INTERVIEWER: Today is July 16, 2010. I am Karen Arenson.

We are speaking today with Claude Canizares, the vice president for research at MIT, as well as associate provost, and Bruno Rossi professor of physics.

Claude has overall responsibility for research activity and policy at MIT, and oversees more than a dozen interdisciplinary research labs and centers. Including the MIT Lincoln Laboratory, the Broad Institute, and Haystack observatory, as well as centers that focus on nanotechnology, magnets, and health sciences, to name just a few.

He also heads MIT's research policy committee and is associate director of the Chandra X-Ray Observatory Center, and a principle investigator on NASA's Chandra X-Ray Observatory. He formerly headed MIT's Center for Space Research, now the Kavli Institute for Astrophysics and Space Research.

Claude, welcome and thank you for talking with us this morning.

CANIZARES: Thank you. It's a pleasure.

INTERVIEWER: America's fascination with space has changed over the years. What was it like when you started your research and how would you describe it now?

CANIZARES: Well, I started my research in space astronomy and astrophysics, actually, just as I left graduate school, since my graduate studies were in elementary particle physics. It was really one of the most exciting times, I think, still in space exploration. Because it was in the early 1970s, and it was really the beginning, in many ways, of the explosion of scientific satellites going into low earth orbit, and in fact, out into the solar system.

So everything was a discovery. I mean every week would bring some new surprise. Of course, in those days we weren't receiving emails and instant tweets on whatever might be the latest discovery. We'd have to wait for the mailman to bring the latest issue of the *Astrophysical Journal* or a batch of pre-prints. When those came, the first thing you would do is grab it and open it up and look and see what surprise had been found. So it was a great time.

INTERVIEWER: America was pouring a lot of money into space research at that point?

CANIZARES: It was a significant amount of money. Of course, we'd come off the peak of the Apollo program, which was a time when -- it's still the time when the US spent more on civilian space activities than it has since. That was the apotheosis in certainly a budgetary sense and in the sense of the sort of public engagement in what we were doing. But it being actually quite strategic and spending significant amounts of research funds, but doing it, I think, quite wisely.

There was a series of campaigns in various parts of the sort of spectrum of possibilities for space exploration. And MIT, of course, was very much in the middle of several of those. That was one of the reasons why it was so exciting. It was happening all around us -- in the Center for Space Research and in our collaborations with people at the Harvard Smithsonian Center for Astrophysics up the street, and other collaborators that we were working with.

INTERVIEWER: Given that you had focused on particle physics and then moved, was there a sort of eureka moment that made you think, ah, this is really what I want to focus on? Did you wake up one day and suddenly say the skies?

CANIZARES: It would be romantic to have such a thing. I could probably make one up if I wanted to. But the truth is more prosaic. I had been very interested in particle physics starting in undergraduate days and went through graduate school doing that. But during that time the nature the field changed, and my interests sort of wandered. I realized that I wasn't so sure I wanted to work in that area.

While it's still a very exciting area, it's one that got centered in a few very large laboratories, none of which were in Cambridge. It would involve going either to FermiLab in Illinois, or SLAC in California, or CERN in Switzerland, and working in very, very large teams. So the sociology of the field was less attractive, and also at that point the field had kind of stagnated a little bit. Nobody really knew what experiments to do. It was in a difficult stage. The quark had not quite been definitively discovered at that point.

So I started looking around for other things that I might do. It happened to be a time, it was very difficult for a PhD physicist to get a job. It's probably the lowest point in the history of employment. So I looked around for a variety of things that I thought might be attractive, and I was extraordinarily lucky that George Clark, here at MIT, was at that point engaged in some new satellite experiments that he wanted to build. He interviewed me, and I was almost going to accept a job somewhere else, and decided at the last minute to give him one more call. He said well, why don't you come down and see me one more time and he offered me a job. So it was serendipity as much as design.

INTERVIEWER: But the process of looking around, which is something I think lots of people experience, how did you go about it? Did you read, or did you talk to professors up at Harvard?

CANIZARES: Well, I did. So I was a graduate student at Harvard and an undergraduate. I had some very good years there. My own advisor knew nothing about sort of cosmic ray or space physics. But he sent me to see another MIT alum, actually, Giovanni Fazio, who was at the Smithsonian Astrophysical Observatory. Giovanni, whom I've gotten to know now, is a good friend and just a wonderful human being, was incredibly generous in speaking to me and giving me suggestions about whom to write to, and even allowing me to mention that he had sent me there.

Because at that point, I mean I probably sent out easily 100 letters. The majority of which were never answered. But the fact that he let me put his name in there probably made a few people read through it to the end at least that might not otherwise have done it. So mentorship was very important in that sense. And then he didn't know me from Adam, but he was very generous.

INTERVIEWER: And he connected you to George Clark?

CANIZARES: George was one of the people that he had suggested I talk to. So then I came down and met with him once, and then I never heard from him and he didn't get back to me until I called one more time and I said look, I have to accept this job, which was actually in a slightly different field, it was in cosmic ray physics -- doing experiments on the detection of cosmic rays deep underground in a mine in Utah. So that would have been a very different future for me, I think, if I had to take that fork in the road.

INTERVIEWER: If young people were to ask you today whether they should enter astrophysics now, what would you tell them?

CANIZARES: I still think astrophysics is -- in fact, now in some ways it's an even more exciting place in some respects. In others it's actually difficult. I'm not so enthralled with the way NASA has been conducting space science these days. I think the pace of new projects has slowed somewhat. So I'm concerned about that.

On the other hand, intellectually, we couldn't be at a more exciting place. The discoveries of a whole variety of, both on the ground, but particularly in space, have allowed us to talk about things like cosmology, the whole evolution of the universe with the word precision. In the old days precision cosmology would have been an oxymoron because we didn't know the age of the universe to at least a factor of two, if not more. And a lot of other properties of the universe we didn't know to a factor of 100. Now we are talking about those things with accuracies of two or three significant figures.

So, the understanding of the content of the universe and its evolution has really leap-frogged in the last, I'd say two decades. So, it's a very exciting time. But one has to be, again, somewhat strategic in choosing areas, and in finding one's place in this. Because the funding situation right now across the world is a little difficult. But when I came out of graduate school, as I said, it was very, very hard to get a job. It wasn't obvious at that point that there was a future. I was thinking of the possibly that I might go into industry rather than academia because of that. So there are ups and downs all the time. I would say follow your passion. If you have the passion, then really follow it. Certainly people at MIT will have the option to create their careers.

INTERVIEWER: It sounds like when you were graduating with your doctorate, that what you were passionate about maybe was the research process and science more than the particle physics per se?

CANIZARES: That's very perceptive, because I think that is really exactly the case. I've always had rather broad interests, and even in my general field of X-ray astonomy and astronomy generally. I have not been one of those to bore down in exactly one area and become the world's expert on supernova explosions or some such thing. Rather I've tended to move around, or, in fact, simultaneously work in several different fields. I sometimes tell my students that I have intellectual attention deficit disorder because I'm not content to just stay in one area. I love digging into something at one point, but then at some point something else attracts my attention and I like to be able to work in that.

One of the wonderful things about MIT is the fact that it's a very intellectually open environment. You can go and talk to people about their work, and sometimes get invited in and sometimes collaborate just on the basis of casual conversations rather than which department and school are you a member of, or what degree do you have. So that has been something that also characterizes what I do.

So when I finished particle physics -- I mean not finished, but when I decided that was probably not where I wanted to continue my career, I had a number of things that looked interesting. It was kind of a mixture of opportunity and a demand side and supply side, so to speak, and I was looking for the right connection there. I think I was extraordinarily fortunate to come into a field that was so exciting. I think if I'd ended up in that mine in Utah, it probably would not have been as exciting and I would have ended up doing something else in the long run anyway.

INTERVIEWER: So was becoming vice president for research at MIT like being handed a candy store? Are you the kid in the candy store--?

CANIZARES: Well, in many ways that's exactly right. So over time, my sphere of regard, if you like, has increased. As the director of the Center for Space Research, I got to interact, again, with a wider group of people, and I spent a lot of time on various committees in Washington, and so forth, like the Space Studies Board of the National Academies of Sciences and the NASA Advisory Counsel. So in each of those cases, there I progressively got to think about and interact with people from all across the space sciences. Not only NASA, actually, also NOAA and other agencies.

