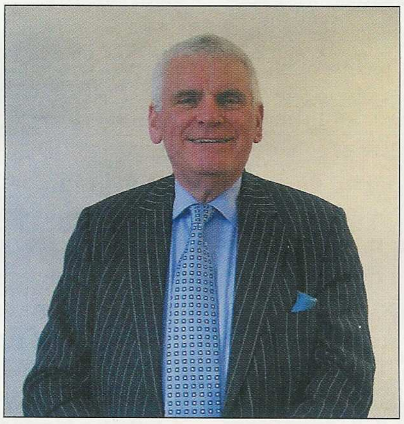
Interview with Bruce Smith

Dr Bruce Smith is Chairman of the Council of the Smith Institute for Industrial Mathematics and System Engineering. Until 1997, he was the Chairman and majority shareholder of Smith System Engineering Limited. Before founding that company in 1971, he worked in design engineering for Decca Radar Limited after a period in the United States with Bellcomm Inc in the US space programme. He is a Fellow of the Royal Academy of Engineering, the Institution of Engineering and Technology and the Institute of Physics. Bruce is Chairman of the Rainbow Seed Fund, Chairman of IP Group plc, a director of a number of private companies and a Domus Fellow of St Catherine's College, Oxford. He is a key player in the UK on stimulating mathematics in industry and promoting knowledge transfer. I met him at our London office to talk about his career and current activities in this area.



You studied physics at Oxford University, acquiring a BA in experimental physics and a DPhil in elementary particle theory. What motivated you to study physics?

When I was at school, I was interested in science and mathematics and particularly in physics. When I was contemplating going to university, my first intention was to read chemistry, a subject that I liked. In the sixth form, I realised that I preferred physics. I think I liked the intellectual cleanliness of physics and the power of combining mathematical models to encapsulate at least some version of reality. I remember very clearly how the application of the simple harmonic oscillator mathematics to bouncing springs opened my eyes. I found that magical. That captured my attention so I switched from chemistry and went up to university to read experimental physics. Later, I went to the United States on a postdoc on a research associateship to the University of Chicago for a year. In fact, I had a switch of subjects, I had been doing elementary particle theory for my DPhil and I switched to theoretical solid-state physics for a year in Chicago.

How did you get on in America?

I had intended to pursue a career in academia; this was in 1964, so it was very much the thing for people in my position to go off to the States for a period. Lots of my friends did and almost all of them stayed and became American citizens. I had got married just before we went out to the States. I had intended to stay only for three or four years and that is what we did. I was an elementary particle theoretician but the people in the theoretical physics department at Chicago wanted to introduce a more many-body type elementary particle field theory approach to what they were doing. They deliberately hired an elementary particle theoretician. They hired other discplines as well in order to give a broader approach to solid-state physics in their department.

Contact with industry soon persuaded you that life outside academia was a more exciting and attractive proposition. Why did you switch later to engineering?

I enjoyed solid-state physics but while doing it, I read about life in industry and heard about the excitement of major engineering projects, in particular the project to put a man on the moon. It was that that convinced me finally that I would prefer to work in industry and in fact, I ended up working in the space programme. By that time, I found the attractions of working in business and in solving real life engineering problems much more exciting than working in academia. It was a very natural switch from physics to engineering. I went into system engineering, which is probably the most abstract branch of engineering.

You joined a company in Washington DC, Bellcomm Inc, carrying out system engineering in manned space flight for the Apollo program, and spent three years as a member of a group selecting the landing sites on the moon. How did this come about?

I let it be known in the department at Chicago that I was interested in looking for an industrial job. I worked for a chap who was a consultant at Bell Laboratories. He told me that NASA had invited them to set up a company to do system engineering for the manned space flight programme. Kennedy had committed the United States to landing a man on the moon by the end of the decade and bringing him back to earth safely. To do that, of course, you need industrial power. So they looked around for somebody who knew about landing men on the moon and of course the answer was nobody. This was a completely virgin engineering task. They thought very wisely that not only would they require people to build the hardware but also to do what in those days was a comparatively new subject of system engineering. This would entail looking at all aspects of the project as a whole and predicting ahead of time what the problems were going to be and hopefully finding solutions for them. They said 'who can we get to set up a system engineering company to land men on the moon?' and the answer is 'who knows, guv?' They said, 'Who in the United States knows about system engineering?' The answer was the telephone company that, in those days, was probably the primary user and creator of system engineering techniques in developing networks.

