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**Sir Martin Wood OBE FRS DL in interview with Sir Rex Richards FRS
Oxford, 25 July 1997, Interview II**

RR Well, Martin, in our last discussion I think we ended by talking about the flotation of the company, which was necessary because you needed a very substantial injection of capital in order to build the huge factory required for building the imaging magnets. I wondered if we could start off today by asking you just to reflect on what the advantages and disadvantages have been, as you see them, of being a public company?

MW Well, as you suggest there are indeed advantages and disadvantages. The advantages are relatively fairly obvious because, as you said, we obtained a lot of capital from the public through a flotation on the Stock Exchange which enabled us to equip and get the new factory for the MR [magnetic resonance] imaging system going and, at the same time, developed a market in the share so that a lot of people who'd had their funds tied up in shares in our company for many years could realise them if they wanted to. I think that applied to one or two of our major external shareholders and also to a number of internal people who had shares and just wanted to realise a small amount of cash. Those were very real advantages. Also, I think it brought the sort of discipline that comes with being a public company; the responsibility you have to the public at large through the Stock Exchange is certainly good. I remember in the process of going public, the prospectus was divided out sentence by sentence and a director had to sign every single sentence. It was a very good discipline in the accuracy of every written word, which I have found useful ever since actually. I mean, anything saying 'We're a leading company...' 'Are you leading? What's the proof that you're leading?' and so on. That was very useful. It's a good mental discipline. It brings one into contact with a lot of other people in industry and the financial world of the City, which has been very useful over the years. The disadvantages I suppose are when you get locked into the sort of short-termism which is the ethos of the City, whereas the essence of our business, the research and the building of very large pieces of equipment for the research community and the development required for getting our basic technology into industrial applications is very, very long-term. It's an esoteric sort of subject. It's not easy to explain and I don't think we've been as good as we might have been at explaining what we're doing, how we're doing it and what the future is. Some of it is guesswork anyway, but putting it over to the people who have their finances in our...

RR And are not very well informed.

MW Well, yes, but that's our fault to a large extent. It does create difficulties.

RR But, nevertheless, you seem to have managed that in a remarkable way and I'm thinking of the development of the synchrotron, which was a huge visionary project, wasn't it? Would you like to talk a bit about that?

MW Well, that's a real case in point because to make a synchrotron - and IBM came to us to ask if we could do this for them...

RR Why did IBM want it?

MW Well, IBM, the biggest chip company in the world, could see ahead to the day when the current processes of optical lithography would run out of the resolution required for making very high density, high performance chips.

RR Because of the wavelength limit with the light?

MW Yes, so they wanted to use X-rays with much shorter wavelengths so that they could make much finer markings and finer boundaries between the chips, just like the electron microscope you go to eventually when the optical system and the wavelength of light can no longer operate on really small things you want to see. It's very similar with chips. The major chip makers are looking many, many generations of chips ahead, as you know.

RR Yes, there's a very long development time.

MW They are having to do the research and lay down the plant for chips, which won't be on the market for five years ahead, or longer, so it's essentially a very long-term thing and to explain all this to our shareholders was quite an exercise.

RR So the synchrotron was really going to be used simply as a source of very, very short wavelength radiation for the lithography?

MW Yes, no more and no less. It was like a machine tool. Most synchrotrons are very large civil engineering products, the ones that use conventional magnets, and the concept of having a very small one which we could put in a box at the factory, albeit a big box...

RR Do you know what the diameter of an ordinary synchrotron is? I'm afraid I don't, but it's many metres, isn't it?

MW Well, they range from 25 metres up to two or three times as much as that. So they're vast things, very expensive and rather inflexible. The IBM people wanted something that, as I say, we could make in our factory, crate it, ship it over and they could just push it into their plant. In the future they envisaged fabs, the fabrication plants for making chips, with one or two of these right inside the factory just like a piece of equipment for processing the chip, as it goes from start to finish through the works.

RR And you were able to make it smaller because superconducting magnets are capable of producing much stronger magnetic fields and so you can bend the electrons into a tighter circle.

MW Yes, we can have a complete electron racetrack.

RR It was about one metre in diameter as I remember it?

MW It was called a desktop synchrotron. It was a fairly large desk! It was about two and a half metres long and one and a half wide, something like that.

RR But the curved bit at the end, as I remember it, was only about one metre?

MW Yes, that's right.

RR So what were the problems there? This was a colossal project for Oxford Instruments, wasn't it?

MW Yes, it was a colossal project really in two ways. First of all, physically, for us, it was indeed a big project. Secondly, it involved a number of different technologies which were not within the compass of Oxford Instruments at the time, but we were trying then, as now and as always, to take more responsibility for all the aspects of our project, rather than just making the magnets and selling them to somebody who'd put them into another machine like an MRI and so on. The technology of getting an electron ring operating and getting the electrons going round on the right path is very complicated. There's a little bit of black art in that. In that case, we got the help from the ESRC [Engineering and Science Research Council]. And, secondly, the whole of the RF technology which you need as the synchrotron emits quite a lot of energy in the X-rays, something like eight kilowatts of X-rays continuously, and you've got to put that energy back to keep...