Then when I went into the central administration, first as associate provost, and then as vice president for research and associate provost, each time I'm learning more and more about MIT. One of the things I will say that I enjoyed about MIT is this openness that I was describing before -- another thing I started doing fairly early in my academic career was getting on some Institute-wide committees. That got me to know and to become, actually in some cases, close friends with faculty from all different departments and schools.

That was the start maybe of another place where I had broader horizons and realized that I enjoyed that kind of interaction. Being vice president for research is, for me, the best job in the world in many ways because I get to see the whole scope of wonderful discoveries. I can tell you, I learn something new every day. Usually more than one thing.

INTERVIEWER: So as VP for research, what do you actually do on a day-to-day or week-to-week basis?

CANIZARES: Well, there's a long list of things I can tell you. Mostly I have meetings non-stop from morning till night, and then sometimes dinners or evening meetings as well. More to the point, I deal with things in several different buckets, but then there's a distribution of them. So I have some line management responsibilities for the research labs and centers, particularly those that are interdisciplinary and cross schools. Frankly, we have an excellent cadre of directors of these labs and centers. They operate very well. But there's a continual need at various times for my participation in decisions or in oversight.

Then there's the area of research policy, and these days a lot of that involves things around technology transfer, conflict of interest in the starting of new companies, for example. We are very active in that area. And there's a huge interest in Washington for a whole set of policy issues that intersect with MIT, these days particularly around innovation.

With the economy in the condition that it's in, there are many people in Washington looking very much to MIT as probably the outstanding model, not just in the country but in the world, for a university that can transfer the fruits of its knowledge to the corporate sector in the economy in the most effective way. They would like us to help them transfer this to other places and to do it more actively ourselves. So, I spend a lot of time on those activities, both within MIT, and outside on national committees. I'm on several simultaneously.

Then there's just the general issue of relationships with our research sponsors, both corporate industrial sponsors, and we have, again, compared to most universities, we are really outstanding in our ability to engage industrial sponsors. Not just to get their money, which of course is important to keep the research activity going, but to have their interest and involvement so that our students and faculty understand what are the leading issues that are important to them, so that the research -- not to direct the research on a detailed basis, but to make sure it's operating in a direction that can be of use and have impact on them.

Then, of course, our federal sponsors, still over 70 percent of our research funding comes from the federal government. There's a continual need to just maintain our relationships with federal agencies. So those are some of the broad areas, and then within those, of course, we could get down into the weeds, but I don't think you want to do that.

INTERVIEWER: It sounds like four or five jobs in one.

CANIZARES: As I said, it's great for someone with attention deficit disorder, because I can always jump from one to other whenever I get bored.

INTERVIEWER: Do you sleep?

CANIZARES: Well, these days one of the other things we're doing is a lot of international engagements. A number of the major ones report to me, or at least in their establishment I play a role. So, in fact, I've just gotten back from three separate overseas trips. So that's a fair point. I don't always sleep very well.

INTERVIEWER: Where were you visiting?

CANIZARES: We had a delegation travel to Russia at the beginning of June. Then I had a short trip to Italy for one of our corporate sponsors. And then came back, and then I had a trip to Singapore where we have established for the first time, a significant research center outside of 02139.

INTERVIEWER: Where there any surprises on these trips?

CANIZARES: The trip to Russia was fascinating. There's another case of where I think there's a group of -- an economy and a government that recognizes that they really need to try to understand how places like MIT, and Stanford is the other leading example, have research universities that engage with the marketplace, in a sense, and the commercial world.

So, I found it quite fascinating to see what is effectively in many ways a highly developed country with a very educated population. But it's also a developing country because of the state of their economy. Their economy is really dominated by oil and gas. They're trying to figure out how to move that into the 21st century with more of a knowledge economy. They're looking to MIT for advice and help, and we're thinking about whether that's a good idea or how we could engage effectively.

INTERVIEWER: How well does MIT understand this process of spurring economies? Is there a belief that more can be done, either here or in Russia or anywhere else?

CANIZARES: Well, the answer to the second question first, yes. I think there's a strong feeling that there are specific things that can be done. But to the extent of how well we understand it ourselves -- I think there are people here who thought quite a bit about it. Richard Lester being one, for example, in the industrial performance center. Suzanne Berger, Fiona Harrison and Ed Roberts in the entrepreneurship center. So that's part of our entrepreneurial ecosystem, as we like to call it. I think it would be great. I'd love to have someone do an even more comprehensive study of it -- it's something that we might think about.

But MIT, I think there's also a feeling that it's not going to be easy for other places to just become an MIT, and there are many people who've started -- the India institutes of technology were started, the Europeans have talked about starting a European MIT, and they've created something now which is more of a virtual university, in a sense, that tries to achieve some of that. There's a lot of culture here that goes back a long way, and that's hard to create anywhere.

But I think one could certainly stimulate a lot of things. And there are places that have done that in very specific areas. There are some regions around the United States -- you think of Austin, Texas. Even Akron, Ohio, which may be surprising, but they've focused in a specific area, more so than biotech. So people have tried to find at least some mechanisms to foster some of the things that happen at MIT. We're very lucky here that it happens really across the board.

INTERVIEWER: Do you think that kind of focus moved MIT from where it's been in terms of basic research into something that's more applied? Does the balance shift?

CANIZARES: Well, I think there's been a little bit of a shift of balance maybe. But one of the things, and I'm glad you mention that, because one of the things that I feel is very important is that we not lose sight. After all, my field is probably -- we're very firmly in the basic research area. While we talk a lot about the excitement that happens at the interdisciplinary boundaries, I don't think you can have an interdisciplinary boundary if you don't have a discipline to start with.

So, in fact, that discipline has to be very firmly grounded. So, I think that's one of the challenges for us is to make sure that we maintain the balance effectively. That said, I think there's no question that, for a variety of reasons -- some of them intellectual, just the evolution of fields, and some of them externally driven by the economy and the recognition that in a sense it's time--. In World War II, it was recognized that it was time for the science and technology community to stand up and try to help the world.

I think while that's always true, and MIT has done that continuously, I think there is again sort of a sense of a global imperative, in terms of energy and environment, and in terms of human health and the vast population of the world that's still living on $1.00 and $2.00 a day. That spirit is very strong here at MIT, both among the students, and among the faculty.

So if you look at the energy initiative as an example, there are now some 250 faculty, a quarter of our faculty, who are in some ways engaged in the energy initiative. People who 15 years ago if you ask them do you work on energy, they'd say no. And now they're recognizing that some of their skills and their abilities and their interest can be focused on this activity. So it is a bit more of a shift. That's happening in the School of Science, and in the School of Humanities, Arts and Social Sciences, not just in the School of Engineering. But as I say, at the same time we've got to make sure that the basic research and the foundations of the our disciplines remain strong as well. Otherwise, we're likely to drift off. I don't think that's going to happen. I'm not worried that that's--.

INTERVIEWER: Well, there are certainly interesting discussions and debates going on in the higher ed community more broadly, and within MIT about whether to shift, say, the undergraduate education. If you look at Engineering Systems Division where they say well, maybe they don't need quite as much mechanical engineering or aero and astro and they should have a little bit more education in terms of political science or economics or management. In research it's common, I guess, to organize around problems and to have the interdisciplinary approach. But the question of how to get your discipline in the education of students, and yet to tackle these problems seems to be a harder one to figure out.

CANIZARES: No, I think this is a continual process of readjustment and renewal. I don't think it's a revolution, at least from my point I would say that it's not that we need to throw out all the old ways of doing things and do something new. I think it needs evolution. One of the things that really made MIT sort of stand out was a recognition now over 50 years ago of the need to have an engineering curriculum that was strongly based in the disciplines, the sort of engineering sciences it's called. That really transformed, in some ways, engineering education.

I think there are many people who feel -- and I'm not an engineer, so I'm speaking very much out of school here -- but there are people who feel that engineering has a lot of aspects of it which are not entirely just the technical ones. They're social, economic. And that the systems view, for example, that the Engineering Systems Division has, is an important thing for every engineer to have. I think the school of engineering has already adapted to that in many ways.

