barely feasible. If you did it, it would start a revolution or start a whole new pathway that we had not thought about. You express strategy by who you hire, and then you count on them to build programmes bottoms up.

Who do we partner with? So many science and tech organisations are designed to fund a kind of entity. The National Science Foundation is a machine designed to fund universities; much of NIH is as well. Our Department of Energy is largely designed to fund our national labs. DARPA is not like that: DARPA sets a programme goal and then we go get whoever you need to make that happen. Almost always, it is universities; sometimes it is national labs, often it is companies, which are sometimes start-ups and sometimes established companies. We do not start by saying, "What entity do we want to fund?" We start by saying, "What do we want to accomplish and who do we need to get that done?"

Maybe to finish briefly on your question about risk and potential, first, DARPA has never had an explicit mission of economic impact. It is not measured or valued primarily on economic impact; its mission is national security with phenomenal ancillary economic impacts that have come from that. For those of us who were managers at DARPA at the director level or the officer director level—the only two levels of management—that is a portfolio management job. I always thought about it as balancing risk and reward. Even within the DARPA portfolio, things had lower technical risk or higher technical risk, different timeframes to impact, different sectors of national security and different sectors of technology. The key for every programme though was: if you did it, would it lead to something that had outsize impact for national security?

Dr Stefanie Tompkins: I will add to that. With the people, it is worth pointing out that Arati mentioned key business processes. Every single one of the people that we bring in has a time limit. We tell them, "You are at DARPA for about four years, say three to five years". It will depend on each person's circumstances. They come from the entire S&T ecosystem. They might come from government labs, but also from universities and industry. We tell them that we are letting them loose to change the world, but they have only a limited amount of time. That tends to drive a much higher

tolerance for risk and a sense of urgency that makes them think differently about how they might go about accomplishing their goals.

Somebody who comes in from a university might have the vision that, in their normal world, they imagine could take 20 years. We tell them that they should have results in one-tenth of that time. That will just flip it for them; we can watch it happen in their brains as they realise what the opportunity space is and it changes how they think. We typically also provide some coaching to help them get over that local minimum that they often are in, in how they think, to expand their horizons.

DARPA has also been given a tremendous amount of autonomy by both sides of Congress, because we have a good track record, because we have earned our trust and because we believe that DARPA needs to re-earn its trust every single day in delivering on its mission. Many decisions in other parts of the Government would have to go up three, four or five levels to get approval. We have the autonomy and the ability to make those decisions at DARPA immediately. That lends to a culture of speed.

Finally, I will point out that the other half of DARPA, the non-technical half, is support staff. These are people who write contracts, manage our human resources, security, information technology and things like that. They have strongly evolved into a culture that prides itself on saying yes. For anything our programme managers ask, no matter how impossible it might be, they love the fact that they are the experts who will figure out how to get to a yes. That also tends to drive the whole agency towards being able to move much more quickly and to tolerate a lot of risk.

One other comment I want to make about partners is that we try to avoid formal upfront partnerships where both sides are contributing money, because DARPA always wants the ability to walk away and say, "We did not meet our goals". We are clear about when it is time to quit. If other people have put money into it, they are usually much more reluctant for us to do that. It hinders DARPA's ability to do its mission of taking on risk for others if we partner too closely or too soon in the development stage, but we are always thinking about partners for transition. We are talking about who would take the technology next and say, "If we prove that this one crazy miracle is actually possible, what is the next step? Who will take the hand-off? How can we bring them in to get the knowledge that they need and to make the decisions at the right time, so that we do not end up with the technology dropping into some type of valley of death?"

Lord Drayson: Dr Tompkins, could I ask you to expand a bit on the effect of money in how you manage risk? It was mentioned that DARPA was formed out of the Sputnik moment. Recently, DeepSeek's launch of R1 was described as a Sputnik moment driven by the more limited resources that it had to build its model. How does DARPA use money and the amount of money that you give to your programme managers to drive an appropriate sense of urgency and risk? The answer you gave about giving only three to five years to change the world was interesting.

Dr Stefanie Tompkins: That is a good question. I will say upfront that we are thinking about that every single day and on every programme, as there is a custom answer for that programme. This is a little bit of a Goldilocks space: not enough money and people simply cannot accomplish the big things; but too much money can lead to people worrying much more about spending their money on time and just getting it out the door, than focusing on the impact. We are always looking to figure out what the Goldilocks space of funding is for what we are trying to accomplish.

I will be honest with you: I cannot tell you that we get it right every single time, which is why DARPA is built around having the freedom and flexibility to change course as we discover new opportunities or things where we need to make course corrections. In the end, it is much more about not having an overarching formula for how we deal with money but using it as one tool as part of how DARPA achieves its mission.

Dr Arati Prabhakar: Maybe to put some numbers to that—and my time at DARPA is now a decade ago—when I was there, we had about 200 active programmes at any time. Again, a programme starts and ends and so some are always ending and some are always starting. Across those 200 major programmes, I seem to remember the smallest might have been $20 million across five years and the largest was close to $500 million. It was a satellite thing, which gets costly. It was a wide range of funding depending on what the programme manager was trying to accomplish but significant enough to move the field.

Dr Stefanie Tompkins: More recently, all we have done is pushed further to the left and further to the right, a couple of programmes bigger and a few smaller where we were focusing on speed and near-term capabilities where we thought the risk might be how quickly we could get it out the door, rather than in some type of significant technology barrier.

Baroness Neville-Jones: I want to ask you a bit more about money. Does your money come from Congress? Is it a direct grant

to you? You paint an organisation with a high degree of autonomy. Does it come free of strings? How do they decide how much they are going to give you? I take it you must give them some evidence.

Dr Stefanie Tompkins: Absolutely.

Baroness Neville-Jones: Do they tie anything to it or does the money come entirely untied?

Dr Arati Prabhakar: We do a lot of work to keep strings off it. DARPA's funding is appropriated through the conventional process. It is a part of the Defense Department budget. It goes through all the standard budget processes. It is a line item. Even within DARPA, DARPA tells Congress every year with the budget submission the DARPA total and then many pages of description of the different areas that DARPA will be working in.

What is different between DARPA and most other agencies is that, when we write those descriptions, we write them being clear that in the course of that year things will unfold in some other fashion and the reader should be cognisant that we will be making changes. Our readers, which is all DARPA's bosses in the Pentagon, all the way up to the Secretary and then to the President and then everyone on Capitol Hill—as Stef said, the House and the Senate, authorisers and appropriators, Democrats and Republicans—with few exceptions, everyone in that community of bosses or people who control the budget understands the mission and that DARPA needs room.