RR And the principle really as I remember it, is that you squirt a parcel of electrons into a racetrack which is delineated by the magnetic fields and then the electrons are accelerated by electric fields generated by a radio frequency applied.

MW Yes, but we simply had almost no RF (radio frequency) technology in the company and that again was something we had to build up.

RR So what were the sort of timescales involved in all of this?

MW Well, initially, it took us at least two to three years to get the order.

RR To convince them that you could do it.

MW To convince them that we could do it. There were other people bidding for it certainly, but that in itself, before we were paid a penny for the system, took a lot of time and a lot of money just simply to prepare for it. They wanted it in a great hurry and we said we could make it in three years and in principle we could have made it in three years, but we met a few unexpected problems down the way. There was quite a bit of development in the process and it was nearly four years before it was finally delivered.

RR They were very funny shaped magnets, weren't they?

MW They certainly were. It was a very advanced piece of equipment and it worked extremely well almost first time. It needed a lot of tweaking, but the overall principles worked very well indeed.

RR And you actually shipped it by air to America?

MW No, it was shipped by sea, but it needed a very special crate because of the rolling of the ship and the weight inside the crate. It was shipped as it was made to work and they just had to...

RR With the refrigerant in, and everything?

MW Yes, and then it was lifted off the truck the other end and rolled into IBM, the East Fishkill laboratory, and was working within weeks.

RR Amazing.

MW But, that's an example of the very long-term. I mean, we discussed this with IBM and we were convinced of this long-term need to move from optical to X-ray lithography for the whole of the advanced chip production and we made the basic bit of equipment for it. That's not a thing you make if you are looking for profits this year and next year only.

RR Did your share price plunge on the Stock Exchange while this was going on or not? It didn't as I remember.

MW I think there was a certain amount of scepticism about. I think everyone was very relieved when it did work and when the cheque came in!

RR Now that's just another arm of Oxford Instruments, isn't it? There are some other businesses that you acquired or generated?

MW Yes, well I think we talked about the medical business and so on and we did, in fact, almost by accident acquire or start a couple of industrial instrument companies. In Newport Instruments there was at least one product that didn't really fit within the superconducting magnet part of the company and we lumped two other products into this and formed an industrial instrument company. The mission statement, if you like, of Oxford Instruments is that we want to become a major international company in scientific and medical instrumentation and we don't want to rely entirely on superconductivity, we want to broaden out, and the whole question of acquisition of other companies and developing new products in new markets flows really from our ambition, as I said, not just simply to stick in superconductivity, but to become a much broader based operation.

RR What about the semiconductor processing division? How did that come about? What used to be called Plasma Technology.

MW You're getting into the whole problem of acquisitions here and they have got rather a bad name, as reported in the Press 'the predators of the world who come

round and take companies over', but there are many good reasons for acquisitions. In the case of Plasma Technology, it was a very good company that had grown up with some very good technology and very good production people, but they had not developed their international marketing very well. They were growing and they didn't quite know how to cope with the international sales side and they thought that perhaps coming under the umbrella of Oxford Instruments would enable them to do what they were good at and still let the company grow using our international sales and marketing outlets. And that's been the case with several other small companies.

RR Yes, I was going to say, some companies have come and asked you to take them over, haven't they?

MW Yes. Well, they did. They actually went to a City merchant bank with the idea of going public themselves.

RR It's an alternative route, isn't it, for a small company?

MW Yes. I think they realised the problems of going public as we had and as we went forward they sort of drew back and said, 'Is this really the right thing for us?' And then they said, 'Well, why don't we join up with another company that has been through this,' and so it became a very good partnership.

RR When the flotation took place, you had the choice of continuing with a very tight grip on the company as you'd had before or of stepping aside to a degree and, perhaps, doing other things and leaving the company in the hands of some younger members of the company. You have views about that, don't you, and the effect it has on the development of new companies?

MW Yes. I think if you examine a lot of family partnership companies, a lot of these small companies have gone to the wall or not developed very far and become what are called 'lifestyle companies' that sort of grow to a certain point and then stick there. This is often because the founder develops a liking for sitting behind a big desk and thumping out the orders and staying there and not encouraging young people to grow into the senior positions. I am very interested in a number of things quite outside Oxford Instruments and have always wanted time to do those. If any younger, more energetic, cleverer person comes along, I always grab them and say 'Come on, take over this and take over that,' and I think this has developed into a sort of ethos within Oxford Instruments. It's a meritocracy. If an old person can do it, age isn't the main criteria, but we always encourage young people.

RR I think this is a tremendously important thing and yet it's very understandable if someone makes an invention and starts a little company and it seems to go very well, you can quite see how hard it would be for someone to, as it were, give the ball to someone else to run with, but you didn't do that, did you?

MW You can say that. I think that is probably true where the person concerned thinks he can actually do the job better than anybody else. I realised very soon that other people could do this better than me and I mean I take an enormous pleasure in

doing two things, firstly, going around our workshop and seeing the most beautifully made products which I know I couldn't do myself

RR They are works of art, these things, aren't they?