Many of our students take courses in the Sloan School, for example. Just several courses in management, recognizing that that's going to be part of their future as well. Just putting a writing requirement in, which we did decades ago, was a recognition that writing equations alone is not going to make an engineer or a scientist successful. That they have to be able to express themselves in language.

So I think all that's part of the same continual adjustment of our curriculum. I spent my undergraduate and graduate years at Harvard and I still have many colleagues and friends there. I'm interacting with people at Harvard almost three times a week on a typical -- for one thing or another. Nonetheless, I see a significant difference in the institutions. When I was at Harvard, I took a course from David Riesman, the great sociologist. He had these categories. He talked about tradition-bound and other-directed and inner-directed -- talking about individuals.

But in terms of institutions, Harvard is a very tradition-bound institution for good reason. It has a long and distinguished tradition. But I used to characterize the difference between us is that when you're at Harvard and you say I'd like to do something new, there would be more of a tendency for people to say well, we've done it this way for 336 years, at least when I was an undergraduate, now it's been more years. Why? Let's examine that one, I'm not sure we should do something new. At MIT you say let's do something new, they say, oh that's great, what is it, let's try it. That means that we're always very willing to renew ourselves and to optimize -- maybe too willing sometimes. But we run experiments. We are experimenters. So running an experiment is absolutely in our blood, and that's a great thing about this institution.

INTERVIEWER: As vice president for research at one of the world's top research universities, do you wake up every morning thinking about MIT's opportunities and responsibilities to solve the world's problems?

CANIZARES: That is very much on, not just my mind, but I would say the mind of our administration. Certainly, Susan Hockfield, I was in a meeting with her yesterday. We were talking about some of these exact same things with a number of faculty. I think MIT in the fabric has a strong sense of a duty and an obligation and a responsibility for really making an impact on the Nation and the world. We talk about the sort of three pillars of creating new knowledge, transmitting knowledge, namely education, and service. And the service is service to the nation and to the world. We do that in a number of different ways. You've mentioned Lincoln Laboratory, which is really an entity designed to provide service by providing the most advanced technology for National security.

So I think this is very much on people's minds. I spend a lot of time, as I say, on national committees doing studies which are not -- or going to meetings and addressing policy issues, which may be of general interest to MIT or might be a general benefit to MIT or maybe not. But would be important for the country and for the world. I think many of our faculty feel that it's sort of ingrained in the DNA of this place.

INTERVIEWER: Do you have any kind of metric for trying to measure whether MIT is doing better on this front year by year or not, or does one simply dive in and do one's best?

CANIZARES: I wish there were a metric I could look at. Of course, we are both a little suspicious of, but also keep an eye on all the usual metrics of rankings of universities just because perceptions of that sort of thing are important. Our reputation worldwide is absolutely outstanding. Having done a lot of traveling around the world, and having had a lot of people come through Cambridge and ask for meetings and discussions and trying to get relationships with MIT, our reputation is absolutely outstanding. One of the things I would do, I wouldn't say every morning when I wake up, but I think of regularly is when you're on top of the mountain there's only one direction you might go in, which is down, and we don't want that to happen. So I spend a lot of time thinking about what it is we need to do to maintain our position.

I think a lot of the metrics that we look at we do pretty well at. Number of patents filed -- we do better than any other single university in the country. Usually the lists have University of California at the top, but that's because it's all the campuses wrapped together. Total amount of research volume, our success rate, proposals that go into the federal government or elsewhere, our ability to attract both international and industrial and corporate sponsors, we're doing very well on all those things.

INTERVIEWER: Some of those are inputs and not outputs.

CANIZARES: Yeah, those are inputs and not outputs, but they are inputs that would only happen -- they're voluntary inputs, because they would only happen if the output is valuable and it attracts--. One of the most important things is the track record of the investigators when they're writing a proposal. In terms of actually metrics to measure the output, we tend not to look at those very much. We don't look much at -- I never look at citation indices or number of publications. I just assume that that's going to be good. Of course, we look very hard at every promotion and tenure case. I sit on the committee that reviews those and advises the president in the last step of those. So having the top people is the number one thing. We are in the talent business, fundamentally.

INTERVIEWER: It's interesting that you talk about the recognition worldwide of MIT's capabilities and so forth, and yet, before the financial markets crashed, when the endowments were soaring, there were policymakers in Washington, in Massachusetts and elsewhere who were criticizing wealthy research universities for benefiting from their tax exempt status and not giving enough back. It was interesting that a lot of the discussion focused on why isn't education free -- there's the education part. And there was little or no discussion that I can recall of are they giving back in terms of research and service. Why do you think that was? I know it suggested there's a blind spot despite the recognition.

CANIZARES: I spend a lot of time in Washington, DC, and that's where most of this came from, actually. I think there was not that much of it coming, certainly not from our state. I will say the Governor in our -- there may be a legislator here and there who might be on a high horse, but we've had very good relationships with the state government. But in Congress there were a few people, Senator Grassley is an example of somebody who has been on a campaign. I spent enough time in Washington to really respect the people there. At the same time, they are very political animals. They get on sort of populist, sometimes bandwagons that look attractive to them.

I also think that it's possible to lump all universities together, and yet we know that there's a huge variety in universities, and these days there are for-profit universities that have had practices that have come under some scrutiny. And again, I think there's a danger, just as in the financial reform we've just had, of lumping all banks together or all universities together.

So, it is true, I believe, and many of my colleagues, my counterparts whom I talk to regularly at our sort of peer universities, feel that to some extent the compact between universities and the federal Government that was established largely through the efforts of Vannevar Bush after the second World War that really started the federal supported research in universities. But that compact is -- it's certainly not broken, but it's a little tattered and frayed. We think it needs to be restored. I think that exactly the issue of creating the case, and really re-establishing what role these research universities play in the country and how they do provide service and a return for the tax exempt status.

The other side of it though is that these endowments are examples of where the universities have put -- and their alumni and their friends -- have put huge amount of effort and resources into providing something that in the end helps the country, helps the students. It's not that the money is being used to have -- I don't know, to buy jewels, for the president or fast cars for the provost. It's really going into infrastructure and research activities and trying to hire the best faculty and giving them the start-up funds that they need. And all those things are things that then put them in a position to be able to take a research grant from the National Institutes of Health and find a cure for a terrible disease like cancer. So I think our case needs to be made more carefully.

Frankly, one of the things that MIT does also, more than any other, is to spend time in Washington -- our faculty, our president, myself and others, to try to keep going around and talking to people and sending some of these messages. But more work needs to be done.

INTERVIEWER: You mentioned that you think the compact needs to be restored. Do you really think that's possible and that that will happen? Or that it's going to be a matter of just thinking it never will be restored and it's time to move on and nail down the other sources and new models of funding?

CANIZARES: No. First of all, I think the compact is still in place. I think it's, as I say, frayed more than broken. And I think it is possible to make some progress. I mean there's an area which is, one arcane area -- excuse me -- a policy that I've certainly worked a lot on over the last 20 years is export controls. Not something that people normally think of, but it's the regulations that normally you think of protecting us from having people export weapons to third world countries, but actually has an effect on research.

We have worked for -- I and a number of people -- have worked literally for decades to try to get the government to recognize some of the issues associated there. We've had some sporadic progress along the way. We just had the Undersecretary of Defense just issue a letter that helps clarify some things along these lines, and the administration is doing a review.

Now that's not only because of universities. Some industries are very concerned about export controls and they've worked on that as well. But there's an example of sort of a piece of the compact. As I say, we're getting into the weeds. A big issue has to do with indirect costs and how those are reimbursed with the passing of just an increasing number of regulations that restrict how we can operate. Reporting requirements without supporting the infrastructure needed to do those.

So it's sort of the detail level to some extent. But it is also at the philosophical level. It's an understanding of the fact that there really is a mutually beneficial relationship here. I think most people in Washington do believe that. I have never--.

INTERVIEWER: Congress, too?

CANIZARES: Yes, and Congress too.

INTERVIEWER: What makes you think that?