Nowhere else in government gets that space and has continued to build that trust, as Stef said, as an ongoing thing. I spent half my career in the private sector; I have not seen that in the private sector and I have definitely not seen it in government. That is unique and has been built and earned over a long time. It is active every day.

Baroness Neville-Jones: How does accountability work in that case? Is it with the OMB?

Dr Arati Prabhakar: We have to be accountable to all our bosses. A good boss would ask, "Tell me what the potential is of the programmes you are doing now. Is it big enough?" They would push to say, "Is it big enough to be worth DARPA?" A good boss or a good hearing on Capitol Hill would say, "Give me an example of something that has failed, because that would prove to me that you are trying something that is hard enough that it might actually break and fail".

A lot of this was building. When I was DARPA director, I would go to all those bosses and overseers and tell them, "This is who we are; this is what we are doing". There was plenty of oversight. DARPA is not tucked in the corner and rogue that no one knows about. It plays by the book, but it plays for its mission and it gets the room to do that job.

Q143 **Lord Borwick:** I want to ask about the DARPA challenge and the grand challenge—that way of structuring and fund giving—because we are not doing it in England. Yet it seems to me, as I look at DARPA, it is the one thing that gets the most publicity for DARPA. The press can understand a challenge, a competition or a winner. Is it as powerful as it seems to be? What percentage of DARPA's efforts go into the challenges rather than into the other structures that you do?

Dr Stefanie Tompkins: It is a fairly small percentage. The way we think about a challenge is as simply one mechanism of many with which to achieve our technological goals. We ask a lot of technical questions where it makes a lot of sense to use the broad structure that Arati described earlier. We lay the question out and we get ideas in from universities, companies and other entities to do that work for us. Sometimes the question is so broad and open-ended that we are not quite sure how to narrow that path down to the goals. The challenge then lends itself well to getting all ideas from all possible entities. At any moment in time, DARPA might have one grand challenge that is visible and then, occasionally, a couple of smaller ones that are embedded often within a programme. A specific phase of the programme might start off with a small challenge.

As an example of a small one, a programme called Ocean of Things was asking whether, if you threw hundreds of cheap little floating devices out into the ocean, could the world figure out how to use that data to predict deep oceanographic currents and measurements and things like that that were going on? That was small; the prize was something like $50,000. It catalysed a niche community.

On the other hand, right now, DARPA has this AI cyber challenge ongoing, which is asking whether humans in partnership with AI can much more effectively defend against cyber threats. That is a live competition, the finals of which will be held this August with as broad a public audience as possible. It is partly because the programme manager who set out the question did not know how to more tightly structure the goals because we did not want to leave solutions on the table.

The Chair: What is the budget for that second category you have just described?

Dr Stefanie Tompkins: The prizes typically will be $1 million to $2 million, sometimes a little more depending on the problem in the community. You might have tens of millions of dollars behind the scenes that are laying out the competition; you have to figure out the rules you need and the infrastructure to actually run the test. If you are going to have a bunch of robots competing against each other, you need an arena in which to work, you need the safety standards, you need to set up the challenge and you need a pretty wide range of people to manage the challenge events and all the different participants. That is one where you see the prize but what is behind the scenes might be a little higher priced.

Lord Borwick: In my mind, the most important part is that you have put down a $50,000 prize and you have a whole mass of other people each putting in $500,000 to win it. The multiplication is quite powerful in this stuff. The publicity that you get from the general press in encouraging young people to think of entrepreneurial ideas of science surely has to be the most valuable thing flying around in this.

Dr Stefanie Tompkins: It is one of the real side benefits. After the robotics challenge, Arati talked a lot about the opportunity to expose to the world the DARPA inside. Maybe that is something to talk to.

Lord Borwick: The automatic vehicles or self-driving vehicles was the big one.

Dr Arati Prabhakar: That was the first big one, yes. I agree with the inspiration and the publicity, but there is a huge caution in what you said a moment ago about how you put out $50,000 and you stimulate all these other dollars being spent. That money has to come from somewhere. Challenges are, in my view, a terrible way to fund the underlying research.

For example, the self-driving car challenge was not how the AI for image recognition was developed, but that was key to that success. That research had to be funded. The challenge brought the application and the integration of a lot of those components of research with a test that was exciting and hard. It certainly pushed the field forward, but you could not have done that challenge without years or decades of funding the underlying research.

To me, it is important not to think of it as a substitute for direct funding of research, but to think of it as icing on the cake or an

accelerator for a field when some of the components have started to develop.

Q144 **Baroness Young of Old Scone:** Does this pick up what one of you said—and I cannot remember now who it was—that DARPA is clear about when it is time to quit? Most of the things that you do are fairly long term, so how do you know when it is time to quit?

Dr Stefanie Tompkins: Our quit criteria—and we talk a lot about go and no-go criteria—are very much defined for the programme. We have big visions for what the impact of the technology will lead to, but we are also clear, in the course of a DARPA programme, what we must demonstrate. That will usually be a specific set of technical goals. That means that, in the course of a multi-year DARPA programme, we will have gates or milestones where we have to stop and ask ourselves, "Are we on track to meeting those end goals?"

Those end goals are often crazy hard. Arati said this multiple times. There is a good chance that we will fail. We are going after something that we believe, if we succeed, could have such dramatic and transformational change that it is worth taking the risk. When you are going after something that bold, you need these guide-posts along the way because it is easy to fool yourself into thinking, "If I just work a little longer on this thing, I will get there". Then you find yourself 20 years later still thinking that you are almost there but you are not. Part of the creation of a DARPA programme involves a lot of painful and hard work to identify what we think those no-go criteria would be.

To be clear, when we hit those criteria, we come back and question ourselves to ask if we had set the right goals. They are not so rigid that we would walk away from an amazing opportunity if we just tweaked the goals a little bit. However, we find that it is human nature to just keep going unless you give yourself some hard questions to answer. It is important to walk away from a lot of things because it is an opportunity cost if we keep sticking to one or two things and are not able to go after other big capabilities.

Baroness Young of Old Scone: Could I turn to Dr Prabhakar? You have had some contact with ARIA here in the UK. What lessons and comparisons with your experience of how ARIA is operating at the moment would you give us? If you were running it, how would you change it?