MW I mean, I wasn't trained to do that and I couldn't do it. Equally, I love going around our clients' laboratories and seeing them do this. We've made equipment now for two Nobel Laureates and seeing our equipment used for really super research like that gives you an enormous pleasure. I mean, I couldn't possibly have done that.

RR So at the time of the flotation you ceased to be the chairman, didn't you?

MW I did. The chairman of a public company has to have a lot of experience and knowledge and intuition in financial and legal affairs which wasn't me, I knew very well, so I stepped down and have been deputy-chairman ever since then.

RR So then you turned yourself in other directions, didn't you? You had the time to do other things?

MW Yes. One of the things that has always interested me is the process of starting up new companies. People often used to ask me whether I foresaw that Oxford Instruments was going to grow to the size it has. I mean, there are not far short of 2,000 employees now, which is almost exceptional amongst the so-called high-tech spin-out companies from universities. People always expect me to say, 'My God, no, I never thought it would.' In fact, I always thought it would. From the discussions we had before, I had visions of the way industry should be run, combining technical efficiency with harnessing the human spirit, if you like, in the way I think it should be and I felt that if one developed a company along those lines, the sky was the limit, and it's always surprised me that in Oxfordshire, where you've got such a fantastic amount of technology, new scientific discoveries, bright people, energy, a manufacturing tradition within the county and so on that there weren't ten Oxford Instruments growing like we have. When I stopped being chairman, I devoted quite a lot of extra time to seeing what I could do on that front, to try and make a study of what is required to make a company, to get a company started and keep it going, and see what I could do to help.

RR Was that the beginning of the Oxford Trust?

MW That came soon afterwards. In fact, when we left one of our early premises in Middle Way in Oxford, we felt it was a very good little nursery for small companies and we negotiated with the owner of the building for Audrey and myself to keep it on and lease it to other small fledgling companies and I think something like five companies have grown through that and have gone on and now developed in the county at large.

RR You also gave them a lot of help and advice though, didn't you?

MW Yes.

RR What are the principal things?

MW The principal things for a company to get going are they want to know how to do it and all the legal, financial and administrative problems in that, they want space to do it in and they want the money for doing it with. At Middle Way we were able to give them the space and, on the side, a little bit of advice, very low costs and very little future commitment.

RR This was the slaughterhouse?

MW The slaughterhouse in Summertown. And if you want to leave, you know, one month's notice. It wasn't the twenty-five year lease you would get if you went to one of these big industrial premises operations and we saw that operate, as I say, with about five companies coming in and going through it and we felt we'd like to do it on a larger scale. The opportunity came soon after we went public to purchase building premises from the Oxford Instrument company, one we'd bought in a hurry when we needed some space once but then didn't need later on, and we bought this from out of Oxford Instruments, formed the Oxford Trust and did this on a much larger scale. We also started a company called Oxford Seed Corn Limited, a sort of micro venture capital company so that we could provide space, finance when it was needed and a lot of avuncular advice and we've had something of the order of sixty or seventy companies who've gone through this now. It's had a very low failure rate, some are stars and are really growing and some have just kept going...

RR Struggling along?

MW Yes, struggling along. It's been very interesting.

RR Are there any general lessons about this. I mean, is this something that ought to be done on a larger scale?

MW I wouldn't necessarily say ought to be done. It can be very beneficial let's say to the university for instance if it enables some of its technology to be taken up outside and be the basis of forming a company; it can lead to substantial capital gains. I mean, this is growing now, this operation that we did. As a member you'll probably remember a committee in the university called OURAD, Oxford University Research and Development Committee.

RR Now, that must have been in the early eighties?

MW Yes. I remember Patrick Neill, who was the vice-chancellor at the time, chairing it and there was Graham Richards, and slowly we worked through how the university should interact with industry.

RR Now, that was a big change for the university, wasn't it?

MW Yes.

RR Quite a change of attitude?

MW Looking back on it, one wonders why it didn't all happen so much better. The Isis that grew up later is such an obvious development; one wonders why it took so long to do.

RR Can you just tell us something about Isis Innovation?

MW Well, Isis Innovation is the operation the university has for getting its technology patented and so on and to big companies or to provide the technology and intellectual property to enable small companies to get going. I suppose Oxford Molecular is probably the best example at the moment whereby the university put in a relatively small amount of money to begin with and took quite a small shareholding, but it grew so well that when the university sold, I think, half its shareholding a year or two later, it made an enormous gain on this and has I think made the university realise that this is, come the 21st century, going to be potentially a very substantial source of funds. It gets its technology used and does it in such a way that the companies that it forms flourish and that the university doesn't somehow sit on them and prevent them growing as it might if it was too parochial about it.

RR And bureaucratic?

MW Yes, but Isis Innovation now has become a very forward-looking organisation that can do this and does what the Trust does in fact in many ways, but does it from inside the university.

RR It's really complementary with the Trust in a way?

MW Yes, they work very closely together because we're obviously right outside the university, but can bring some support to bear on the ventures of Isis.

RR What part do you play in the Oxford Trust now? Is that another example of something you planned, launched and then left to someone else to run?

