PRESENTER: The MIT Science Reporter brings you Big Magnets, a program about the new National Magnet Laboratory at MIT. Science reporter, Dr. Bert Little's guests are Dr. Benjamin Lax, Director of the Laboratory, Dr. Francis Bitter of MIT, a pioneer in high-powered magnet design, Dr. H. Fernandez-Moran, a research biologist from the Massachusetts General Hospital, and Mr. Max Swerdlow from the Air Force Office of Scientific Research which is sponsoring the laboratory.

INTERVIEWER: Research with high magnetic fields is one of the most active and productive areas in science today. High fields are used to probe the nucleus of the atom. They're used to study the plasma fuel for controlled atomic fusion, to investigate the electrical properties of solid materials, giving valuable information toward such developments as transistor technology. And very recently, they've been used in a new area, biomagnetics. This is the study of high magnetic fields in relation to living things.

Now certainly, one reason for this mushrooming activity was the announcement last year of the National Magnet Laboratory to be built at MIT. The laboratory is designed to accommodate a large number of experiments in many different fields and it is hoped, experiments from all over the world. The laboratory sponsored by the Air Force Office of Scientific Research. And it will be a unique facility.

It will house the strongest magnets in the world. Work is already underway. The magnets have been designed. And although construction has not yet begun, the laboratory is expected to be finished by 1963 at a cost of $6 million. Now the idea of a large scale effort to produce very high magnetic fields for research was developed in great part by Dr. Benjamin Lax and Dr. Francis Bitter.

Dr. Lax is now head of the laboratory and is also the director of the Solid State Division at MIT's Lincoln Laboratory at Hanscom Field in Bedford, Mass. Dr. Lax, why do you want very strong magnetic fields?

LAX: Well, we are very much interested in the basic properties of electrons and solids. These influence to a great extent the behavior of the electrical, the optical, and the magnetic properties of the solids themselves. Electrons behave entirely differently in a crystalline environment than they do in free space. For example, if we put an electron in a solid and we try to accelerate it in different directions along the crystal, we find that it behaves differently. That is, the mass is different.

Similarly, if we put it in a magnetic field and the electron goes around in circles, the rate at which it rotates about the magnetic field will be strongly influenced by the direction of the magnetic field relative to the crystal axes. As a matter of fact, if we put radio frequency or microwave frequency together with this magnetic field, we arrive at a phenomenon known as cyclotron resonance, which has been tremendously successful in probing the interior of the solids.

Now on the other hand, if we look at the magnetic properties, similarly, the crystal environment will influence the electron, which is a tiny little magnet. And as we turn the magnetic field along different directions, there will again be a complex behavior. Now up to now, solid state experiments, for the most part, have been carried out in conventional electromagnets which were of the order of maybe 20,000 oersteds or about 40,000 times that of the Earth's magnetic field.

But today, with these high magnetic fields, we can increase these to 200,000 Gauss or more by a factor of 10. And this will open up a new host of possibilities, new experiments, the old experiments with greater precision, greater accuracy. And therefore, we are tremendously excited. In addition, we hope to be able to achieve and examine some practical things.

For example, we have looked at what we call the tunnel diode, which is a new member of the transistor family. And when we put this in the magnetic field at low temperature, we found tremendous effects on the electrical properties, the resistivity, for instance, of a metal or semiconductor is strongly influenced by the magnetic field. It, of course, has directional properties because of the crystalline property itself.

INTERVIEWER: Sure, sure. Magnetic fields then primarily affect the electrical and magnetic properties of solids-- their conductivity and their electrical resistance, their ability to amplify currents and their magnetism and so on. And it is these electrical properties that are contributing so much right now to modern electronic technology, with the transistor, and the semiconductor and other electronic devices which figure so highly in computers and space technology. Dr. Lax, do you think this kind of technological success provides a spurt of basic research? We usually think of this as happening the other way around.

LAX: Well actually, the two go hand in hand. Sometimes technology gives an impetus to additional basic research. On the other hand, often basic research leads the way and gives a rise to improved technology. However in many cases, the two go hand in hand.

For example, I would say today, high magnetic fields in terms of superconductors are a technological development which are going to give tremendous impetus to new developments, new research. At the same time the technology itself will have to be developed in order that superconducting magnets become a practical reality.

INTERVIEWER: They're a big problem, I guess actually.

LAX: Yes.

INTERVIEWER: Right. Dr. Lax, you call this new laboratory National Magnet Laboratory. What do you mean by this? You must have some specific reason for giving it that name.