Dr Arati Prabhakar: I attended ARIA's annual meeting a few weeks ago in London. My experience with ARIA was that some of your colleagues and compatriots reached out a few years ago when

ARIA was starting, and I ended up being asked to serve on the committee that was recruiting the first CEO. They ended up recruiting Ilan Gur, who I have known for a number of years and is a terrific first choice.

Then I went to the White House and got busy with other things, so I came back after a period of a few years to this annual meeting recently and saw what had happened. I want to congratulate you all on what you have started with ARIA. It is difficult to start building the kind of organisation that Stef and I are talking about with missions, processes and people that ultimately build the culture that can go big and take smart risks and reach for big impact. I saw at the ARIA annual meeting all the ingredients, the clarity of mission, the way that they are doing business, the people and the smart, thoughtful ways that they are thinking about reaching for impact. To me, all the signs are that it is very much on track.

Comparing ARIA to DARPA, DARPA is in the business of national security and, as we have stressed, that is how it gets measured and that is how priorities get set. It recognises that that is tied to how the economy works and sometimes, to achieve a national security impact, a technology has to be commercialised for commercial markets to achieve the end goal that we want for public purposes.

ARIA is different in that it has an economic impact mission. Nothing is ever a direct copy of DARPA because the mission, purpose and context are different, but the focus that it has put on stimulating entrepreneurial activities, from my perspective, makes a lot of sense for the particular version of this high-impact work that it is focused on.

Dr Stefanie Tompkins: Yes, I completely agree. I spent several hours meeting with the team, about a year ago, and was incredibly impressed with how it has adapted these core and important tenets of what we think makes DARPA work with the mission that it has and with the ultimate goals that the UK had set out for it.

Baroness Young of Old Scone: The money ARIA has is pretty tiny compared with DARPA. Do you think it has a hope of success with as little money as it has?

Dr Arati Prabhakar: It has enough to get started and then you prove it as it goes. Certainly, my hope is that it proves that it works and that it can scale successfully. Yes, there is a lot of potential.

The Chair: One concern we have is how to ensure that ARIA's efforts will ensure that UK science and technology research funded by ARIA benefits the UK. There are questions about intellectual property and so on. How does the US handle those questions? How does DARPA handle the returning benefit to the US Government?

Dr Arati Prabhakar: First, I will say that we struggle with that question here as well and I will tell you we have a mixed track record. Again, especially software-intensive information technologies have led to enormous economic benefits for the US. However, in hardware area after hardware area, over a course of some decades, we found ourselves very dependent, especially on China for semiconductors, clean energy technologies and more. We did not fully solve that problem.

I note your use of the verb "ensure". You cannot guarantee this. You can take some actions to improve your chances and that is good to do.

Intellectual property is an area that we have struggled with because, on the one hand, we want to see the fruits of publicly funded research end up benefiting the US in businesses being built here. On the other hand, we understand that if we too strongly constrain how companies use intellectual property—given the global nature of markets and how different components of technology get built for ultimate products and solutions—we can over-constrain as well. We have struggled with that over many years. Different parts of government have interpreted the rules in somewhat different ways.

It is an active area, but I would caution against thinking of the control of the intellectual property as a particularly determinative lever because so many other things have to happen before a company can produce a product and generate economic benefit. I would think of that as only one lever.

You can do some things that we have, in some cases, to encourage growth here. One thing that we have not talked about that distinguishes DARPA from most of the rest of federal R&D in the US is that the endpoint for most work at NSF and most work at NIH is the publication of a research paper. DARPA deliberately spends a good portion of its budget building prototypes and doing things that end up being early commercialisation. Unfortunately, in the US in the period since the Second World War, a growing gap has developed. The research community, in my view, has developed too much of a culture of science for its own sake with the notion that, if you just generate good science and publish papers, good things will happen economically.

I spent 10 years as an early-stage venture capitalist and I can tell you that we funded companies that were brand new—two graduate students and a faculty member, at the very beginning—but they had to have something that was pretty far along to be able to make a venture bet. Sometimes that start for private capital is far from the end of NSF or NIH research. DARPA is one of the few places that goes far enough that the private capital can catch the ball and keep running with it.

Number one, think about deliberately encouraging your research investments and agencies to go further. Number two, we have had some success across our agencies coaching researchers at universities on entrepreneurship and helping them to become bilingual, not just in research and science, but also in business. Ilan Gur was the master of this in the work he did in the US. Some things are not about the research investment but are about capital markets and, of course, encouraging that risk taking. The venture capital industry, of course, points to the treatment of carried interest a few decades ago as opening the doors for more risk-taking capital in their context. There are a host of things, but deliberate strategies can help if not guarantee outcomes here.

Dr Stefanie Tompkins: To shift from strategies to tactics, DARPA has consciously been tackling this question because, as you can imagine, in the DoD, it is even more of a penalty if a company or a technology ends up being advanced or developed, for example, by China, because the DoD probably cannot use that. We cannot even touch it, even if it were to have economic benefit to the country. We focus pretty heavily on this question of helping start-ups and other entities that are developing DARPA-funded technologies to access US and western capital where it would remain open and available as a product in the long run, which the DoD could use.

That meant a lot of coaching and focusing on the business case. Even though we have a much more entrepreneurial mindset among a lot of our university researchers now, they are still often abysmally ignorant about what constitutes a business, what has market value and how to scale it beyond the one or two prototypes that they know how to make to potentially making thousands of something. DARPA invested in curating a network of experienced entrepreneurs that pair up with these companies that have reached a stage where the technology is starting to look interesting, as Arati pointed out, but often they do not have a business model that is attractive to your typical investor. We coach them to get them to a point, often with even an embedded entrepreneur sitting in the company and helping them, to develop what might be, for example, a dual-use business model that says, "This is how this

product will scale. These are some of the hard choices and trade-offs you will have to make".

We have found that it has been incredibly successful. I was looking at some numbers and, over the four years that I was shepherding some of this forward, it was about $1.1 billion in private investment into DARPA-funded entities and $0 of adversarial capital. We went back and forth on those two metrics, as well. There are some other things regarding additional federal government investments or state government investments, but fundamentally we kept our eye on the question of private capital versus adversarial capital all the time as we advanced this.

Baroness Northover: I want to follow up on the original comment about the culture change in the universities. You have been addressing this, but it seems you originally indicated that the universities had shifted as far as this was concerned. I was interested in that shift, but you are also now saying that they are going backwards, seemingly, and want to produce papers that relate to their research but are not necessarily applicable. That is, of course, a debate we have in the United Kingdom in higher education, on the purpose of research and so on.