AT&T was the telephone company and it had this amazing subsidiary, Bell Labs, stocked to the gunnels with very bright scientists and engineers. So they asked Bell Labs whether they would be prepared to set up a company to work exclusively for NASA on the system engineering for the manned space flight programme. Bell Labs did, and no doubt for a substantial remuneration, set up a company called Bellcomm Inc. Half its staff came initially from Bell Labs and then it advertised on the open market for bright, young scientists. The interesting thing was that there were many Brits in Bellcomm. Indeed when I started, the whole chain of command from me, a member of technical staff at the bottom level, to my supervisor and his supervisor and all the way up about four or five rungs to the Vice President were all expatriate Brits.

Do you know why or was it just a coincidence?

I think that the British education system generally, but particularly at university and in the sciences, especially physics, actually gives people a lot of freedom and the ability to think laterally about their subject. When you are doing something that is outside the normal line of thinking like putting a man on the moon, well-educated people who have broad, lateral thinking are very valuable. So I do not think it was by chance that that happened.

What was this experience like?

Well, remember I was a young man of twenty-five and this was my first proper job. I was thrown right to the centre of what was probably the most exciting engineering project going on in the world at the time. Money was no object, so therefore if you wanted to travel you could. I was responsible for thinking about the nature of the surface of the moon. The way I did that was to talk to experts, whether they were astronomers who looked through telescopes or people who did infrared scans, or people who built radar systems that scanned the moon. I could go anywhere. I could talk to anybody and, because this was such a high profile political activity in the United States, I could get to speak to any scientist at whatever level to discuss the project. That was really extraordinarily stimulating for a young man. It was a pretty exciting engineering project as well. The system engineering strategy is to construct a theoretical model of the whole activity, everything about it and well before you do it. The intention is to work out logically where the points of failure are and what is likely to go wrong and then to have in your drawer contingency plans for when things do go wrong. I found that intellectual approach to solving a major engineering problem very satisfying.

In hindsight how closely did the model that you anticipated match reality?

Quite well. There were one or two spectacular mistakes, terrible mistakes. For example, the space capsule that was going to travel to the moon clearly had to have a door to get in and out. If that door opened by accident when they were in space that would be curtains for the astronauts. Therefore, you had to design a door that had the least chance of opening by accident. The original design was a hole with a door inside it that had a flange around it, so the question was, do you put the flange on the outside or the inside? They put the flange on the inside so that there was no chance of the door flying open because of the pressure inside the capsule. A very logical engineering judgement, a good piece of systems engineering, or so they thought. The second thing was what will be the composition of the atmosphere inside the spacecraft? Do you have a low-pressure pure oxygen atmosphere or do you have ordinary air with a lot of nitrogen. Now if you have mixed gases you have to have a piece of machinery to check that the mixture is staying correct. That means extra complication and weight. So they decided they wouldn't do that, they would have a low-pressure pure oxygen atmosphere. Another very sensible decision, so it seemed. In 1967 they had a test of the space capsule on the launch pad with three astronauts all dressed up in their spacesuits in the capsule. There was something wrong with a little bit of the wiring in the capsule and it overheated and started smouldering. Because it was an oxygen atmosphere, the smouldering very soon turned into a fire that generated heat. The heat caused the pressure in the capsule to rise, so that even though the people on the outside knew that there was this disaster impending they did not have the physical strength to push the door open, to push it inwards, in order to get at the astronauts. The result was that three astronauts burned alive. Clearly that was terrible for the astronauts and their families and it also set the programme back by eighteen months because they had to completely redesign the space capsule so that the door opened outwards rather than inwards.

So that makes you even more aware that what you are modelling affects peoples' lives.