MW Yes, I guess it is. I've got a lazy streak in me, I think. It's easy to launch something, but it's much more difficult to keep it going later.

RR And what about Oxford Innovation. Have you been involved in that?

MW Well, the Oxford Trust is a charity and there are very strict rules, correctly so, as to the sort of commercial activities of the charity. Helping small firms to get going is not exactly a charitable event and so where we were specifically asked to do that or asked by outside bodies to come and advise them, we felt it was a worthwhile thing to do but could not do it as a charity, so we started a commercial arm. In the same way that OXFAM has its shops around the country, so Oxford Innovation is the commercial wing of the Oxford Trust. It's a management consultancy and undertakes all sorts of things.

RR But, it's also doing a great deal with education, isn't it?

MW That's the Oxford Trust itself. That is charitable, of course.

RR Because you've got a very vigorous programme of scientific projects, haven't you?

MW Well, I think the mission statement if you like, again, of the Oxford Trust is for the study and encouragement of science and technology, the application of science and technology, and the study forms a major part of it. One of the things I'm of course very keen on, as you are I know too, is giving young children the opportunity of seeing how exciting science and technology is.

RR Well, I know that you've got all sorts of very imaginative and exciting projects going.

MW Well, it's coming. It takes a long time to nudge the culture forward in that respect.

RR Is it limited to Oxford schools?

MW No. Mostly, we do tend to work very carefully within Oxfordshire, not because we've got anything against the neighbouring counties, but we think that the lessons that we would like to be applied more widely get learnt much better by people seeing what we are doing, rather than going and telling them what might happen. Rather than writing great tomes on the Oxford Trust and what it does, we just do it and let people look at it and see.

RR And maybe do it similarly, but not perhaps quite so.

MW Yes, we keep it quite small. We don't write a great deal, but we have a lot of lectures and courses. We actually work on the ground in a practical way in Oxford in the primary and secondary schools.

RR Well, tell me about some of the other things that you have launched, for example the African company.

MW Well, you asked me what I did after we floated and there were a couple of other things that I was able to give more time to then. I've been involved for many years with a project in Northern Tanzania. My elder brother was a surgeon and he started the flying doctor system in East Africa and he was always telling me about the problems, of the equipment not working and not being maintained and so on. And he persuaded me to start a little project in Tanzania where we could maintain equipment that was brought to us and we could train people working in all the bush hospitals, not just in Tanzania but in other countries in East Africa, so that they could look after themselves and look after the equipment themselves when they were back at home. That has grown and is now quite a flourishing operation. Again, I don't go there very much now, but it's a great pleasure to go there and see how it's getting on.

RR How did you get that going? How did you do the launching for that?

MW I went out once or twice and went round the hospitals with him. He was doing the operating and I was looking and seeing what equipment was needed and going to other parts of the hospital and looking at all the different bits of the equipment, the sterilising plant, the lighting equipment, the generators, the blood pressure machines and so on and seeing what was working and what wasn't working and how we could improve them. Then we drew up a plan for what we thought would be a centre for maintaining this equipment. We came back and raised the money and OXFAM was very generous to us on that front. We chose a site in Northern Tanzania for doing this, took the equipment out and we worked quite closely with the church in fact on this. We were given an old, disused Catholic church to operate from to begin with. Very like the slaughterhouse in Oxford.

RR Did you manufacture equipment?

MW No, we didn't manufacture equipment, we just repaired and maintained the equipment that came in from the hospitals. When people don't know how to maintain equipment, let's say a blood pressure thing with a mercury column and a bellows, and it gets a little leak in it, it's much easier for them, let's say the missionaries or whoever it is who's running it, to apply to headquarters for another one and push the old one to the back of the shelf and I've been into places where there are maybe fifty machines, three-quarters of which I could get going in a morning, and they're just not used. No blame on anyone, it's just the system, but I just think when equipment goes to these developing countries, the training of people to use modern equipment is absolutely vital. It makes the system very much more efficient.

RR I once did a study of medical equipment for ACARD [Advisory Council for Research and Development] or something and one of the companies told us that they had manufactured some X-ray equipment and various other technical medical equipment really specifically with the Third World in mind, making the equipment relatively easy to service and removing some of the detailed luxury items which are so common here and they found that it couldn't be sold. They wouldn't buy it because they thought it was patronising and they were being offered something that wasn't very good. It just shows how careful you have got to be with your marketing, doesn't it?

MW Yes, and I mean the sort of craziest problems crop up. We used to find that the sphygmomanometers, you know the glass tube, they were very often broken. Well, I thought this was mostly carelessness to begin with, but you then find that mercury is very useful for extracting gold from ores and for doing your assays and so on and there were other reasons...

RR So they were being broken on purpose?

MW Yes. Then the alternative is to have a system with a pressure gauge, a Bourden gauge...

RR But, they're not very reliable, are they?

MW No. So in the end we used to work with the Bourden gauge manufacturers for something that could be treated by somebody who's perhaps not used to using scientific instruments, that didn't leak and that could be dropped on the floor many times before it broke. Nonetheless, they were more expensive than the simple glass tube and the mercury, but they usually worked for a lot longer.