You have said some incredibly interesting things about developing entrepreneurial skills among academics, but I hear two things: one is that they have moved in this direction; two is that they have moved back. Could you comment further on what you were saying?

Dr Arati Prabhakar: I am happy to comment about that. I am the one who said the contradictory sounding things. They are both true at the same time. I will distinguish that, at some level, this is a little bit about engineering faculty and engineering research, versus some of the sciences.

I will tell you a couple of stories. I was a young DARPA programme manager in 1986. At that time, I would point to our Bayh-Dole legislation, which traces back to the 1970s. That legislation started an important part of the cultural shift that we are talking about in universities. It applied to various kinds of organisations, but it said that, when universities in particular did federally funded research, they would own the intellectual property that came from that rather than the Government owning it. The purpose behind Bayh-Dole was exactly the issues that we are talking about. The notion was to incentivise universities by giving them ownership of the IP so that they would be more active in pushing it out. Today, when you look across our universities and you see many of them with vigorous tech transition offices and the ability to help faculty find paths to commercialisation, whether it is licensing the technology to an

existing company or an entrepreneurial route, that all grew out of Bayh-Dole legislation.

When I started at DARPA as a young programme manager in 1986, my hair was still black. This was a while ago. Back then I still talked to a lot of faculty, even engineering faculty, who said, "I am not sure I should talk to industry. That might taint me." That ivory tower idea was still pervasive even with the engineering faculty that I was working with. Today, I look at engineering departments in our universities. I am walking distance to Stanford University, which even before Bayh-Dole has been commercially oriented, but at this engineering faculty—and I would say many more—it is hard to find faculty members who are not thinking about commercialisation almost to the point that you wonder if the pendulum may have swung. You need room for other things. That is engineering.

I contrast that with basic biomedical sciences in the US where NIH funding grew dramatically. It quadrupled in real dollars over 40 years. As that growth happened, the culture of understanding the molecules and doing the science for its own sake grew in parallel with a subset of that community that was also becoming more entrepreneurial.

The short answer to your question about the contradiction is that we have a large and vigorous ecosystem and parts have this culture of deep science for its own sake that is getting withdrawn from impact in a concerning way. Then we have this other shift that is, again, more engineering driven. That is why both things might be true at the same time.

The Chair: Dr Tompkins, do you agree with that?

Dr Stefanie Tompkins: I absolutely agree. As a provost of a university, I deal with this problem every single day. First, if you have spoken to one university in the United States, you have probably spoken to one university in the United States but there are hundreds. There are a lot of subtle idiosyncrasies and what drives their culture relates often to the state in which they reside and some of the local incentive structures and how they define their mission.

However, a core problem that we have not fully resolved at any university are the individual incentive structures around promotion and tenure for our faculty. It is easier to count papers and citations of those papers than it is to count something related to this broader entrepreneurial mindset and commercialisation. Many universities are conducting experiments in that struggle.

I have not yet seen anything that is easy enough that everybody else would like to adopt it. We are in a middle of a complex time where we often give our faculty members mixed messages and telling them that they should work in big multidisciplinary problems and they should move for societal impact and commercialise the technology. Then we say, "However, if you do not publish so many papers in these specific journals, you are not going to get promoted". We are wrestling with that. I have seen interesting movement in what you all have done in how you evaluate universities that I am anxious to learn a little bit more about because you might have insights that we could borrow.

The Chair: I can speak with experience. I am from the engineering department at Cambridge University and I know we have a big problem called the REF, the research evaluation framework. However good the intentions of the people who devise the REF, it comes down to counting papers in a big way. Time and again, people have said we need a new version of REF—we need a REF with a soft touch.

Baroness Neville-Jones: They have said it again. They are going to do a new version of REF.

The Chair: But it always is in the end counting papers. However, we must move on. Baroness Neville-Jones.

Q145 **Baroness Neville-Jones:** What we have been discussing is a good backdrop to what I want to ask you about, which is the role of procurement. In the UK, government departments, particularly those that have a rather monopolistic position—for instance, the Ministry of Defence for the defence industries—get stick for not using their power of procurement to help advance products, test them, and generally play a much more partnership role with the British defence industries. We do not have much left and they could do a great deal more. It is fair to say that the Government are now quite conscious of this, but we have not yet cracked how to ensure that the Government do more to help their own native industrial base.

DARPA has a reputation, particularly through the DoD, for clearing a pathway to commercialisation by pull-through. Is that accurate? Is it effective? Do you have comments on it? The notion, I suppose, is that this leads to activity in DARPA being quite disciplined and results in a real product.

My other question is if you compare the situation on the defence front with other programmes in other areas, does the same apply or do you find there is a different situation for the role of

procurement by Government?

The Chair: Dr Prabhakar, would you like to start?

Dr Arati Prabhakar: Sure, I am happy to start. If you work backwards and you look at the major industries that had their roots in publicly funded research in the United States historically, in some of them the role of government procurement was absolutely essential, but in others it was not. The trends are shifting because of the role of Government and the scale of our economy. If you look historically at aerospace, absolutely, the Government was the first and for a long time the only customer. That is true of semiconductors, computing and specifically vaccines, which are a public health issue.

On the other hand, if you look at the explosion of technologies and industries around the internet and then social media, if you look at smartphones and biotech, in none of those was government procurement a key factor in getting those industries started. They all still had their roots in publicly funded research, but there were consumer or healthcare markets that pulled those things forward. It can play a role, but it is not magic or automatic.

One funny misperception I hear a lot about DARPA when people are trying to start DARPA-like organisations in other areas is people like to say, "You had the Defense Department to take your things and buy a lot of them". Stef and I are both laughing about that because, of course, every big thing that DARPA ever did took sometimes enormous effort to get the Defense Department to do anything because the more radical the breakthrough the harder it is for the user to adopt it. I am a little sceptical of that being some kind of magic solution. I think that there are places for government procurement in the form of prototypes, early products, demonstration projects that show how these new technologies and capabilities can have impact, but in a sense that is an extension of R&D as opposed to classic procurement. Again, bridging that gap seems to be the fertile area to focus on.

Baroness Neville-Jones: You make a distinction between some of the sort of physical things that defence involves, and then there is the internet that has developed differently. Is that because of the nature of the activity or is it because the relative role of the state has shrunk between, say, the Cold War and now?