CANIZARES: Well, because I talk to a lot of people there, and I know -- I know what the staff feels, I know what many of the members feel. Susan Hockfield goes and visits a great many members of Congress during the course of a year. And mostly, we've had many come to visit and visit us here. We had President Obama here, recognizing, in a sense, the role that MIT plays, in that case, in energy -- sort of new energy green technologies.

So I think there are many people who understand it. That doesn't mean that you're not going to have somebody who's going to be poking at us. And frankly, as much as I hate to say this, having critics around is not a bad thing either. I think we have to maintain, we have to be vigilant ourselves to make sure that we are fulfilling our end of the bargain at all times.

INTERVIEWER: I think you said that MIT at this point derives about 70 percent of its funding from federal agencies?

CANIZARES: That's right.

INTERVIEWER: That's down from a higher number 20, 40 years ago?

CANIZARES: It's gone actually up and down a little bit over the years. But yes, 10 years ago it was more like 80 percent. So it's been slipping down a little bit, and 20 years ago it might have been 75 percent.

INTERVIEWER: In 10 or 20 years, you think it'll be the same or higher or lower?

CANIZARES: Frankly, I don't think anyone can read the newspaper and not recognize the fact that the federal Government is going to be going through some significant austerity period, the whole country is. And I hope that people realize it more and more and figure out a way to do it sensibly. So I actually think that I would not expect that to be going up a lot in the near future. I think there is a recognition in Washington right now, certainly in the administration and in parts of Congress, but not all, that a lot of the federal research funding is, in fact, something that can drive innovation and help the economy in the long run. But it's not going to help it always in the very short run, and that's a dilemma for them when times are tough.

INTERVIEWER: How successful has MIT been in finding other sources to underwrite research and what kinds of issues are raised in turning to these other sources?

CANIZARES: We've actually been quite successful. And by we, I really mean the faculty, because they're the ones who individually write the proposals. Those of us in the administration do everything that we can to make sure they're aware of all the opportunities, to provide sort of convening power to make things happen. We've done that around some of the opportunities coming out, for example, the Department of Energy recently have been very successful with the federal funding. And when the energy initiative was started, the plan was to look first to industry for funding. So that amount of activity, that was very successful. We raised $250 million for the first five years of the energy initiative from industry before even starting some of these Department of Energy opportunities.

There's a great deal of interest in international circles for partnership with MIT. And so the Singapore-MIT alliance first, and now SMART, which is Singapore-MIT Alliance for Research and Technology are examples, and those are significant sort of sources of funding for us, as well as new opportunities of working in a new place. We have other international activities that we're exploring.

So I think there are other opportunities we have to maintain. The federal Government will still be the most important, and the sort of foundation of our research activities, particularly in the basic sciences, because a lot of these other areas are more interested in a little bit more of the applied research.

The issues are simply that research, with corporate sponsors and foundation research, foundation funding, which is also another area that's grown, and international, all have their own challenges. We have a pretty standard way of dealing with the federal government from a contracting, intellectual property, et cetera, point of view. Every private sponsor is a one-off negotiation, and those are both time-consuming and sometimes raise issues that are difficult to work through, particularly, as I say, in the areas of intellectual property. There's also the issue of conflict of interest, because many of our faculty also consult for companies; one has to be very careful to make sure that we keep MIT pure and isolated in a sense from both the perception and the reality of conflict of interest.

So I spend a significant amount of my time, I think I have two meetings a day on this topic alone.

INTERVIEWER: In 2006 when you became vice president for research, you said one of your goals was to foster an outstanding research environment for MIT's Faculty, students, and staff. How do you define such an environment, and what parts of it do you think work well at this stage and what would you like to change?

CANIZARES: Well, the environment has a lot of different parts of it. Some of it really is, again, the nuts and bolts of research administration, because for our faculty, a lot of -- what we try to do is make it as easy as possible for the faculty to spend as much time on research and education as they can, and less on administration and reporting and filling out progress reports. Unfortunately, a lot of our sponsors and particularly the federal Government has only increased the amount of activity required. So what we try to do is put in place tools and support mechanisms that allow them to do that.

I think we still have progress to be made there. We're working on it a lot. The task force identified recently -- the task force on-- Institute-wide task force that was really driven by our budget concerns, but was recognized as an opportunity to also learn how to do things better. I looked at ways that we could operate more efficiently, and we're going to try to implement those.

Another area, though, is things like research infrastructure. So, in fact, I've spent a lot of time in the last year and a half on a major effort to try to establish a high performance computing center in western Massachusetts where energy costs are a lot lower than they are here in Cambridge, that would provide tools for all those across MIT who need high performance computing to enable them to do their research. So that's another kind of example, and we're working a lot with the Koch Institute on establishing centralized facilities in the life sciences.

So that is another example of the research environment. Of course, then there's just the issue of making sure that our research community, the faculty, and then groups like the postdocs, for whom my office has general responsibility from an Institute-wide perspective have them entering the training that they need and that they deserve.

INTERVIEWER: You mentioned task force recommendations. Were there any in particular that came out that people said, gee, this really will make it a better place?

CANIZARES: I think it was more incremental than having discovered the secret sauce. As I say, I think I've already mentioned they're really mainly issues of greater efficiency and consolidation and trying to--. We now have a whole variety of systems that were sort of home-grown and all the labs and centers were just doing their accounting and proposal preparation. We're trying to get that streamlined so not only will that make it easier for them to submit proposals through our office of sponsored programs, but it will also make it easier for them to collaborate with each other because now they can write a joint proposal and they both have the same software. So little things like that can make actually a significant difference. I wouldn't say that's in the nature of something that is not very attractive or sexy, but it's essential.

INTERVIEWER: And it takes an effort to get there, I guess, too. You may say when you're there, there are efficiencies that'll make your life easier, but first you have to find them out.

CANIZARES: Getting from here to there is not easy. Anybody who's bought a new computer knows that.

INTERVIEWER: You also said when you took this job that you hope to enable major research initiatives that cut across the Institute. Have you been able to do that? MIT's always done some of that.

CANIZARES: Has always done some of that, but we're doing that more than ever. And again, it would be absolutely wrong for me to take more than an iota of credit for this because it's happening. So all I'm trying to do is do what I can to encourage it and foster it. There are two major initiatives that now report to my office that didn't on the day that I took office. Again, one of them being the Energy Initiative, and the other being the Koch Institute for Integrative Cancer Research. Those are two outstanding examples, and our two largest activities across disciplinary boundaries.

So I'll start with the second first. The Koch Institute took our outstanding center for cancer research, with what is it, six Nobel Prizes, and is combining it with, thanks to generosity of David Koch, with a group of outstanding engineers from a whole variety of different departments and putting them in the same center. They're already working together, but when the new building opens at the end of this calendar year, it will be absolutely outstanding. And that convergence of life science with engineering is one of the very exciting things that's happening on campus. And that we're trying to enable, from the central administration, just by helping in any way we can.

The Energy Initiative, while we've had interdisciplinary activities in the past, there's nothing as interdisciplinary as the Energy Initiative. It covers all five schools, and really all five schools. It's not just a tagline, it's the reality. It's brought together people from across the Institute, and students and faculty and staff, not just a selected group of faculty, in ways that are unprecedented. I've been very pleased and proud to be able to make small contributions to help as we can from the center to foster the development of the Energy Initiative.

INTERVIEWER: You mentioned the postdocs end up on your plate. Are there parts of your experience as a postdoc that help you think of things you want to do on that front? How do you encourage mentorships? Isn't that something that's hard to make happen -- the chemistry between two people?

CANIZARES: It is hard. First of all, I came to MIT as a postdoc, and they were some of the most exciting years that I spent here. So I think it's a great period for a young scholar. I think the postdocs still are somewhat the neglected population at MIT. The numbers have grown very considerably. And now, a very significant fraction of our postdocs are international students, or international visitors, which gives them additional sort of social adjustment that's needed. I think we need to do more. So that's an area, since you've asked where I think more attention is needed, I think we really need to do more there.

INTERVIEWER: Let's back up and talk about how you came to MIT and your life until then. Where were you born? Where did you grow up?

CANIZARES: I was born in Tucson, Arizona, but that was an accident of where my family happened to be at the time. My father was stationed there during the very end of the second World War. So I really grew up in New York or in the near suburbs of New York, in Yonkers, and my father worked in Manhattan. So I consider myself at least an honorary Manhattanite. I spent a lot of time there.