Absolutely, you have to get it right. They still use the same process in the space programme. The missions we hear about are the high profile ones. When something goes wrong, they have plans or mock ups on the earth that they can pull out immediately to actually try out solutions. This is very powerful system engineering. You have an analytical approach to thinking ahead of time of things that can go wrong. It is a very impressive, intellectual approach to engineering design.

How did you respond to subsequent missions?

I left the United States in January 1968, which was before the mission to the moon. I went into other, quite different work when I came back to the UK so therefore I was just an informed member of the public as far as the subsequent missions were concerned. But since I knew a lot about their planning, I was completely involved in listening to the news about them.

You started your own consulting engineering company, Smith System Engineering. How did you begin to do this?

I based it on my experiences in the United States. I was very impressed by this rigorous, intellectual approach to planning major engineering tasks and indeed mathematics was the core discipline within that. I thought that this was so exciting and so interesting that I would like to do that for my career. Also, I suppose I was developing an entrepreneurial turn of mind and it struck me that maybe I could build a company to do this because, from my experience in the UK, I did not think there was anybody else doing this stuff, so why don't I try and do it and build a company?

What sort of problems did you start to tackle?

Well if you are running a business, you work on the problems that people are prepared to pay you to solve since you have to be completely market driven. When I first came back to the UK, I had worked as a system engineer in what was Decca Radar on military electronic systems. They found my approach of making mathematical models of radar systems attractive. This was something that was not widely used, certainly not in Decca and I achieved some reputation for doing that. I left them on very good, friendly terms, and they went on employing me as a contractor to do the same sort of stuff that I had been doing when I was on their staff. That made a smooth entry point for me in starting a business and gave me the basis on which I could seek out other customers in industry and in government as well, particularly in the Ministry of Defence, to sell the same sort of services.

You moved from engineering to become an entrepreneurial businessman. You say that theoretical physics has been at the core of your business activity. Can you explain how this worked for you?

The business started with me in a room and I built the company up to one hundred and fifty people of which one hundred were high-powered scientific men and women. I stopped doing sums and became an entrepreneurial businessman, planning the business activities. I still went on doing engineering and the application of mathematics but of course, I was doing it at a higher level and deciding what the company strategy should be and what sort of people we should hire and so on. My approach was still analytical. By temperament and by training and experience, I think mathematically, I am a theoretical physicist. I like real life but I like the mathematical, analytical approach to real life. Whenever a problem comes up these days in the financing of a business and what equity structure it should have and so on, if there is a difficult issue to work through I always work through it as a theoretical physicist/applied mathematician would. Again, it has to do with the cleanliness of the approach, which enables you to uncover things that are inherent in the reality. I agree with your comment that it has been the core of my business activity.

You state that the view you first formed in the USA of the value of coupling university research into industrial engineering remains your guiding principle. Does this happen in the UK?

If you want the best industry producing the best products in the best possible way, which I think you do if you want the economy of the country to be successful, then you want to be as clever as you can be about everything you do: your design, your methods of managing production, everything. If you want novel, new ideas, particularly in the applied sciences, you look to the universities who are educating the people who are able to do this stuff, or because the research departments are generating the ideas. If you want the maximum economic benefit, you should combine the organisational skills and the resource handling skills of industry and the intellectual skills of university. It seems to me a no-brainer. I should say, unfortunately, in the UK that does not always happen or it happens rather too rarely. It has been getting better. I have worked in this country for thirty-five years and it has been improving but we are still nowhere near where one would like it to be.

Where do you see the balance between pure and applied research?

We need to have both, clearly, because in my book you need to have academics handling applied research because that makes it easiest to apply their intellectual power and knowledge to the real life situation. Just as much, you need the pure scientists who are helping to build the foundations of the subject which maybe will not come to fruition for ten, twenty, or thirty years or maybe will never come to fruition. They are there to provide the intellectual underpinning of the subject, which is of value in its own right. That begs the question of what the balance should be and I believe it the UK we have the balance wrong. I should say I was a Chairman of the Economic and Social Research Council for seven years so I know how the research council system works and how government policy works in the funding of scientific research. If I were in power, I would shift the centre of gravity of spending away from pure science and more in the direction of applied science. This should only be a shift in the centre of gravity, it would not stop anything but I would give a different emphasis to what we have now.