LAX: Actually, it's the basic philosophy behind it. We are building a very expensive instrument. And furthermore, this kind of instrument cannot be justified for any single individual or a single group.

And in terms of the number and kinds of experiments we can carry out, it is expected that we will have participation by many scientists in addition to those at MIT, those from university laboratories, from government laboratories, and even from industrial laboratories. We intend to encourage graduate students to carry on their research, post doctoral fellows, and distinguished visiting scientists from this country and from anywhere in the world, for that matter.

INTERVIEWER: But the laboratory is sponsored by the Air Force Office of Scientific Research.

LAX: Yes.

INTERVIEWER: What arrangements do you have with them? I mean, will Air Force projects receive priority? Or how do you work it?

LAX: Well actually, the Air Force is a very enlightened sponsor of research. They are our modern patrons. And we have had very little problems. They have given us very little in terms of scientific direction. And they have supported us in a very liberal way.

Furthermore, I think this answers the fears of many who are worried about interference by government agencies. Actually, our relations have been excellent.

INTERVIEWER: Good. Well, thank you, Dr. Lax. Now one of the most exciting things about this new laboratory is the very great strength of the magnets that it will house. Magnetic fields are measured in Gauss. The Earth's magnetic field is about 1/2 Gauss.

But one of the new magnets to be built for the National Magnets Laboratory will be capable of producing a continuous field of up to 250,000 Gauss. Dr. Francis Bitter of MIT is supervising the design and construction of all the magnets for the new laboratory. Dr. Bitter is a pioneer.

In the mid '30s, he developed a magnet capable of sustaining a field of 100,000 Gauss. That was the highest sustained field ever attained at that time. This is Dr. Bitter's laboratory at MIT, built in the late '30s. It now houses 10 magnets ranging from about 80,000 to 100,000 Gauss.

Such large magnetic fields as these require very large electric currents. They heavy black tubes you see leading into the magnets are water-cooled buses, heavy copper cables that carry the power. The power is supplied by a giant generator which converts the alternating current from the city's power supply to the direct current needed by the magnets.

The 10 magnets are all controlled from a central board. Power can be diverted from one magnet to another for greater flexibility. And this system will be incorporated into the new laboratory.

The 10 magnets in this laboratory support 18 separate research projects. Now in a situation like this, there has to be a good deal of internal cooperation. One man readies his experiment while another gets power and takes his readings. And still a third might be waiting for his turn.

This particular experiment is designed to measure certain electrical properties of a solid material. A sample is put into the central core of the magnet and the power is turned on. And the high magnetic fields cause the electrons in the sample to react in a way that can be measured and analyzed.

Much the same kind of work will be done in the new laboratory. But even so, work in this one will continue much is it has for nearly 25 years. But the new magnets will far outdo the old ones in size and scope. This is a full scale model over here of the new magnet which will produce the big 250,000 Gauss field.

This field itself is exceptionally strong. But even more important is the fact that it can be maintained for a very long time. The magnet was designed by Mr. Bruce Montgomery and Dr. Francis Bitter. Dr. Bitter, will you tell us about it please?

BITTER: Yes, I'd be glad to. First of all, these strong magnets that we are talking about consist essentially just of coils of wire or a conductor of some kind, conducting a current. And the field is produced inside of them. This is the model of the latest newest magnet which we are proposing to build.

And in it, there is essentially a conductor in the form of a coil which can carry tremendous currents-- 40,000, 50,000, 60,000 amperes, as compared with the 1 to 10 amperes that you have in an electric light cord. And the field is produced in this central region down in here.

Now with these big currents, the magnet would very soon melt if it weren't for the fact that it was cooled. The same energy that you have to supply to drive this magnet makes the filaments in electric light bulbs red hot. And this heat has to be taken away. In this particular magnet, the water comes in through these pipes here and flows out through there. And then the current will come in through water cooled conductors at these electrodes here.

I've always been fascinated with the problem of designing new magnets of this kind. The challenge is something like that which is given to a mining engineer when he's asked where you should dig to find gold, or diamonds, or oil, or whatever it would be. How can he tell?

Well, he has to study the whole geologic formation, make maps, models, and then finally says here. We have the same kind of a problem. We might build lots of different kinds of magnets which would blow up, or not work properly, or not work as efficiently as those which somebody else might produce. So we have to study the whole area and finally decide that the most promising region is here. And we built a model sometimes when it's very important and get at problems of this kind.

Now then, magnets are not only required to make strong fields. One also wants high precision magnets, magnets in which the fields are extremely uniform for certain kinds of work. And I want to illustrate what I mean by a high precision tool with a simple example of measuring, for example, the diameter of my finger.