Dr Arati Prabhakar: Yes, a lot of things were happening at the same time. Many of the things that I described not having a major government procurement path are consumer-facing technologies. Of course, sparking that information revolution was a huge

outcome from public investment but what drove it was consumer commercial markets, and industrial markets in some cases as well. Partly it is that but it is also true about what our economy looks like today—I am astonished when I go back and look at what the US economy looked like in the 1950s and 1960s. The role of the public sector, especially for military, was just enormous. Yes, it is the structural shifts, and the types of technologies and markets.

Baroness Neville-Jones: Is space suffering the same thing now? The States seems to be moving out, to some extent.

Dr Arati Prabhakar: Stef knows a lot about that. Do you want to talk about space? It is pretty dynamic in one way or the other.

Dr Stefanie Tompkins: Let me add a little bit of a reminder that even when the commercial market was exploding in certain areas, when you think back to the public missions and goals, often there are key technical developments that industry is simply not going to make because they are not incentivised to do so. I think that space is a good example of that. There are a lot of things in this proliferated low earth orbit space where there are immense opportunities for commercial capabilities.

On the other hand, there are very key government missions and roles related, for example, to weather forecasting and things like that, that are part of a common good where research and development and procurement still might lie on a balance of taking advantage of commercial investment but at the same time understanding that it will not happen without government investment as well. We are regularly having to explain that when people ask why not, for example, simply allow the commercial market to advance artificial intelligence in whatever direction it needs to go, but there are plenty of problems where the kind of data that you need for AI to succeed or the liability associated with the kinds of problems that need to be solved—the life and death importance of getting something right—falls into a category of problems that the Government might care a lot about and the commercial market will not want to touch.

Maintaining that but not absolving the Government of responsibility in certain areas but always thinking about the balance between how to take advantage of what both sides can do well is really important. Space is a great use case for walking yourself through some thought experiments.

Baroness Neville-Jones: It sounds as if the procurement question all depends on the field you are in, the state of the market, and a number of different factors.

Dr Arati Prabhakar: Can I chime in? We have been talking about a lot of history. Stef mentioned AI and I think it is worth taking a moment on it. This is probably the longest conversation on S&T I have had in a couple of years that was not all about AI, so let us take a second on that. I think that the AI conversation today globally is overwhelmingly focused on business productivity and that is because the people who are talking about it are all the people who are putting billions of dollars into the models and businesses that build on top of that, and that is fine. It has to be done responsibly, not embedding bias, not killing jobs. There is a lot to do to just get that right, but I have to tell you I think it is sort of boring if all we are going to do is use AI to be more productive at doing all the things that we are already doing—if I am just going to send you more emails with my AI and you are going to read my emails. That is just not that exciting. So the productivity has to be done right — but the really big possibilities, the things that will change people's lives around the world, are still fuzzy visions today for AI.

They are things like developing new drugs for impossible diseases in months rather than decades. They are things like closing educational gaps for kids. They are things like delivering a better weather forecast and many more. I live in downtown Palo Alto and in my neighbourhood people are saying, "I will start a company and I will solve that problem"—but none of those will be solved magically by someone starting a company. If you have biological design tools, you can design a molecule, but if you want a medicine that is about clinical trials and regulatory approval. You can have ed-tech tools with AI but if you want to reach not just well-to-do kids but all kids, that is a public responsibility. You can have weather models that people build but if they are not informed by the sensors from NOAA [National Oceanic and Atmospheric Administration] that are on buildings and satellites and ships around the world, you just have garbage in, garbage out.

Again, I think that the public role will be so critical for these dazzling possibilities that lie ahead and everything I mentioned will have commercial possibilities, but ultimately they are serving public purposes. I think that public and private will need to play their roles working together.

Q146 **Lord Lucas:** You mentioned that there was a role for public procurement in prototypes and demo projects. I can see how that lifts some of the risk from the civil servants involved but are there other ways that you have discovered to make it easier for a civil servant, who is not motivated by making millions for themselves—indeed is probably pretty risk averse—to become involved in

procurement of an earlier stage idea? Have you learned anything in particular from your time with the Other Transaction Authority?

Dr Arati Prabhakar: I will start and Stef will have more to say. The Other Transaction Authority was designed to open up DARPA's ability to work with entities that are not structured to deal with federal government procurement. DARPA started it but that is a process innovation that has had far bigger use and impact. I think it has been very constructive in that regard.

On the issue of what motivates a civil servant, what I saw over and over and over again was people being very upset that the Defense Department, not DARPA but the rest of the Pentagon, did not take more risk and reach for bolder goals. The fact of the matter is—again not for DARPA but most of the rest of the bureaucracy of the Pentagon—people are working in an environment in which they are punished if anything goes wrong and they are never rewarded for taking risks and achieving anything big and interesting. It is just incentives and if you do not fundamentally change that, you can tell them to be bolder and do bigger things, but it is just not going to change anything.

On Stef's point about the DARPA programme manager who comes in, has four years, first of all, it is not a forever job. The reason they come, often leaving far bigger salaries to come to DARPA for this public service stint, is they are going to change the world and they just run to work to do that. I would like to see us being able to find ways to make that impact orientation something that is rewarded and celebrated, at least here in the rest of our systems, for example in the Pentagon and across government.

Dr Stefanie Tompkins: We often had conversations with folks, for example in our contracting office, about their regularly having to undergo audits to make sure that they are fully legal and compliant with all the rules and regulations—the many, many, many rules and regulations of government procurement. One of the things we used to say is, "It is very important that you pass the audit. It is not necessarily critical to us that you get an A+ because what is much more important is that within the role required, within our written guidelines, your focus and the reward is on enabling this technology to go forward." That cultural shift to say, "It is what I did for the programme and what ultimately my programme—the technology—might have done for the world", is what we try to make sure they are recognised for and rewarded on, not because they got every single check-box passed with flying colours in a process audit.

That is something you have to live and breathe every single day and you have to make sure that you are remembering what their contributions are and making it very clear what their role is so that they genuinely believe that they are part of the mission and are recognised for it.

Q147 **Lord Ranger of Northwood:** Dr Tompkins, Dr Prabhakar, I say this with all genuine feeling, you are absolute rock stars, obviously, of the R&D world and it is a real privilege. Thank you for the generosity of your time today.

I personally have not been in the R&D world or the academic world. I spent my career in the private sector, 25 years in tech, and I stepped out for four years. I worked for the Mayor of London then, but I did set up the digital office for London in 2010. We did that because we had a small ecosystem, things were happening, start-ups were beginning and we thought it was important to help engineer and support what was happening then. You have the super ecosystem of Silicon Valley in the US and you have had that ultimate tech hub to potentially hand off to.