Should we invest in long term, speculative research?

Absolutely! Partly because it is the intellectual heritage of humanity and the country that we should do this sort of stuff and secondly because you never know what is going to be useful out of it and it provides the underpinnings for people doing applied science later. They do this rather well in the United States.

You are the Chairman of the Council of the Smith Institute for Industrial Mathematics and System Engineering. The purpose of the Institute is to enable companies to improve their products, processes and services through the application of cutting-edge mathematical modelling. Where do you see this work leading?

There is no shortage of business and opportunities. There is work to be done to persuade people in industry that the application of mathematics can help them solve the problems. Industry is only interested in solving its problems, building or designing new products or processes. What it does not often know is what it needs to do in order to solve those problems in the best way. So we have to be in the right place at the right time to explain to them that if your telecommunications network is not working properly that maybe it is because the underlying structure of it is not right and you should modify it in the following way and then give them a quantitative model to show them how to do it. Where the work is leading is just more of the same. I think in some respects we are in virgin territory.

How do you deal with your customers with no previous knowledge of the value of mathematics?

This is a human contact sport. Once an industrialist is talking to one of our technology translators or an academic, a good personal relationship develops. They learn each other's method of working and what the other wants. Then comes another exciting step where the applied scientist starts to say, 'I understand that this is the way you are doing it at the moment but have you thought of doing the following?' The industrialist will say, 'that's a good idea, think about that a bit more for me.' Then new ideas come bubbling out of that association. Once you can get people talking together then creative thinking goes on and new ideas come up.

Do you think enough people realise that the answer could be a mathematical solution?

No, and indeed the publics' view of mathematicians is that they are clever chaps who live in ivory towers who do interesting, intellectual things, but probably is not much use to everyday life. There is that general feeling around and one of the major tasks that the Institute does is to try to convince users that that is not the case and you really only do it by example.

We keep hearing at the IMA about the lack of interest in young people in taking scientific and technical subjects, and particularly mathematics. They tend to go for the easier options. Yet we hear that mathematical skills in the Far East and Eastern Europe are excellent and that young people there admire mathematicians and aspire to learn the subject. How do you think we could improve the situation in this country?

I think it is very important to stimulate an interest in mathematics in young people. As I have explained, I have a particular view about how the country is going to improve itself. Feeding that need requires clever young people who have the right education, experience and training. These are chicken and egg associations. You need a good educational system, well-organised schools and competent teachers. However, where do you get your teachers? If you are not teaching small children to do the right things there will not be any new teachers coming out at the end to teach the next generation of small children. It is a question of firing people up to believe that this activity is important. So how do you do that? Well, one very important thing is role models. When young people see people like me, who have used theoretical physics to build companies maybe that turns them on a bit. They think they might like to study physics or mathematics. Another very important way, I think, is that government has a huge role to play in funding projects that are very carefully and cleverly chosen, like the moon project, that do something to catch the attention of mankind and young people in particular. There was no question about it that landing a man on the moon attracted a whole generation of young people.

I have a theory, which I think that a lot of people have, that the success of Silicon Valley was built upon the climate that existed amongst the people who lived in that part of California whose fathers had been part of the space programme or the various military programmes that were going on that involved advanced, applied science. So there was a condition in society that was ripe for grabbing hold of and building Silicon Valley. Now whether the Americans planned that or whether it was a chance that they took advantage of, who knows? No doubt, social scientists will investigate that. So well-organised schooling, role models and projects that attract the public attention and then if I was a smart government, I would also give maximum publicity to these projects once they came to fulfilment.

Do the UK political parties have a grasp of the significance and role of mathematics and science in stimulating the economy?

Let me say here that I do have political involvement and in fact, I have just finished co-chairing with Ian Taylor MP the policy group thinking about science, technology, engineering and mathematics for David Cameron. We produced our report about two months ago. It has gone to the Shadow Cabinet and no doubt they will use it or not as they see fit. So I am involved in the politics of this applied science business. Although I should say, the work we did was for a Tory purpose, a Tory organised think tank or policy group but what we were talking about was pretty apolitical. Some of the conclusions were more political. So, do the UK political parties have a grasp of the significance and role of mathematics and science in stimulating the economy? The answer is up to a point. David Sainsbury was a very good science minister, fully seized with the significance and role of science. He chaired a Smith Institute meeting we had in the House of Lords when he was science minister so I am sure he was aware that mathematics is important. I think he was unusual. Most politicians might have the general feeling that science is important but they probably might not realise that mathematics is important. I think they would think that other more important things deserve their attention.