An ordinary ruler would be quite sufficient to say roughly 3/4 of an inch. But my finger has sort of variable dimensions. It isn't smooth. So it isn't important. It makes no sense to make very refined measurements.

On the other hand, if you have a rod like this and you want to use it as a bearing, you want to know its diameter very much more accurate. And the ruler is simply not suited to this sort of a measurement. You have to go about it quite differently. And the way you do in modern technology is to get a micrometer. Now this is an entirely different sort of a thing.

Similarly, we are designing high precision magnets. Of course, on the outside, they'll have a case like this. But what goes on inside will be very different. And we'll have special features to make highly precise uniform and constant magnetic fields in them.

INTERVIEWER: Dr. Bitter, you've devoted a good deal of your life to the design of large field magnets. And this is the biggest one yet. Now I know your eagerness to build magnets has come about because you wanted to use them for research. But why magnets?

BITTER: Well, magnets have fields around them which are penetrating. You need probes to find out what's going on inside matter. For instance, if a doctor wants to know if you have a broken bone or a busted appendix or something like that, he has to probe with his fingers and feel what's in there. Well now, magnets are surrounded by fields which penetrate all matter.

Little magnets have around them such fields. Now if I take this magnet and hold it near my finger, the field extends right through the inside and it probes essentially the solids, the liquids, the atoms, even the nuclei inside of my finger.

INTERVIEWER: All right.

BITTER: But now how do you find out what's going on inside? The point is that each atom is made up of tiny little magnets. And each one vibrates in a particularly characteristic way and sends us, in this way, signals as to what's going on inside.

INTERVIEWER: But then why do you need such big magnets?

BITTER: Well if I'm examining a situation with various tools, for example if I'm examining my finger with a lens here, I can go just so far. But then if I want to go further, I need better tools. And this is a better tool than the magnets we've had.

INTERVIEWER: I see. These very large magnetic fields require proportionately large amounts of electric current to generate them. And yet over the past few years, there has been a real breakthrough in magnet design which allows for very high fields with relatively little current.

The phenomenon is called superconductivity. And it's a term that you'll be hearing more about in the next few months. Dr. Bitter, would you explain what superconductivity is?

BITTER: Well, the details are very difficult to explain. But the facts are simple. If you take a piece of wire and put a current through it, you need a voltage to drive the current. Because there is resistance to the flow of the current through the conductor. Except in certain metals and alloys at very low temperatures for reasons which have only recently been clarified, you need no such force to drive the current. The current will flow by itself.

INTERVIEWER: Almost no resistance, then.

BITTER: That's right. There is no electrical resistance. And so there is no heat effect. And this, although it's been known for many decades, was not of very great interest because the magnitudes of the currents that could be used in such known superconductors was small.

But recently, it's been discovered that in certain alloys, you can send very great currents in the presence of high magnetic fields. And this opens up a whole new area of technology which will greatly supplement what we are doing here.

INTERVIEWER: Very good. Thank you, Dr. Bitter. These very precise magnetic tools we've been talking about hold great promise for one of the most exciting areas in the application of high magnetic fields. This new area is the area of biomagnetics, magnetic research with living systems.

Pioneer work on several aspects of biomagnetics has been done this past year. But one of the most promising seems to be in the further development of the electron microscope. Now this microscope is the foundation of all modern medicine. Without it, we would not even see such deadly germs as some of the viruses like the polio viruses.

There are lots of these deadly germs that we can see with the electron microscope. Dr. H. Fernandez-Moran, of the Massachusetts General Hospital, is a very special kind of doctor. He's a biologist and an electron microscopist. That is to say he works with one of the most powerful microscopes yet designed to do basic research on the fundamental nature of living things.

He has conceived of a possible way to use new superconducting magnets to make an electron microscope of even higher power and precision. Dr. Moran, will you tell us about your microscopic work, please?

FERNANDEZ-MORAN: Actually, electron microscopes, which use electromagnets primarily to focus electrons, are but one of the many analytical tools for basic biological research which will become available with increased knowledge in high magnetic fields. The electron microscope has already permitted us to extend the useful magnification of microscopy to magnifications of about a million times. For example, in a virus, it is now possible, like in this bacterial virus, to pinpoint many of the larger molecules which play a role in its function.

The electron microscope inherently should go much further if it were not for the fact that the lenses are imperfect ones. And now with the possibility, for example, of the new superconducting high field lenses which are completely stable, as has been demonstrated, among others, by Dr. Autler here at the Lincoln Labs, it should be possible to design microscopes which will go down to the limits of resolution of the present art and permit us to see the details of molecules and even certain parts of atoms and imperfections of atoms in bodies.