INTERVIEWER: What did your parents do?

CANIZARES: My father was a physician, a dermatologist, a clinician, but always very interested in research. He ended up writing a number of books, including a major textbook on clinical tropical dermatology. So I always think of him spending pretty much every weekend with a legal yellow pad, writing, and wrote many articles. So he set a good example, in a way, for scholarship, even though he was also very much a clinician and had an active practice in Manhattan, and visiting physician at several hospitals in New York.

INTERVIEWER: And your mother?

CANIZARES: My mother was an artist of -- she was a commercial artist part of her life, but that was I think just to help to support the family. She was a fine artist and an art teacher. Informal, she had art classes that she taught out of our basement for decades. And worked in a variety of media, but watercolors and oils were her sort of mainstays. She got into graphics later in her life. So that was actually a nice combination of science and art. She also helped my father a lot. He had a lot of activities involved in the writing of his papers, but also in organizing some societies. He created a society for tropical dermatology, he focused on third world countries. He was born in Cuba, so we always had a lot of connections and interest in Latin America, which then also spread to southeast Asia. He had connections in Thailand, spent some time there for the World Health Organization.

So she would help him a lot in organizing these societies and they had contacts all over the world. The house was always full of international visitors that would come and stay -- they couldn't always afford the high prices of New York hotels. So it was a very interesting environment in which to grow up.

INTERVIEWER: And your mother was an immigrant, too, wasn't she?

CANIZARES: Yes. My parents met in Paris. My mother's family was, I guess you'd say, evacuating, if not escaping, Germany. Her family's Jewish, and my grandfather, her father, was very prescient and decided in 1931 that it was time to get out. Then they lived in Amsterdam then Paris. In Paris she met my father. They decided to get married, but they were not married yet, and my grandfather had arranged for his family to come to New York. And so my father followed and my parents were married by a Justice of the Peace in lower Manhattan.

INTERVIEWER: What language did they speak at home?

CANIZARES: They met because my mother was studying art and was very interested in Spanish art and wanted to learn Spanish. She already spoke Dutch, German and French, so this was not a hard thing for her to add. And my father had to pass the German exam. He was studying medicine at the Sorbonne, at the University of Paris. So they met because there was a language exchange. She taught him German, which he had enough to pass his exam and promptly forgot. And she was fluent in Spanish.

By the time I was born, they were speaking English fluently -- that was the language at home. But both my parents decided that, my older brother and I and then later my younger sister, should learn Spanish. So we had this tradition of trying to speak Spanish only at home. Certainly at dinner time, our dinner table conversations, which were lively, were only to be conducted in Spanish. My Spanish got a little rusty after I started going to school, but it's still serviceable after a tune up, when/if I go to a Spanish-speaking country.

INTERVIEWER: Were you interested in science as a child?

CANIZARES: I was always interested in science and things, I remember early. Not so much chemistry. I had a chemistry set, but chemistry always baffled me a little bit more. I liked electronics and things like that. So later, physics seemed like a natural--. And when I was probably, I can't even remember now, I must have been maybe eight years old, I had a neighbor who was retired, a Bell telephone engineer who was a ham radio operator. I got friendly with him, and he basically taught me all kinds of things about electronics and hand radio, and I became a ham radio operator and built a lot of equipment.

Spent a lot of time -- more time building and tinkering and trying to get things to work than actually talking to people around the world. But that was my real introduction I'd say. So I initially thought I wanted to be an electrical engineer, electronics engineer. I worked for several summers for the company of a neighbor and friend who was a guy named Jack Whitehead, who later endowed Whitehead Institute at MIT. He had a company called Technicon. I worked in their own electronics shop, and discovered I probably didn't want to be an electronics engineer. But I was getting interested in physics at that time. So when I started applying to schools, I applied in physics.

INTERVIEWER: Did you consider becoming a doctor? Sometimes children of doctors--.

CANIZARES: I really didn't. I spent some time with my father -- I totally admired what my father did, but I think I felt more at home with mathematics and sort of what's sometimes called the harder sciences and physical sciences than the life sciences. So I never really felt myself drawn very much in that direction.

INTERVIEWER: How did you decide where to go to college?

CANIZARES: I was lucky to have gone to a rather good private school in Tarrytown, New York, the Hackley school, which was excellent for me. The motivation was that my parents were rather taken aback when the public schools, which were not too bad in my neighborhood, went on half session because of the baby boom. So we were going to get cut down to a half day of school and they thought that was not -- or what seemed to them like a half day of school. They thought that was not sufficient. So they looked for a place for us to go, and Hackley was a great place for me. It was not that strong in the sciences, interestingly enough, although we had a terrific chemistry teacher.

But I was in a good position to apply to the top schools. So I applied to Harvard, Princeton, Yale, MIT, and others. I remember my interview at MIT at the time. MIT was to techie for me, to be honest. And I went up the street to Harvard and visited them and that felt much more comfortable, because I was very interested in history. I had taken a terrific Shakespeare course and was really interested in following that up. Harry Levin, the great Shakespeare scholar, was at Harvard at the time. I had used his book in high school and this was like a terrific thing for me. Oscar Handlin, the wonderful historian, I became friends with later, he and his son.

So MIT's changed tremendously from that time. So, although you haven't asked me, I'll answer the question of how it's changed.

We had a much more rigid curriculum at the time that I was applying to college. I remember the admissions director saying that well, some people take as much as -- almost like saying that it would be a shocking thing to do, but permissible to take as much of half of your courses that are not in science and math. And I was still interested in a science-based, liberal education. So that seemed -- I wanted to have lots of other opportunities. Now MIT is much more open. It's much more diverse -- the student body is much more diverse.

At the time that I applied, I remember the college handbook said there were 4,000 or so students of which 123 I think were women. That was not that appealing to me. Now, of course, it's transformed. I feel that I've helped in very small ways to at least help some of that transformation. I was on the search committee for a new admissions director, and one of the things early on in my career here, and one of the things that we wanted very much was someone who was devoted to expanding the range of undergraduates.

INTERVIEWER: Mike Behnke?

CANIZARES: It was Mike Behnke who was the one we hired in the end, that's right.

INTERVIEWER: What was it like to be a science major at Harvard? How was it when you actually got there?

CANIZARES: Well, that's an interesting question. It was fine, but it was different. I lived in the Harvard houses, of course, and very few of them -- in fact, I would say almost none of my friends were science majors. Most of my good friends were historians and architects -- turned out to be architects later, or majoring in English. I had a few friends who were scientists, but not too many. So, I felt very much at home in some ways. Not in others. There are parts of Harvard that even now I don't find that attractive.

At the time, things like the final clubs, I thought were kind of a throwback to a previous century, now two centuries. But I loved the intellectual environment, the stimulation. I think the houses are great, and I know we're working here at MIT to try to create more community for our undergraduates, if not identical, at least have some of those positive aspects. But that said, the other thing, though, is there were just some great faculty in the sciences, and I admired them greatly and enjoyed interacting with them to the extent I could.

My own advisor, so as an undergraduate, Harvard, of course, didn't have anything like the UROP program. Actually MIT didn't either at that stage. But I was able as an undergraduate to just talk my way into a research group in physics, and I spent a lot of time with the graduates, more with the graduate students, but some with the faculty working on research projects as an undergraduate.

INTERVIEWER: In particle physics?

CANIZARES: In particle physics.

INTERVIEWER: Because you knew you were interested, or you got interested because that was where you--?

CANIZARES: No, I knew I was interested. I was interested in particle physics at the time. As I started learning about the atom and quantum mechanics and the nucleus, the idea that you could actually study things at that scale. I guess I always like extremes, right. I think when I came to MIT I went from studying the very smallest submicroscopic constituents of the proton -- my thesis was actually, my PhD thesis was actually essentially talking about the structure of the proton, to studying the largest things in the universe. Clusters of galaxies and the large scale structure of the universe. So it's just the middle stage that I kind of avoid.

Actually, I will correct that. It's not that I avoid that. Actually, all the things that I've done have actually focused on not just the technology and the technical aspects of it, but also the organization of people to conduct those scientific experiments. And the interaction with others is really one of the things that I -- I consider science primarily, actually, a human endeavor, not some abstract thing that takes place without humans. So that part actually appeals to me as well. I find that I've -- maybe that's why I ended up in administration, because, of course, that's very much a human endeavor.