Now officials of course who in theory take the instruction of politicians and then put the policies into practice are better. Clearly, the Research Council officials are fully seized with the importance of mathematics and science but the centre of gravity of their activities are very much towards the academic community in a way that I would like to change. People in the Department for Innovation, Universities and Skills, formerly the DTI, know more about it than politicians but they are nothing like as informed as they should be. I have certainly spent my career trying to introduce better practices into science policy. I have to say, I have not got very far. This was one of the reasons why I accepted Ian Taylor's invitation to co-chair his working group. I knew him before, when he was science minister and I was chairman of the Research Council. I have a high opinion of him and, as it happens, he is my local MP. I discussed this with my wife and she said 'you are always bellyaching about the fact that science policy in the UK is not what you think it ought to be. Here is one opportunity if you have good ideas. If the Shadow Cabinet accepts those ideas and a Tory government is elected then you might have a chance of getting them put into practice. So go ahead and get on and do it!' We are a long way off the pace in the UK, even though we are better than most other countries. It is silly because there are plenty of people in Britain who realise that this would be a powerful thing to do. They would do it if we gave them the chance but it does not happen. I believe it does not happen because politicians are not seized with the importance of doing it.

When Gordon Brown was Chancellor of the Exchequer he gave every indication that he believed science was important to the economy. His actions since becoming Prime Minster have made one wonder whether there was not something wrong with that conclusion because a number of his actions do not seem frightfully helpful. Gordon Brown as Chancellor of the Exchequer was good news for science, Gordon Brown as Prime Minster is a question mark.

Is there a country in the world that you would say has found the right balance?

Well, I do not know and perhaps I do not even know what the right balance is but certainly the United States would be a model. One thing that the United States does is that it has the organisation DARPA (Defense Advanced Research Projects Agency) which funds way-out, exciting technological projects. One of the recommendations in the Tory party group, largely due to my arguing, was that we ought to have a similar organisation in the UK. Take the 'D' off because you do not want it exclusively associated with defence. You would then have an ARPA and you could give it exciting technological projects to do and choose them cleverly so that they could form the basis of new industries in the future. The projects would require the right mix of industry and academia because they would be very difficult so you would pull technology out of industry and universities. The aim would be that using the market would actually feed through into economic benefit and the Americans have used that very expertly. Again, whether they have done it by chance or whether they planned that role for DARPA, I do not know.

Well, DARPA gave rise to the Internet really.

They developed ARPANET, the original Internet under contract in the Sixties. DARPA paid for it because they probably wanted to have nuclear bombproof communication systems for the military. They devised the idea of packet switching and using the existing telephone lines in a different way as a network to make it robust to attack. To do that you require packet switching and so on. That was a perfect example. The interesting question is whether at that time we could have developed the Internet in the UK. Did we have the structures of funding of science it would require or could we do the equivalent now? I suspect we would do it only with great difficulty.

Your role as Chairman of the Council of the Smith Institute is central to the idea of technology transfer and promoting the exploitation of mathematics in UK industry and business. What are you current goals and objectives?

One thing I spend a lot of my time on now is venture capital and in particular spinning high tech companies out of university research departments and government research establishments. I have two jobs. I am the chairman of a publicly quoted company called IP Group plc, which has long-term deals with ten UK universities to spin companies out of university research departments. I am also chairman of the Rainbow Seed Fund, a government funded venture capital organisation that does the same for certain government research establishments and indeed research councils. So I am very interested in the use of venture capital as one of the mechanisms for bringing new ideas out into the market place. Now traditionally, mathematicians have not been part of that game. Life scientists are probably most advanced; engineers and to some extent, physicists work in academic departments that have relationships with venture capital companies that have some history of spinning companies out. Mathematicians generally haven't. I think there are two sides to that. Academic mathematicians perhaps don't think that making money is something for them. Although a terrific example is the financial institutions that have woken up to the cash value of mathematics. On the other side of the fence, venture capitalists think of mathematicians as strange people in ivory towers. They're also worried that mathematics generally doesn't lead to intellectual property that can be corralled by means of patents.