Dr Prabhakar, you were talking about the hand-off between R&D and the private sector. I always found that challenge between the two areas, and the language—I think you talked about bilingual people. How do you get academics to talk to commercial people? I found it impossible. There are three areas in this kind of marriage. There are the academics, the Government and in the middle are the big commercial tech businesses. I do not mean the normal ones that we would be thinking about. I mean the ones that provide the plumbing and the infrastructure, people like IBM, Cisco, Atos, who I used to work for. How do we bring these things together? I realised there was a language problem and a cultural problem and many other problems. You have highlighted some of the priorities for academics. By the way, academics keep coming up with the same answer because they keep asking themselves the same question, I would say.

How did you, when you were in your rock star position, engage when you were in DARPA and in government with that ecosystem of commercial business in Silicon Valley? How did you crack that nut? What approaches did you take?

Dr Stefanie Tompkins: I can talk about what we are doing more recently, but do you want to provide broader context?

Dr Arati Prabhakar: At DARPA, who you engage with and how you engage with them is driven by the goals of each individual programme. In instances when we were working on countering terrorism online or working on cybersecurity matters, you cannot

do those things without working with the commercial tech industry, and so that is who we went and worked with. We tend to think "work with" means you send them money and they do something for you. Some of these industries do not need that but you have a shared problem.

When ISIS was surging about a decade ago, we were working on counterterrorism issues, online recruiting, and we did not pay YouTube to do something but they had a shared concern with our concern and so we were in touch with them and engaged with them. Those tech platforms often ended up being direct users and testers of some of the new research that we were drawing out of academia. That is an example where they did matter. For a lot of the things that DARPA was trying to do at least a decade ago, that commercial tech industry, if you were doing a hypersonics programme, is not really who matters for a lot of the basic research that I am talking about. Again, it was just driven by the programme goals.

Dr Stefanie Tompkins: I have a couple of specific examples. I mentioned the AI cyber challenge right now and the premise of that was whether or not generally the AI large language models specifically could really accelerate the state of cybersecurity. In that, four of the very big gen AI companies—Google, Anthropic, OpenAI and Microsoft—became partners and their contribution was to donate access for all of the competitors to their latest behind-the-scenes, highest-level foundational models. As we had those conversations with them, it was fairly clear, laying out what was in it for both sides, what was in it for the country and what was in it for those companies in being able to take advantage of what came out of the prize challenge—what might be in it for them in some of the longer-term relationships with the competitors, universities and small companies, it was not anybody doing anything simply out of the goodness of their hearts. A pretty pragmatic set of decisions were made by those companies.

Similarly, a mechanism we used in a lot of different programmes across the United States—DARPA had one that I think of as on steroids; it was a hundred times bigger than what I see at most universities—is the industry/university consortia, where multiple industry players come together and contribute something like a membership fee where they are pooling their resources around common grid research areas, and then multiple universities on the other side are contributing not just research but also workforce. Often the students who are participated in those consortia are becoming the bilingual translators.

We find again that I do not know of any company that will simply contribute money to a consortium if they are not getting something out of it. What they are getting out of it is the research that they want the results of, that is not high enough priority within their own budget to cover, and direct access to a workforce pipeline that is often too complex to get otherwise, especially if you are in a new technology area.

They are a couple of very specific examples of ways to bridge that gap.

Lord Ranger of Northwood: I think you are absolutely right, Dr Tompkins, about your description of the relationship. It will always have a commercial bent, but I am also interested in Dr Prabhakar's point about the fuzzy visions where the commercial elements might not be so visible. How do we bring people together to tackle those challenges? What will it take? Does DARPA have a position to say, "We are going to do it regardless of the commercial side"? At the moment it is the national security focus; the mission is national security. Will that mission become something for the greater good broadly?

Dr Arati Prabhakar: Well, it happens across all our seven decades and DARPA has pretty consistently fought that mission getting too diffuse, and it is partly why Stef and I and other DARPA directors over the years have supported the initiation of an ARPA for energy, an ARPA for intelligence and most recently—President Biden started it—an ARPA for health. I think why we have a DARPA in our Defense Department is to interpret national security not through a narrow lens but through a wide open lens. Why would someone at DARPA in 1960s be daydreaming about what became the internet? What did that have to do with delivering firepower on target? It was because they understood the role that information was playing and would play in national security. I always thought of the job of conceptualising national security as much broader than just narrow military capability but not infinitely broad, absolutely balancing. There is a balancing act.

To your point, with the ARPA model here I think we have shown that it works not only for national security but for other areas. I think ARPA-E has started to show that for energy technologies and ARPA-H I think is on a great path, if it can survive, to show what impact it can have for health. It is a matter of adapting, keeping that culture but adapting it to a different mission and a different context. I think ARIA is doing that for you all at this moment.

The Chair: Dr Tompkins, do you have anything to add?

Dr Stefanie Tompkins: I will just add that very strongly throughout DARPA's history, at any moment in time among those 200 to 300 active programmes, there will be a significant number where there is not a clear commercial pathway. It is not clear that anybody wants it. Often our Department of Defense customers actively do not want it but we see a vision that is beyond their ability to think about what they need the most. We might have a clearer vision on what could be possible with the technology and we will fulfil the mission of taking on that risk on their behalf. If it turns out that it is a complete failure and no one wants it and nothing happens with it, that is part of DARPA's role in the ecosystem to test things out. Sometimes you just have to make some things that everyone else thinks might be a bad idea.

Q148 **Lord Drayson:** Dr Tompkins, I want to probe a little bit further on the example that you gave us, which was really interesting, about the hybrid AI-human defence in the cyber space and that the major foundational model companies had donated access to their behind-the-scenes, as you put it, latest foundational models. I understand that in that context it is within the remit of American national security but, apart from the point you made about the benefit of new introductions being made to the cutting-edge researchers who make a breakthrough, what else are these companies, who have invested literally billions in the development of these models, looking to get out of participating in such a grand challenge where presumably the winner will not necessarily translate into a commercial opportunity for them?

Dr Stefanie Tompkins: The simplest answer is the technology itself. The whole array of technology that is very rapidly sussed out through the process of this competition is of value to them. If you think about it from their perspective, think of cyber vulnerabilities—being able to defend themselves against the range of emerging cyber capabilities that might be made even more dangerous by the use of AI. The ability to defend is something that they are very invested in, but any one company going down a single investment path of trying to solve that problem is much less likely to get the full array of possible answers than they might be through this type of very open competition. DARPA's role in convening that competition is much greater than any one of those companies could have done on its own. There is direct benefit to them in the purely technical space as well as in the access to people.