INTERVIEWER: Were you a student leader? Were you active in student government in high school or college?

CANIZARES: Not so much government, but more activities. I tend to like projects. So I was editor of the newspaper in high school and captain of the debating team in high school. So I would tend to join organizations that did things, and then somehow would end up in some kind of a leadership position in those. So I think it was fairly natural that I would end up in areas of science that required some kind of human interaction, as opposed to, say, being a sort of lone--. These days, of course, there are very few areas of science that involve just a single investigator without anybody else. At minimum you have a group of graduate students or postdocs, and more typically, collaborators around the university or across the world.

In my case, dealing with first, high energy physics, where I had a fairly large group at that time. I think there were 10 students and postdocs working together, and our faculty supervisor, obviously. Then later going to satellite projects where our teams were a dozen or two people, but you're really dealing with thousands of people by the time you're actually building a large scale, massive project. That's part of the challenge and part of the fun.

One of the things that I sort of have felt all my life is that I end up with these projects where not only are they fairly long time scale -- building a satellite takes a long time. There's sort of delayed gratification, if you like. Then but secondly, there's also a risk factor that you don't tend to have in terrestrial experiments. I mean it's possible that an experiment will fail, but in the case of a satellite it's possible it'll blow up and never make it to orbit.

So, I learned a long time ago that it was really important to not just think about the end point but to enjoy the journey, because there was at least some probability, however small, that the journey's all you're going to get out of it. And that's helped me a lot, because some of these journeys have been very long before gratification. I've been lucky, though, that they've also tended to be fairly successful.

INTERVIEWER: Were you involved in activities at Harvard as well? The newspaper or debates?

CANIZARES: At Harvard, because I happened to have a friend who had gone to Harvard a year or two before, got me involved in the radio station, WHRB. So I got engaged in that. Interestingly, I wasn't so much engaged in the technical parts. It was I ended up as the director of the news and public affairs. We did a lot of interview shows or newscasts. We had a regular show where we had the Nieman Fellows who were journalists who come and spend a year at Harvard. It was called Nieman Fellows View The News, and they would come in and opine on whatever the--. This is before there were that many talk shows on television. We were ahead of our time. That was a lot of fun.

I spent a lot of time at the radio station working on just general organization, but also news-- I was sitting in the radio station one day when -- we had a teletype in those days that would ring bells, and I think it was supposed to be like three bells was a major story and five bells was disaster. At one point the bells were just ringing continuously. I literally remember looking at the teletype -- it was in the closet, because it was noisy -- and said Kennedy had just been shot. So that was my freshman year at Harvard.

INTERVIEWER: What made you decide to continue on for the doctorate?

CANIZARES: At that point I was putting one foot in front of the other and just walking down the path. By the time I got into physics as an undergraduate, I was just convinced that this is what I wanted to do, and I wanted to continue on a research career, presumably in academia, although I thought a little bit about going into industry or going to a research laboratory, a national laboratory type setting. But I liked the academic life very much. I think I'd always thought of myself -- at one time I thought I might want to be a historian.

As I say, I've had sort of a broader tastes-- I always loved to read history and enjoyed it when I was in high school. But if I had done that, it would also probably have been as an academic. So somehow I saw myself in that role. As I say, both my father and mother were intellectuals, in the sense of always reading and thinking of things of the mind. My father more in his science, but also in art. He was very interested in art. And my mother in the arts. We always did a lot of theater. My grandparents were great opera lovers. My grandfather almost became a concert pianist, so I grew up with a lot of music around as well and theater.

INTERVIEWER: This was your mother's father.

CANIZARES: That's my mother's father, yeah.

INTERVIEWER: Did you consider going to any other university than Harvard when you were thinking about the PhD?

CANIZARES: I did. But there, there was -- and I again applied to MIT, as well as to Princeton and others, and was lucky enough to get in to all those. But because I had started as an undergraduate working for this group, I was already well along. And I recognized that probably I'd get through faster and more smoothly. I was very comfortable working -- I mean it was a good group doing exciting things. Although, the nature changed during the course of the time I was there. So that was an easy thing for me to do, and I just stayed.

INTERVIEWER: You mentioned that you weren't sure what you wanted to do after getting your doctorate, but that you ended up coming to work with George Clark at MIT. What were your first impressions when you got here?

CANIZARES: There was a real sense of excitement in the Center for Space Research in those days. Bruno Rossi, whose name I am proud to hold, carry -- holding the Rossi chair, had just retired about the time I got here, because of course there was mandatory retirement in those days. But he was still a figure. He would come into his office and I was very pleased. He had written some of the fundamental textbooks that I used as an undergraduate. So, having a chance to meet him and slowly later become very friendly with him and his wife and his family was a great privilege. But there was a lot of excitement, because X-ray astronomy had really taken off. When I got here there was an earlier small satellite that MIT had helped build, and it was just launched. So while I was working on building a satellite that wasn't going to be launched for a number of years, I got to work on the data from that previous satellite.

Also, everybody involved -- so my field is x-ray astronomy, which is looking at x-rays from celestial objects. That was, as I say, a brand new field. It only started -- you had to do that from space. So it was only started with the coming of the space age. The first real satellite devoted to x-ray astronomy, other than studying the sun, which also is a source of x-rays, but sort of of a different nature, really only started right about the year I came to MIT with the launch of a satellite called Uhuru, which was the first satellite devoted to x-ray astronomy. Started by, again, an MIT team, but led by Ricardo Giacconi, who was at American Science and Engineering, a small company in Cambridge that had been started by MIT people, and of which Bruno Rossi was the chairman.

So, all this was happening at the same time, and all of the physicists -- it was all done by physicists, not by sort of more traditional astronomers. All of them physicists who actually didn't know very much astronomy, including me because I had never taken an astronomy course, as I delight telling my students, even though I've now taught them. So, we were all learning astronomy at the same time as we were collecting data on astronomical objects and trying to understand what it meant. So it was just a wide open, exciting time. I also recognized immediately some of the cultural differences between Harvard and MIT. Harvard is definitely more tradition-bound. MIT is more sort of looking at new things, and is a more, I would say where Harvard has a kind of a hierarchical, still has a remnant of a hierarchical structure, MIT's a very flat organization, and very much just a meritocracy as opposed to looking at a little bit more of heritage, maybe one would say.

So, I recognized those differences right away. It's also true that MIT people, I found when I got here, worked very hard, and I saw people at Harvard also worked very hard. But there was sort of a difference. The Harvard system is more like the British one of valuing people who get a lot done, but appear to do it effortlessly and are never running around very much and seem to spend a lot of time, in those days maybe puffing on a pipe or staring into space. At MIT you had to look busy in order to be recognized as being busy. It was something which I thought was a little too much in the other direction. I think some of those differences are still true, although there's been more homogenization over time.

INTERVIEWER: Talk a little about the development of your field and to what extent you and your colleagues and mentors were figuring out how to get a handle on what's out there and what tools you could use and what you could do.

CANIZARES: Well, in the early days -- so x-rays are the most, or not the most, but among the most energetic forms of radiation that we can detect from celestial objects. Therefore, they reveal the really violent, explosive activities that are going on wherever they're going on in the universe. But initially nobody really expected to see very much, because it wasn't thought that -- I mean you knew you could make x-rays in a laboratory in small numbers, but to think that there would be sources of extremely intense x-ray emission in the cosmos. Because nobody had any picture for why that would happen. Although they were some hypotheses, nothing very certain.

So it was kind of an exploration when the first x-ray satellite -- I mean x-rays had been detected from the sun, but they could also do the calculation that if you looked at the nearest star, it would be a million times too weak for us to detect with the instruments that were then available.

INTERVIEWER: Because we were trying to do it from Earth, and the x-rays weren't--.

CANIZARES: No, no. Even if you put them in orbit, because the flux of x-rays is so small. So in the early days, effectively the detector that was used was like a Geiger counter. You could just build a box, and then x-rays, no matter where they came from, if they got into the box, some fraction of them would cause a click and you'd count the clicks. Effectively that's how it worked. Later it was a little more sophisticated, but not much.