One of the missions in my life is to put these two communities together and for mathematicians to get involved in the venture capital business. The argument I use with the venture capital community is that the use of patents is only one method of preserving ideas and getting them to market. Other methods that are used quite widely in the software industry already are *speed to market* where you just do things quicker than your competitor, and *know how* where you are more expert than your competitor. Now admittedly your competitors will catch up but provided you have new products every eighteen months, you keep ahead of the game. I have not yet sold that idea but, using the Smith Institute, I am in the process of putting the venture capital industry and academic mathematicians in contact with each other. I want that to be successful. Google is based on a mathematical algorithm. The World Wide Web is based on the application of mathematics, certainly. So there are a number of examples where mathematicians have made a huge impact on business. And of course, financial mathematics, that whole industry is another example. So that's one of my goals at the moment.

How do you relax? Do you have hobbies?

I do. Work is very important to me. I work most of the time even though I have now no executive jobs. All my jobs are non-executive. I do work every day. Doing other things is important to me. I have always been a very keen dinghy sailor although I don't do so much of that now. I do a lot of cycling. I do a lot of walking, particularly hill walking. Through no fault of mine, I have a very musical family. My daughter is a professional musician, married to a professional musician. I am very fond of classical music.❑

TERRY EDWARDS
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Industrial Mathematics Internships

The Smith Institute, in its role as manager of the Knowledge Transfer Network for Industrial Mathematics (KTN), and the Engineering and Physical Sciences Research Council (EPSRC) are injecting fresh energy into UK businesses by launching a programme to bring cutting-edge techniques to business innovation and to develop long-term working relationships between companies and universities.

An **Industrial Mathematics Internship** is a way for companies and university research groups to promote direct knowledge exchange and develop long-term working relationships, through engaging a dedicated postgraduate researcher to work on a specific industrial project over a period of 3-6 months.

Each Internship is a collaboration between a host company, an Intern, and a research group within a university. Industrial Mathematics Internships are a new opportunity with a threefold advantage: for companies, university departments and the Interns themselves.

Benefits

- As an **industrialist**, you will explore new horizons or improve existing operations by bringing mathematical expertise and cutting-edge techniques into your innovation activities.
- As a **university faculty member**, you will use Internships as a seed for growing new industrial collaborations and relationships.
- As an **Intern**, you will demonstrate your knowledge and insight in addressing industrial challenges, and gain first-hand experience of the business environment.

We believe that Industrial Mathematics Internships will develop into a major engine for innovation. A pilot phase of the initiative will run between September 2007 and August 2008 and will establish 6 Internships.

Each Internship will last between 3 and 6 months and will be supported by one of the KTN's Technology Translators, who will assist in establishing the projects, building the relationships, exploiting follow-on opportunities and disseminating a final case study through the Industrial Mathematics community.

Please find further details on Industrial Mathematics Internships on the KTN web site at www.ktn-internships.net .

The launch of the Industrial Mathematics Internships was held at the Institute of Engineering and Technology (IET) on the evening of 18 September 2007. Industrialists, academics, and representatives from government and the public sector joined the Industrial Mathematics KTN at the launch of this exciting initiative and made it into a really successful event.

If you would like to apply for an Internships or simply discuss a project idea, please contact Dr Claudia Centazzo at the Smith Institute (claudia.centazzo@smithinst.co.uk).

Dr Tim Bradshaw, Head of innovation, Science and Technology, at the CBI, said, "The Industrial Mathematics Internships programme is an excellent example of how business and universities can collaborate for mutual benefit - helping businesses become more innovative and successful by making effective use of skills and knowledge developed in universities while at the same time providing extremely valuable experience for postgraduate researchers. The critical component is that researchers will work on finding solutions to real business problems, something for which the Smith Institute already has an excellent reputation."❑

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