Lord Drayson: In that sense, there is an alignment of interest in providing defence to the systems, but you open the aperture to, let us say, the use of such AI models to undertake really detrimental effects on society, for example, which is not a defence matter but

is a quality of society matter. What success have you been able to have to get similar alignment from big tech to those issues, which are not about national security? They are about letting us live in a healthy, happy society where people are not using these tools to pursue hate.

Dr Stefanie Tompkins: I have some thoughts on that but I think it is more in the broader OSTP remit.

Dr Arati Prabhakar: Yes, just for context, I showed up as President Biden's science and technology adviser a month before ChatGPT came into the world. From OSTP at the White House, we started what then became a very broad effort across the White House and across Government to deal with exactly what you are talking about, which is the broad set of policies and actions to manage AI's risks and seize its benefits, recognising that it is the most powerful technology of our times.

The programme at DARPA that Stef described is a premier example of an R&D investment that the public sector is making, but much of the work we were doing from the White House was captured in a major executive order that President Biden signed in the fall of 2023 about AI. Of course an executive order is not new law but it is the interpretation and the implementation of law. It turns out that so many of the risks and harms from AI—the use of AI to exacerbate fraud, to embed discrimination in housing and lending and criminal justice and healthcare—are illegal already.

A lot of what that executive order did was to beef up our agencies' ability to enforce those laws when AI is used. In a whole host of practical ways today, Americans are protected because of regulations that came from that — when they go to a bank asking for a loan, when they go to an emergency room or to a healthcare provider. They are protected from fraud. Our Federal Trade Commission, for example, ruled that you cannot use AI to impersonate a business or government agency to commit fraud. Those kinds of simple actions were some of the ways that we dealt with putting the guardrails in place so that AI's harms could be mitigated, because we see this enormous potential to use it to do good things.

The Chair: Dr Prabhakar and Dr Tompkins, you are both giving us such interesting responses. Are you both okay for about another 15 minutes? Is that timing all right for you? Can you live with that? We are just so keen. We have more questions for you but we do not anticipate being longer than about another 15 minutes. Thank you very much.

Q149 **Baroness Northover:** This is following up on the cultural differences between the US and UK, or Europe maybe. One of the themes of our inquiry has been that there are differences in the entrepreneurial mindset and attitudes towards risk. We heard some evidence from other European countries yesterday that echoed some of that. You have talked a little bit about how you approach risky programmes. Can you say any more about a healthy attitude towards risk?

It is very interesting, going back to what you said about universities. I did a PhD a long time ago in the States and encountering the can-do attitude of the States was quite different from what I had experienced in the UK. That said, everybody wanted to stay away from the military-industrial complex; they did not want to have anything to do with commercial things. Since then, my son was at one of your business schools and the stunning engagement right across the university, business and so on, was dramatic, and being able to sit in as a parent and see how they were being taught was astonishing. I wanted to import it immediately back to the United Kingdom to engage everybody but I am not sure that I have managed to do that as yet. Can you tell us how you encourage that kind of approach to risk? You have talked about failure being okay. How do you encourage that?

Dr Stefanie Tompkins: It really is digging in to understand what the root causes are that discourage it. What are the incentives? What are the ways in which we talk about it? It is far from a solved problem. At DARPA we ask ourselves every day how we change the language of what we do and how we talk about our programmes to make sure that people are celebrating, for example, the decision to terminate a programme. Even with everything that we understood about the value of failing, we recognised that the word "fail" has a lot of connotations.

We were constantly hunting for a better way to talk about it, but we recognised that we were really good at celebrating the start of each new programme. It was just embedded in the culture of our technical officers that they would hand out cupcakes or whatever it was when somebody had just launched a new programme. They did not tend to do the same thing when a programme ended, and we wanted to get much more focused on celebrating the outcomes. Even programmes that did not meet their DARPA goals often did something transformational within their discipline and had pathways elsewhere into maybe commercialisation or new lines of research.

You really have to dig in and look for those hidden mixed messages around appreciating the value of the failure and yet maybe your

behaviour not matching what you are saying. I think that at every level, whether it is the individual motivation or whether it is the institution's motivation, you have to look for those mixed incentives and figure out how to make a clearer incentive structure.

The Chair: Dr Prabhakar, do you have anything to add to that?

Dr Arati Prabhakar: I will add that we always end up having a conversation about risk. The reason you have to be open to taking risk is for impact, and I think that it is more important to focus on that. In fact, I used to say to people at DARPA, "If you find a high-impact, low-risk opportunity, please do it immediately", because impact is why we are doing it. Unfortunately, there are very few of those so you end up having to take risk if you want to achieve impact.

It is culture. It is the cupcakes and what you celebrate. I used to think very deliberately about what I would say to people in the elevator when I was DARPA director. I never said to anyone, "Stay out of trouble". I frequently said, "Go cause good trouble". The casual thing you hear from the director in the elevator I think actually is part of the culture.

I loved to walk around in my building. One of the marvellous things about DARPA is you only have about 100 programme managers, and when a programme is under way, the programme manager is never in the office because they are out working with the people doing the work. However, when a new programme manager was putting a programme together, I would often stumble into them in their office and then we would have a whiteboard conversation about whatever they were working on.

I will give you a great example. I had a programme manager who had just come on board. He had worked in a lab before. When you come into the Defense Department at DARPA, all of a sudden you have access to real users of technology. He was very excited because he had talked to a lot of folks in the Air Force, and he started telling me what he was putting together that would meet some of their immediate needs. I said to him, "How does that change national security outcomes?" I really pushed him because in what he was talking about, he was excited that it was practical—his prior research had been less practical—but that was not enough. I needed to know that he was working on something that was big enough, that it was transformative, pushing him to think about what he heard from today's users as a potential stepping stone to something that is big enough to be worth a DARPA investment. That happened because I stumbled into him in his office and we talked at the whiteboard.

Again, it is just deep in the culture, but to me it all is about pushing for impact, then taking intelligent risk, and then using your programme to kill the risk. You are trying to get it so low risk that other people who are not in the risk-taking business can take it on.

The Chair: That is a nice example.

Q150 **Viscount Stansgate:** Good morning, if it is indeed still morning for both of you. I want to ask a couple of questions about the challenges that face start-ups and science and tech companies. In the UK, start-ups and spin-outs often talk about the difficulties with regulation and access to capital. The UK has a much shallower capital market situation than the US, and our institutional investors seem a lot less willing to invest in science and tech, although there are some discussions at the moment in Britain about whether we should make our pension funds more active in investing in science and tech companies.