RR Well, that must have been very rewarding?

MW Yes, it was a lot of fun, and still is.

RR Is it still a flourishing company?

MW Yes, it is. I mean, as the medical instrumentation gets more sophisticated in these countries, so the need for maintaining it grows.

RR And did you send people out to train the engineers in Tanzania?

MW What we did was we used to run courses on training and get the hospitals to send in...

RR And you sent out engineers from England, did you?

MW No. There were staff out there.

RR There were sufficient staff out there?

MW Yes. In fact, that side of it has always difficult to pursue because we're settled in a bush hospital in fact way out, way beyond telephones and electricity and so on. I think in retrospect it would have been better if we'd settled in one of the big cities to which people have other reasons to go to and can get to, because it's quite difficult to get equipment and people out to us. And in fact, the major part of the operation now is in actually using our equipment for doing things that are required in the district, nothing to do with medical equipment, you know, repairing tractors and building furniture and erecting buildings and so on, and doing our training, which is training young people there in the elements of workshop technology from which they can go to other centres.

RR Yes. How very satisfying that must have been.

MW Yes. Then I began to devote more energy to my early love of forestry and that takes more and more of my time now.

RR Does it? Could you tell us something of what it means?

MW Well. It's partly a hobby.

RR Are you interested in the conservation of forests or in planting new ones?

MW Every aspect of it. I think I enjoy forests just simply because of the smell and the sound and so on of the forest. I just like wandering through the bits of woodland that I know well, like other people like playing golf or sailing or whatever. The whole environment is one that I enjoy a lot, but I take a fairly active role in it in several directions. As you know, this country over the centuries has cut down a lot of its woodland, we have about half the area of woodland in this country under forests compared with Europe as a whole and there's quite a big national move slowly to build this up with communal forests, national forests and so on.

RR Are they building hardwood or softwood forests?

MW Depends where. Of course, in Scotland and Wales they go mostly on the softwoods, the conifers, and around the lowlands of England, there's a move back towards hardwoods as much as possible and I've enjoyed both of those equally, I think. But with the development of genetic technology, biotechnology, I think there are lots of ways that we can actually improve the varieties of woods, and it's one of my dreams that we will be able to develop trees that perhaps grow faster, that are more resistant to disease and grow straighter. I like making things out of timber too with my hands and I like growing trees that are actually going to produce useful products and I think if that has got to be one of your prime objectives. If you get the organisation growing for developing forests with good timber in it, conservation and all the other aspects of forestry, even to the sort of leisure activities of the public at large, those come along too. If you go for the other objectives like landscape and so on the thing doesn't fit together so well. I think it's better to grow really good timber

RR It's better to have some commercial possibility rather than generalised things about the environment and the CO₂.

MW Yes, all those things come along too, but I think the prime objective is to grow good timber and you have only to draw back a fraction, a few percent from the maximum of that and you have beautiful forests for people to go and enjoy and the wildlife conservation too.

RR Have you got a company or a charity involved in this?

MW No. I did start the Northmoor Trust, which spends its income primarily on conservation and that now has got, out in South Oxfordshire, a mature woodland to look after for the conservation side.

RR Is that a hardwood woodland?

MW Mostly hardwood. It's got a little bit of softwood in it, but almost all hardwood and from the woodland there we use timber for the maximum income we can, but the prime objective is conservation. We've got about one hundred and fifty acres of land that was farmland which we are using now for forestry trials in the more conventional sense of planting trees, collecting seed from the best groups of trees we can find, planting those, seeing which grow best and then taking the seed from them and doing it again, but even so you've got a ten or fifteen year cycle minimum on that and I believe that it should be possible, within the next ten years or so, to be able to do

some genetic manipulation. If we could actually find what genes are responsible for vigour, for disease resistance and for growth...

RR Is there an academic forestry department anywhere in the country which is looking at this?

MW We have, round the corner here in the Forestry Institute. They are very interested in that, both on the natural forestry side and the molecular biology side.

RR There are some tremendous opportunities.

MW Yes. Absolutely tremendous opportunities there, I think.

RR And what are the limitations? I mean, there is only a limited amount of land in this country, isn't there, now?

MW Yes. Well, that's one reason for trying to maximise the useful timber that grows out of what land is available and there are very few farmers that don't have the odd fifteen acres that is not that useful, either it hasn't got good tracks going to it or a number of reasons why...

RR You don't need vast acreages? Does that affect the economics?

MW You need both.

RR Is it advantageous to have a large forest?

MW Yes, it certainly is. We've started a thing called the Oxfordshire Forestry Group, which has now got hundreds of members. If a lot of farmers get together in one area and they each get, let's say, five or twenty acres of forest, that's quite enough. If the timber is grown properly, it's good timber and good species, that's quite sufficient; if you've got a few blocks of that within a limited area for the people that come and do it in the mills.

RR Forgive me for asking a very simple question, but what are the problems of maintenance of a piece of woodland? I mean, you've got to keep the undergrowth down, haven't you? Is that something that can be automated or is it highly labour intensive?