So, the first x-ray satellite, and the first rocket that Bruno Rossi, Ricardo Giacconi and others launched in 1963, I believe is when they published the paper, or 1962, was, again, one of these boxes. They just had sort of blinders, like a collimator on it to just look at a piece of sky, and scanned around this sky, and discovered intense x-rays of an intensity that was much higher than you would've predicted from the sun, which was the only other celestial source that had been detected so far.

INTERVIEWER: Because it was a more sophisticated detector that they were--?

CANIZARES: Yeah. They had built a much more sensitive detector than previously used, and they scanned around this sky. Other people looked to the sun because that's what they were looking at and they just kept staring at the sun and they did solar experiments for awhile. But anyway, if they had looked elsewhere, the chances are they wouldn't have seen much anyway, you needed a more sensitive detector. And this was Bruno Rossi's great genius was to recognize -- I think the way he put it was something like every time we open a window on the universe we find that nature is much more clever than we are and has figured out a way to reveal something.

So, that's what had happened only, whatever it is, less than 10 years before I got to MIT. In that time, and that was on a rocket experiment, so there was five minutes of data, that was it. You go up, take a quick look around, then falls down and you hope the parachute opens so that it doesn't crash. The first real x-ray satellite that was launched, as I say, was right about the time I got to MIT. At that time, the reason I came to MIT, that George Clark hired me, was to work on what was going to be the first real sort of x-ray telescope in space. It was called the Einstein Observatory.

So part of the real advance, and I would say was a major advance, was a recognition that you could actually make a telescope where you could focus the x-rays and not just have a box and a Geiger counter. But actually have the equivalent of a camera and take a picture and actually see with much higher angular resolution, a picture of what was really emitting the x-rays. And then furthermore, and what most of my career's been devoted to, is to analyze the x-ray signal and figure out what wavelengths are enhanced and which ones are diminished along a region of the x-ray spectrum, just as one does in the optical or other parts of the electromagnetic range. And get much more detailed signals about what's giving rise -- you know, the physics of what's happening inside the x-ray emitting source.

So, my first project was to develop a crystal spectrometer for the Einstein Observatory, which I did. It was then launched in 1978, and operated for not quite three years, and really opened up the field. Then not long after that, I started working on what became the Chandra X-ray Observatory on another spectrometer instrument. That was a long road because that wasn't launched until 1999, and has been operating now for 11 years and is still going strong.

INTERVIEWER: Was your particle physics training in some way useful to you in figuring out how to complete that first assignment? Or did you have to start studying engineering? And how did you go about it?

CANIZARES: Well, I certainly learned a lot of engineering. I did a lot of -- I think physics, it's not always written that actually physics is a pretty good general education in how to carry out experiments and how to do analytic modeling. I had to model the instrument before I could build it, and how to go about getting things done. But in terms of actual details, I had to learn it all from scratch. While I was writing my thesis, I'd been offered a job at MIT, but I was finishing up my thesis at Harvard before I came down over the summer. As I say, I didn't know any astronomy or astrophysics.

So I went out and I went to the Harvard Coop, and I bought the densest textbook I could find on astronomy and astrophysics and had the most equations, because I thought that would be closest to physics. It was actually a rather nice book. So, when I took breaks from writing my thesis, I would read that book. That was my intro. That was the total extent of my astrophysics knowledge. Also, some of the experimental techniques were different from -- I mean the details were all quite different, but the fundamental underlying principles are the same.

INTERVIEWER: So by the time you showed up here, you had some sense of the field and what people knew and what they didn't know--

CANIZARES: Just a little bit.

INTERVIEWER: --And how they were measuring?

CANIZARES: It was a steep learning curve, but it was great fun, because as I say, it was all happening -- it was all new. So the reality was that I wasn't that far behind even the people who had been working in it for a while because of the fact that it was all being invented.

INTERVIEWER: So it's not as if he could have gone, and George could have gone and found another postdoc who had three or five years of experience doing what you were reading about?

CANIZARES: He probably could have found a few, and I'm delighted that he didn't, but I think at that time there was still -- so this is a different scale, a smaller scale of interdisciplinary work. At that time people were coming from all different -- George himself was a cosmic ray physicist working first under Bruno Rossi as a cosmic ray physicist. Ricardo Giacconi really opened up, was really the mastermind of opening up the field building these sensitive detectors had been a nuclear physicist who later got the Nobel Prize for really opening up x-ray astronomy. Bruno Rossi, of course, was a cosmic ray physicist who moved into these other areas himself. So, I think the fact that I was coming from particle physics was not -- I wasn't that much of an outlier.

INTERVIEWER: And you didn't have the feeling, gee, I saved myself from becoming an electrical engineer, but I've somehow backed into a kind of engineering approach to physics now?

CANIZARES: Well, it's not that I didn't like electrical engineering, it's just that all the things that an electrical engineer does, at least what I saw in my very narrow slice of it -- of course, I didn't know anything about academic engineering. This was more hands-on, sort of engineering that you would do in a company building little instruments. It's not that I didn't like that, it's just that I didn't want that to be the only thing. It didn't have enough of a sort of intellectual overlay, which, of course, when you're working on your own experiment to learn something about the cosmos, there's plenty of intellectual overlay.

But it is amusing because I said that it was very hard to get a job when I first got my degree. I wrote to many people. I was offered one -- or at least was interviewed for a job where the person told me, well, one of the things that you would -- this was to work on another NASA satellite at the time that was being worked on -- and saying that well, this would involve making many trips to Huntsville, Alabama to the Marshall Space Flight Center, to working in these -- was talking about a lot of the organizational things. And I said, I don't want to do that. Of course, that's exactly what I ended up doing. But I was doing it from a different perspective, and by the time it happened, it felt very much like -- because I had a real goal that was intellectually important to me, this became just part of what you have to do to get the job done.

INTERVIEWER: So you were deeply involved in this project after three years of postdocing and it was kind of inevitable that they were going to offer you an assistant professorship?

CANIZARES: Oh, no, no. That was a lucky stroke. No, after a year or two, I remember having a conversation -- in fact, we got involved in optical astronomy at the time, too. Because, of course, when you start finding things in space with x-rays, you want to understand them from all aspects that you can, and that involves doing optical astronomy. So we got involved in that, and I started going back to Tucson for the first time, my birth place, to do astronomy on the telescopes that are just outside the city of Tucson. I remember coming back with George on a flight and I had gotten my courage together and asked him a question about what the future looked like. At that time he said, you know, I just don't think there are any positions in the physics department at MIT. I was rather crestfallen I remember at the time.

So I started thinking about well, what am I going to do next. I would have loved to stayed at MIT. As it happened, a position did open up and the person who I thought would be the logical person to fill it decided not to apply for it, and suddenly it became available to me.

INTERVIEWER: And this was a position described how?

CANIZARES: It was assistant professor position in the physics department, primarily in astrophysics to work in this group, so it was ready made. And I luckily made it into this.

INTERVIEWER: So you didn't end up applying for jobs elsewhere.

CANIZARES: I had not. Luckily I didn't have to go through that. Now, when it came time to tenure, that was also very iffy. I was working on these big experiments, and our satellite was just going to be launched about the time that my tenure case was being prepared. So I worked on building an experiment, but it had no results. It did make it into orbit, it did operate.

I remember being at the Goddard Space Flight Center in the middle the night when the instrument was first turned on and it had a lot of motors and motions. You don't want to put motors and gears in space if you can possibly avoid it, but I had no choice. And everything worked. It was wonderful. But we had to get that science and data and published papers. So it was by no means a forgone conclusion that my tenure case would go through.

INTERVIEWER: But you'd been analyzing data from other collectors and learning about it?

CANIZARES: That's right. So I had a lot of publications, but the question is was my own experiment really a success. It just started returning data enough -- I'm happy to say that my tenure case went through.

INTERVIEWER: So you were actually able to write a little about what you had done and what you were beginning to get before the decision--?

CANIZARES: Yes. I was starting to present papers at scientific meetings, and I think one or two of them may have gotten into press, but they were certainly submitted and the community was recognizing what was happening. But I was already looking for other jobs, because it wasn't at all obvious to me that the tenure was a foregone conclusion.