In your experience, what works well to support growing science and technology companies? What elements of the US Federal Government policy exist to help them grow? Of course, you have talked about procurement already. What public finance and loans can they get access to in the US, and what nudges, you might call them, exist in the US system to encourage private finance to invest in innovation? Finally, what role, in your view, do regulators play in encouraging innovation?

There are quite a lot of things there, but you will appreciate that we are trying to see what is wrong with us in this country where we have good research and good start-ups, but we are failing to scale up successfully. This is really the heart of the inquiry we are doing now. By the way, there are other committees of Parliament that are busy examining very similar issues in different areas. Today is the day our Government have published their spending review, but I will not go into that. It is an important day for science here. Anything you have to say would be very helpful.

Dr Arati Prabhakar: I am happy to start on that. I want to break all of science and technology down into some categories that are a little bit more tractable. Again, on software-based technologies, we have had tremendous success in the US with venture capital and entrepreneurship. The capital costs are relatively modest because the proof of the technology can be established without putting billions of dollars of capital at stake. Those are the places where I think that this iconic notion of public funding of research, a spin-out, of venture capital, entrepreneurs, has worked very well and very much to our benefit.

The hardware technologies in general are a completely different story, and I will use the example of clean energy technologies like solar to contrast that. Venture capital is not well suited to manufacturing-intensive businesses. I was in venture capital during a period that is now called Clean Tech 1.0, where venture made a big surge in clean tech investments, including a lot of manufacturing investments, and quickly realised that the amount of capital at a stage where the risk was still very high did not lead to venture returns, by and large, so people retreated. The new generation of clean tech venture investing is a lot more software intensive in many regards.

Venture capital is only a piece of the story for hardware. It can play a role, but it will only do a piece of the story. In the United States for many decades the term "industrial policy" was considered taboo. For many years we had on both sides of the aisle a conviction that Government should not participate beyond early stage research. Over a period of many years, when we realised that first Japan and then China were very dominant in manufacturing and increasingly as we became more and more dependent on especially Chinese and Taiwanese manufacturing in the case of semiconductors, that concern about the US lack of manufacturing grew and grew and grew.

It crystallised during the pandemic when, for example, semiconductor shortages in Asia meant that our auto manufacturing lines were shut down. People started realising how critically dependent we were in that case, a disruption from a natural cause, from the pandemic. Of course, the geopolitical risks for semiconductors in Asia are a huge issue. It is similar with solar technology, which started in many regards here. The first commercial solar cell came out of Bell Labs in the US in the 1950s, but over the course of many years, with massive subsidies, the Chinese dominated that market as well.

That all came to a head with a series of policies that President Biden pursued. You will have seen the Bipartisan Infrastructure Law, our Inflation Reduction Act, which had massive investments in clean energy technologies, and our CHIPS Act for semiconductor manufacturing. These are not about research. These are about scaling manufacturing and making sure that we have domestic capacity. What happened over those clean energy infrastructure and semiconductor investments is the public capital that we appropriated and then put to work from the public sector drew many multiples of private capital. For example, for semiconductor manufacturing, we put $30 billion of manufacturing incentives out

from public sources. That drew $400 billion of private capital for semiconductor manufacturing in the US.

To use that particular sector as an example, we went from having only one of the five leading-edge semiconductor manufacturers with plans to build in the US—that was Intel—to now having all five of the major leading-edge manufacturers with plans and actions now to build in the US. No other country has more than two. In a very short time, with a significant but still minor public funding of $30 billion in that case, we drew a lot of capital and we have created a new trajectory for manufacturing of that particular critical technology.

I say all that simply to broaden this from research, which is important for hardware technologies and manufacturing in particular, to how very different the tools and the mechanisms are to have that flourishing in our economy.

Viscount Stansgate: Thank you very much for that. As a present to both of you, we ought to send you a copy of the Government's new industrial strategy, which will be published at the end of this month, just so you keep your eyes peeled. Dr Tompkins, is there anything you would like to add?

Dr Stefanie Tompkins: In addition to the incentives, especially when it comes to new and emerging technologies, sometimes there are really hard problems to be solved in the scaling itself, and that is often not considered particularly interesting or exciting or sexy. However, there is science in the scaling that might have to be addressed, and some conscious thought into that can help. Sometimes it is just about getting the right people together to do the knowledge transfer.

I remember some of the biocement-engineered living materials, the biocement start-ups that were tied to a programme that DARPA funded. Despite having leadership in the start-up who were very business-savvy, they lacked an understanding of the manufacturing mechanisms that were out there that might allow them to scale up. As an example, being able to use existing factories and facilities meant knowing exactly what size biocement tile or brick they needed to produce. It turns out that the difference of an inch in one direction or another was the difference between wild success and utter failure. Connecting people to getting that knowledge was one of the things that we learned took a little bit of time and concentration and an investment in the expertise to make those connections.

Q151 **The Chair:** Thank you both very much. We have reached almost

the very end. The last question I have for you on behalf of us all is that our committee is charged with producing a report with recommendations to our Government. What are your three recommendations to us that we should have in our report to support the growth and development of science and technology in the UK? What are your three recommendations, Dr Tompkins?

Dr Stefanie Tompkins: I feel like most of these are things that we have covered, but maybe to pull them back up again, thinking about the barriers and the incentives to taking risk, the barriers and incentives to scaling, and maybe across the board looking at the outcomes you are trying to achieve and digging into to look at the root-cause issues. It will often be three or four layers down from what seems obvious as to what really might be preventing entities from moving forward.

The Chair: Thank you. Dr Prabhakar, what are your three?

Dr Arati Prabhakar: Again, restating some of the things that we have talked about, recognising that it is an ecosystem of R&D and innovation and supporting that, including new elements like ARIA. That is number one. Number two is encouraging high impact rather than what I think is typically an emphasis on compliance. I think that Stefanie told a very good story about that, asking the questions that elicit and reward the behaviour that leads to high impact. Finally, outside of R&D, are the policies, including procurement policies, that can be constructive for the economic growth that you are seeking.

The Chair: That is excellent. Thank you very much indeed, both of you. We have very much appreciated the time that you have spent. We have learned a great deal from your experiences. Thank you for joining us and for bearing with all our, I hope not too difficult, questions. We have very much enjoyed listening to you. Thank you again. Now I will bring the session to a close. Thank you.