INTERVIEWER: Now in addition to this fundamental work, there has been a small but extremely intriguing body of work done on the direct application of high magnetic fields to living things. Papers have been published about the effect of high fields on longevity, on cancer, on psychotic disturbances-- on body tissues generally. Most of this work is still too new to make any but the most general speculations about it. But we'd like to know what this work is and what you see in it for the future.

FERNANDEZ-MORAN: Well it's very interesting work. It's still highly preliminary. In fact, at the forthcoming high field magnetic conference to be held at MIT, the first coherent account will be given of some of this work. It ranges all the way from the effect of weak fields, the Earth's magnetic fields on orientation in animals, from snails to pigeons, to some very recent correlation between the admission of psychotics and disturbances in the Earth's magnetic field.

It's still too early to evaluate this. But one thing is certain, that high magnetic fields will play a great role in all biological sciences. In medicine, for instance, one can already foresee the use of these fields for focusing electron beams in the destruction of certain cancers in localized regions of the body or the use of superconducting magnetic shields to protect man against the radiation belts he is likely to encounter when he ventures out into space. It's a whole order of magnitude of tools that we now have in an area which in the past has shown such a capacity for fruitful interaction between the various disciplines.

INTERVIEWER: Thank you very much, Dr. Moran. Now all this work owes a great part of its existence to the Air Force Office of Scientific Research, which is providing complete financial support for the laboratory. Armed forces-sponsored research has been the subject of considerable controversy. It's been attacked from at least two sides.

On the one hand, people say armed forces-sponsored research is tainted research, tied down to military projects, not free to follow the research wherever it leads. On the other hand, people say the government has no business spending the taxpayers' money on projects that just might not pan out. We've heard Dr. Lax's view about this first objection.

He described his relations with the Air Force as very satisfactory from the scientist's point of view. But my next guest is Dr. Max Swerdlow, Project Scientist in charge of the National Magnets Laboratory for the Air Force Office of Scientific Research. Mr. Swerdlow, will you answer the second objection, why does the Air Force spend money on basic research anyway?

SWERDLOW: Well normally, I should become annoyed at a question like that. You mentioned something about tainted research. I would say it's not tainted. It's very much needed. The Air Force is a technological organization.

It's basing its entire superiority in aerospace upon its exploitations of technology as we know it. It draws from this larger reservoir of knowledge, generally called basic research. It should pay some of it back if you want to look at it on just a direct consumer point of view.

Conservation of our resources-- these resources are materials. They're human resources. They're energy sources. Now Dr. Lax has indicated to you how important and how profound the use of a high magnetic field may be in understanding the behavior of solids and matter in general.

We're very much concerned about this. Because the more we understand about materials, the better uses we can put them to. For example, the little simple crystal that is the basis for the transistor is just a little nearly perfect arrangement of atoms of germanium. But it has revolutionized the whole electronics industry.

We can now have a whole radio station put into a small aircraft and flown simply because of the reduction in weight. And consequences like this can make profound changes in our whole weapons systems plans. The DEW line, the Distant Early Warning station that are locating radars up around the Arctic Circle, was an awful job to install and maintain. With the use of new electronic sensing devices, known as a maser, which is a very--

LITTLE: What is a maser?

SWERDLOW: Well, it's an acronym.

INTERVIEWER: In two words.

SWERDLOW: It's a simple little device based on a crystal of aluminum oxide that can sense very weak signals and amplify these signals in such a way so that the static or the noise associated with these weak signals are kept in the background. And if we had maser up at the DEW line, we could eliminate one out of every 9 if only the maser were three times as sensitive as the present radar set. We could scan 27 times more space with them. So you can see that these things have long reaching and very important economic effects as well as military.

INTERVIEWER: True. Well thank you very much, Mr. Swerdlow. This has been very interesting indeed. Now we have a very good background for the exciting work that's sure to be coming out of the National Magnet Laboratory.

But next week, the MIT Science Reporter turns to a very different problem, the bleak poverty and ignorance which causes up to 1/2 the children in Central America and other developing parts of the world to die between the ages of one and five from malnutrition. My guest will be Dr. Nevin Scrimshaw, head of the Department of Nutrition, Food Science and Technology at MIT. And for 12 years, he's been head of the Institute for Nutrition in South America and Panama.

Dr. Scrimshaw let the work in INCAP developing a protein enriched flour. Incaparina, it was called. Some say that it's a food for the hungry angels of the world.

PRESENTER: This has been WGBH videotape production.