MW It's pretty labour intensive and for that reason is often not done. The old way of growing trees, of putting a fence round, planting trees, going away for forty years and coming back and seeing what you've got, with very little maintenance, is pretty wasteful of area. And one of the things I am interested in doing is finding the correct balance between the cost of maintenance and the labour you put in during the period of the life of the tree-time, relative to the income you get back from it. Undoubtedly, if you start off by getting a good provenance for your trees and they are well planted, manured, fertilised, pruned and guarded, you get a much better tree quicker. The exact economics of this is something we are working on.

RR Is there any possibility of automating this maintenance problem and making it more efficient?

MW Well, chemicals are used for weed control. I'd like to start using MRI systems for getting an image right through the section of the tree, to see how it's growing...

RR And how the sap moves through it and so on.

MW Yes, and the speed of growth and the width of the rings. If you could get a picture of how the different trees are growing, that would be one more system of monitoring the progress of different trees and different varieties.

RR Fine. Well, let's think about the future now, shall we? Where do you think that Oxford Instruments is going to go now? Is that something you've thought about?

MW Yes, we spend a lot of time thinking about it.

RR High temperature superconductors are one new discovery which might have an impact, I suppose?

MW You say it's new, it's about eleven or twelve years old now which is indicative of the time it takes for something, which I believe is as important as high temperature superconductors will be in the future, to get off the ground. Oxford Instruments is probably the biggest company largely dependent on superconductors in the world, and yet we have hardly sold a single product using these new materials. They are so difficult to make and develop into regular commercial products.

RR Is this largely because they are essentially ceramic materials and therefore don't lend themselves to the kind of shaping and coil configuration that one needs?

MW Yes, they are brittle and hard and difficult compared with the materials which we were looking at earlier, which are fairly malleable and you can easily wind into different shapes. These are much more difficult for that, though we've had that problem already with the A15 materials. Certainly the high temperature ones are much more difficult, but they are extremely complex materials in themselves. If you see the chemical formulae for these things, you'll realise it's difficult, partly because nobody yet fully understands how they work and why they are superconducting. The fact that they work at higher temperatures and you can run them without the use of liquid helium is undoubtedly going to make the introduction to standard industrial products much easier. Oxford Instruments has been trying to make the cryogenic use of superconductivity easy for many years and we've been reasonably successful. We're running a magnetic separation plant one thousand miles up the Amazon in liquid helium.

RR Now, that's an astounding thing, isn't it?

MW When people say the great thing about high temperature superconductors is that you don't have to use liquid helium, on one hand we can turn round and say 'Well, we've made it easy.' It's still not quite true. If one could run magnets without

liquid helium it would undoubtedly make life a lot easier and people will want to do it. And with the advance, not only of high temperature superconductors, but the mechanical refrigeration systems so that one can get down - even in a high temperature superconductor they have still got to work at very low temperatures, but not quite as low as helium - the fact that one can get those temperatures and maintain magnets made of high temperature materials in the sort of twenty to fifty...

RR With a mechanical refrigerator?

MW With a mechanical refrigerator...

RR Which is very reliable?

MW Yes.

RR So you don't have actually to put liquid helium into them?

MW No, you just put a cooler with its compressor and so on nearby and switch on and the thing cools down.

RR So where do you think the most likely applications are going to come? Have you any views on that? How is it going to start?

MW Almost all the industries into which this will ultimately go are quite large and quite conservative and industries in which the reliability of the equipment is of paramount importance. You do get people and particularly people who develop one slightly more efficient superconducting material in a university, who can't understand why it takes so long to get it into industry, but for instance we will be able to make superconducting generators and transformers, but now the big electrical utilities know that every minute they are not supplying power, it's costing a vast amount of money. So it's going to require not only little tabletop examples of how this might work, but full-scale prototypes that are put into service alongside existing ones and they've got to be seen to be reliable and working for a matter of years before things are going to get taken up in a big way. I mean, in magnetic separation for instance, if we went back to the people who are now using our helium based superconductors and said we could do exactly the same thing without helium, that's a way...

RR That would be wonderful. Perhaps you could tell us about this because this is a great project, isn't it, in a very remote part of the world?

MW Well, yes, it is. It works that the china clay that's dug up very often has a very small percentage of an iron oxide impurity in it and the problem of that is that the kaolin is used for the whitening used in china and paper and so on and if it's got this iron impurity in it, it makes it less white than it might be. It's a classic case where magnetic separation works well because you've got a ferric magnetic impurity in something which is otherwise not magnetic with very small particles and a very small percentage of it, so if we pull this small impurity out it increases the value of the rest of the product.

RR So what do you do? Do you pour this ore down through a great tube?

MW You make it into a slurry which is fairly liquid and that is just passed through a tube through one of our magnets which has an iron mesh in it which becomes magnetized in the magnetic field at the edges of...

RR And the ferric oxide sticks to that?

MW Yes, the ferric oxide sticks to that and when a certain amount has gone in, that is then removed and another mesh is put in and it's built into a continuous system, in fact, and is really very simple to operate.

RR And you were saying that it's in South America?

MW Well, there are a number of places. There is one of these in Cornwall in the St. Austell works of British China Clay and there are a number all over the world. Georgia in America has got a lot of china clay, there is quite a lot in Eastern Europe and there are two or three quite large ones in Brazil. To make a comparison though, if we make a magnet and send it to some university laboratory, there are skilled technicians looking after it and loving it, but there they say the sort of conditions that it's got to work in with this man coming round at the end of the week spraying everything with water and cleaning it up and going away, you know, it's got to work in a very hostile environment. So it's done us a lot of good really.

RR And this is all functioning with helium in it?

MW Yes. They fly helium out once a year from Rio in a container and I don't know how often they top it up.

RR And they presumably have a refrigerator for dealing with the liquid nitrogen?

MW Except they probably use a big industrial plant.

RR That's a good example of how one can bring superconductivity into big industrial projects.

MW Another project which is probably going to be one of the first impacts in industry altogether is a thing called a fault current limiter which exists now and is used in the National Grid.

RR Tell me what that is all about.

MW Well, if you have a major fault in the system...

RR This is in the power system?

MW Yes. In the power system in the National Grid, if there is a big fault somewhere, which can be due to a lot of things, thunderstorms, earthquakes, a breakdown of the equipment itself in some plant, you've got to be able to isolate that

with switches and switching off very large currents can be quite a problem. Now, there are a lot of different levels of switching gear that operate throughout the system so that they can isolate these because you want to isolate that out so you can then go on supplying. The power station isn't affected itself and it can go on supplying to other customers and there is a way with superconductors of introducing a very high resistance in the system between the power supply in the place where the fault is, which is far more efficient than using any form of conventional system. And if we get these going and there are quite substantial prototypes being built, there's one actually in service in Switzerland, then it will not only be a more efficient sort of switch if you like than those used now, but it will enable more power to be put through the existing grid. It will upgrade the whole grid system.

RR Because they will feel more confident?

MW Yes. These I suspect will be one of the very first things that will come. People won't see them, they won't notice them, but the thing that we will see quite soon, within a few years, is the Japanese train of course.

RR Tell us about that.

MW Well, there's a major transport problem and there has been for a long time which was why the Bullet trains were made to go all over Japan. The biggest single section of that which is overcrowded is going from Tokyo to Osaka and it's about five hundred kilometres. It's a very mountainous area and they're short of land for building airports and so on and so they've decided to build a magnetically levitated train going between the two cities, and they're starting with something like a forty kilometre section on which they're trying out the system.

RR And the whole idea of magnetic levitation will be that it will go faster and have less friction, I guess?

MW I think they're aiming for it to go at about five hundred kilometres an hour, so you will be able to go from downtown Tokyo to downtown Osaka in an hour. It's less maintenance on the track, but I'm not saying it's less maintenance altogether, and a very high percentage of this distance is going to be in tunnel. You'll hear a lot about it soon because it's going to come into operation. It's being tested now and they're running tracks over the lines, it's quite off the line with levitation, and you use a superconductor of course because it's just so much lighter and uses much less energy.

RR Is the superconductor in the train or on the track?

MW Yes. The superconductor is in the train itself and the present ones are with helium liquefiers in the trains themselves, and the track just has coils all the way down it, which sends a wave down to pull the train along and keeps it off the ground. I went to a place just outside Tokyo last year where they are doing this and across the valley you can see a hole one side of the valley and a big bridge has been built right across the valley with the town underneath it and another hole the other side of the valley and when it works the train is going to come out at five hundred kilometres an hour and go 'pshh' and just disappear, and it's going to be the biggest public demonstration of the

use of superconductors. You may say internationally there aren't many places for which the overall transport problems are the same as there, but it's going to be a very good demonstration of superconductivity and it's for real. These sort of projects of course help to convince the world at large that superconductivity is something that should be encouraged and will help develop the cryogenic technology and everything that goes with it. The other thing, of course, is the new accelerator at CERN [Commission Européenne pour la Recherche Nucléaire] that's starting to be built that will rely entirely on superconducting magnets. Those are probably the two most publicly visible projects that are coming.

RR I mean, superconductivity is an amazing manifestation of the quantum theory really, isn't it?

MW That's your theory, not mine.

RR That ordinary everyday people can see which can only be explained by the quantum theory, which is intuitively a very hard thing to grasp.

MW Yes.

RR So to see a train travelling on the basis of this really will be a remarkable demonstration?

MW Yes.

RR Is this train really being done as a tremendous technical tour de force or is it thought that it might eventually be an economic proposition?

MW Bit of both, but I think mostly the latter. I mean there is a real problem, particularly in Japan, between these two enormous centres of population where people want to go to and fro. You can say that maybe in this modern day and age you can do things by fax and telephone and e-mail and so on and that you don't need to move people around, but actually you do and will do for a long time to come.

RR Yes, and I suppose the more quickly you move them the fewer trains you need because they can make more journeys in a given time and that's an important economy there?

MW It is extremely expensive, although the superconducting part is not so expensive. I mean, you've probably got one hundred kilometres of tunnelling and that's where the really big expenses come in with special power lines, frequency converters and everything.

RR How are they going to get over the problem of the train being a piston in this tunnel working up to a colossal speed?

MW Yes, and another one going at five hundred kilometres quite close to it the other way.

RR The air pressures are going to be quite tremendous.

MW Yes. But, these can be done. It's going to work, that one. There are of course lots of other applications in the SQUIDS [Superconducting Quantum Interference Devices].

RR Now, SQUIDS are superconducting devices which are extremely sensitive to weak magnetic fields, aren't they? What are they used for?

MW They are used mostly for scientific experiments still now, but I mean they are being used, for instance, for measuring the magnetic fields in your head.

RR Generated by your thoughts?

MW Generated by your thoughts. It's very interesting what's happening now in brain research and it's just beginning to be used routinely for pre-operation tests on epileptics to see just where the seizures start so as to help the surgeons who are going to deal with that. You can measure the foetal heart rate, which you can't measure, I think, by any other means, by measuring the external magnetic field. There are lot of microwave applications in telecommunications and so on which are going to use high temperature superconductors. As I said, it's been eleven or twelve years since high temperature superconductors came...

RR So we're still really at the very beginnings of it, aren't we?

MW Yes. The Japanese in particular are probably spending more funds than any other single country on this with a firm belief that this is going to be one of the key technologies of the 21st century, and I heard a famous gentleman say about five years ago that the five years up to the end of this century were going to be on materials development and then industrial applications really will begin to take off early next century.

RR The Japanese have been very shrewd and very successful at their forecasting, haven't they?

MW Yes. Well, they are able to take a very long-term view of this and they are willing to spend a lot of money on way-out demonstrators of possible industrial applications without requiring the sort of short-term payoff that is often required when you don't have government assistance and where the individual companies look to their shareholders and are expected to operate on a shorter term.

RR You have many friends in Japan, don't you, and you often visit Japan?

MW Yes.

RR And Oxford Instruments has a company in Japan now?

MW Yes, we do.

RR Does it manufacture?

MW No, we don't manufacture there. Again, we did manufacture MRI magnets there for a time, but we found it very difficult to get the costs down to what they are now and our joint company with Siemens is manufacturing magnets which we supply to Japanese big medical equipment suppliers to fit into their MRI systems. But, in the company as a whole, we supply a lot of equipment to Japan, partly because it's got this ethic that when there's a depression, a downturn in recession, one of the instruments they use for pulling out of recession is to speed up development of the next generation of products. Sometimes the government will inject a lot of money into research and Japan has become a very important customer of ours. One of the advantages of marketing around the world is of course when one country for some political reason eases back on the funding of research, another one comes up and Japan fits very well into that, particularly that in times of recession they tend to spend more on development whereas let's say, America, will cut back in times of recession. So they're very useful.

RR Have you got any other new projects in your mind or are you beginning to sit back now and look back on the past?

MW Well, no, I think the forestry is something that I'm spending more and more time on.

RR That's your real love actually, isn't it?

MW As I said once, I tossed a coin when I was about twenty as to whether to go into engineering or forestry and it came down on the engineering side, but I've never given up the wish to make some small contribution to forestry and I'm spending more time doing that. In fact, this is linking up with the African business, but because the place where we run this project in Tanzania is just on the edge of the Rift Valley in Northern Tanzania near the Manyara National Park. And for years and years and years, when I was out there, I saw the whole of the Rift Valley getting more and more eroded as people went up. The population was going up, and they used to go up and cut the trees for their firewood and so on, and I used to say that one day they are going to have problems. And they slowly saw this as their wives used to have to go five miles, then six miles, then ten miles to fetch firewood every day and so on, and as other things began to happen, the whole water system became eroded, the springs stopped running and it was a classic case of what happens when you destroy your forests. It was very visible because it was on the side of the escarpment just above where we were working. Then, about five years ago, one of the village heads came along to me and said 'Look, we're having a bit of a problem now, we can see this, we need to renew the forest on the side of the escarpment, is there anything you can do?' Through another organisation, I do some work with Farm Africa which has got a project in the area, we built a forestry element into this and are now working with a number of villages, working all along the escarpment to replant.

RR And do you plant the same trees that were growing there before or are you experimenting?

MW A bit of both. If you're going to get the local people to really take an interest in it, they want to get something from it too, so in a simplified way I'd say that the bottom one-third of the escarpment is now being allocated to people to plant the trees which grow fairly quickly and they can use for all their household purposes and so on, but above that we're steadily replanting with the old indigenous trees. We have started off, which is quite exciting, by just fencing off some specific areas, doing nothing about them and just seeing what comes. The very first thing we did was to stop the grazing and that had an absolutely dramatic effect in about one year. It's just changed in colour, it's become green instead of brown, water is coming out of the springs again and it's really very exciting. It's all happening much quicker than I expected too and in these areas we've fenced off, some of the indigenous trees that were eaten off when they were about one millimetre above ground before when all the cows and goats went up there, they're just beginning to grow again. It's very exciting.

RR Yes, that is very exciting indeed, isn't it? Well, I think we've come to the end of our discussion, haven't we?

MW Yes.

RR Thank you very much indeed for keeping me interested.

MW It has been great fun.