INTERVIEWER: Were you able to do any kind of testing of whether this mechanism you had built would be able to stand up to *Consumer Report* type of flogging?

CANIZARES: We tested it a lot. We put it on tables to shake it, and we'd put it in vacuum systems to see how it would survive in the vacuum of space. The very first time we put it on a shake table, before we would shake it really hard, you'd just shake it slightly and shake it at different frequencies, and to look for so-called resonances. Is there something in there that will start moving much, much more, like the Tacoma bridge.

So I remember we started doing the survey through the shake spectrum, and suddenly we saw this -- you know, you would put accelerometers on there to measure it and we saw this thing going wild. There was something that was--. So late in the game we discovered this design flaw, mechanical design flaw, and I remember our mechanical engineer was there and was shocked. We figured out a fix to it. We decided we better not ask NASA for permission because they would establish all these committees who would do it.

So we just decided what would fix it. We started doing the fix, and we informed them about it, and then we re-did the test about three weeks later and it worked. But it was harrowing. You put it through all those tests, but there's only one launch, and you can never be 100 percent sure that all these things are going to work.

INTERVIEWER: Did you sleep before this?

CANIZARES: Oh yeah, I slept. As I say, it was the middle of the night in a control center at NASA where we could watch on this -- the telemetry signals that come back from the satellite, you could sort of see where the various switches being turned as the mechanism moved, and when it did, I'd breath a great sigh of relief.

INTERVIEWER: So it started feeding back data and you started analyzing it and kept writing papers?

CANIZARES: That's right. They just kept going. Then as I say--.

INTERVIEWER: Were there any surprises? I mean once you started getting this data, did it open up new windows, as you were talking about?

CANIZARES: Well, so what it really did, and this instrument was the very first to be able to analyze the x-ray spectrum with a very fine resolution. So what we were really doing was looking for signatures of individual chemical elements of highly ionized atoms. So what happens is x-rays come from regions of very high temperature. At those temperatures, an atom like oxygen, which normally has eight electrons, will have only one or two. So it looks like a hydrogen or helium atom, except much, much more condensed because it's got eight protons and the nucleus that causes a much stronger positive charge, shrink the size of those one or two electron orbits.

So what that allows us to do is really to do a chemical analysis, and also a temperature analysis, depending on which ions are present -- you can decide how hot the material is, and in some cases even a density analysis, again, just by looking at the strengths of various different sort of individual spectral lines that you get from these sources. So this was really the first time that those kinds of techniques, which had been applied to some extent to the solar x-rays because they're -- while the sun is inherently a weak source, it's very close by, so to us it looks, the flux is much higher.

So people had been doing that for some years, but how to apply these techniques of what's sometimes called plasma diagnostics to diagnose the nature of these cosmic plasmas, had never been done before. So we really had to invent all that as we went along in our context. That was a lot of fun and very exciting. It was also frustrating because given the size of the telescope in the Einstein Observatory and the sensitivity of our instrument, we could only look at sort of the most intense -- the strongest of these very weak sources, wherever they are in this sky, and that limited us. Which then was the motivation for making a much more sensitive spectrometer for the next observatory, the Chandra X-ray Observatory.

And there, MIT's openness helped a lot, because I discovered a colleague, Hank Smith, in electrical engineering and computer science, who was an expert at making these really -- actually, at that time, I think he held the record for making the smallest sized features in computer chips, for example. But he had also made x-ray gradings, which are one of the tools you could use for spectroscopy, and zone plates. I was amazed. I didn't know anything about making what was then called submicron structures, now would be called nano structures.

So I went to see him and he at the time wasn't very interested in collaboration, was too busy. But then about a year later he called me up and he said, you know, maybe we should work together. I think he had lost some of his funding and some other sources. So I had a graduate student at the time, Mark Schattenburg who was very interested in the technology. I brought him along, and he got very interested in working. So he ended up working in Hank's lab developing technology, which we then moved to a much higher level and became the core of our transmission grading experiment on the Chandra Observatory.

INTERVIEWER: And that went up in '99.

CANIZARES: That's the one that went up in '99. And that had 1,000 times the sensitivity of our first detectors that we did in '79. So it was a big advance.

INTERVIEWER: And began to feed in the new data?

CANIZARES: Began to feed in the new data. So by this time, and as we speak now, these techniques of plasma diagnostics are very well established. The instrument is used, of course, not just by us. This is a national observatory, in fact, an international observatory. So observers from around the world can propose to use our instruments or others on the Chandra Observatory to look at celestial objects.

So I think rather than sort of one big breakthrough or one big discovery, if I think what might I feel some satisfaction for is not actually even doing all these things, it's helping to organize the doing of these things. I had designed the experiment, I did a lot of that myself, but with a lot of help from others. But the actual building of it was, of course, very much a team effort.

INTERVIEWER: So then two years later you moved into the central administration as associate provost. Did you give up research at that point or were you able keep doing it?

CANIZARES: I've never entirely given up research I'd like to think. That was part of the deal-- I was already director of the Center for Space Research throughout this whole period, but that was very much -- that was consistent since I was running a big project. It was, at the time, one of the bigger projects in the center, so running the whole center wasn't that much different than that. Going into central administration certainly took me away from that. But at that time, the data had been coming in, we had the system set up.

I'm extraordinarily fortunate to have a terrific team of professional researchers working with me on Chandra, they were there right from the start. Mark Schattenburg is still a member of the team. He's working on much more advanced detectors now for future satellites. So it's a rather self-propelled group, which is terrific because they can't count on me very much, I'm afraid. But I still have the pleasure of parachuting in. Now and then we get to propose new observations once a year and we get involved in that, and I end up making the final decision of what we're going to do. But the real work gets done by the research scientists and the postdocs, the terrific group of postdocs and graduate students.

INTERVIEWER: As associate provost you were suddenly dealing with a different kind of space.

CANIZARES: I was. And I always thought maybe that was why they got me for that job. So I joined the administration in 2001 as associate provost working with Bob Brown who was then the provost. And we agreed that I would take on a number of things, some things which were just sort of things that need to be done, and some things that might be more in my sweet spot, so to speak. So, in the latter category, I took on the general oversight for Lincoln Laboratory, which is a wonderful entity that maybe not enough people at MIT know a great deal about, but there are some who know a lot about it.

Then another, since I had already been doing a lot of work in Washington, I took on a fairly significant role in our federal relations working with our Washington, at that point, Washington office, led by Jack Crowley and working with Chuck Vest on that, who was president at the time. Then I took on all the responsibility for space and capital planning from an academic point of view--

INTERVIEWER: Within MIT?

CANIZARES: --Within MIT. But that's the inner space, not the outer space. And there's a lot less of the inner space, I can tell you. But it actually turned out to be a great way to learn a lot about MIT. I could pretty much tell you where almost any building number was and what was in it. But more importantly getting to know what the needs of the faculty were, new faculty. This very building that we're in, this room -- I can tell you that there used to be a MEG machine here for studying the brain and required a certain amount of magnetic shielding. So it had some interesting aspects to it. Although a lot of it was -- I sometimes thought that what I really needed on my staff was a full-time psychologist, and I still think that, actually.

INTERVIEWER: To deal with faculty and researcher psyches?

CANIZARES: Yes. There's a very strong human element. First of all, I think this must be deeply rooted in human beings since you had to stand at the front of your cave with a club to protect your turf, and all animals have some kind of turf. People have visceral reactions when you start talking about space. And parking. Luckily, I didn't have to deal with that.

INTERVIEWER: Do you have any idea of how you came to be the person they picked to do these things? Had you worked closely with Bob Brown or with Chuck, or had you raised your hand or done something where they said you're the obvious suspect?

CANIZARES: I don't know about obvious suspect. But, as I say, I had spent a fair amount of time on a lot of committees. When I was -- for whatever reason, I don't know why -- I was asked to be a member of the faculty committee that advised the corporation search committee that was looking for a new president. So I was involved with it at the time with those who were here will remember were actually two searches, because the first candidate--.

INTERVIEWER: in the last 1980s.

CANIZARES: Yeah, decided at the end not--

INTERVIEWER: Phil Sharp.

CANIZARES: --To actually become president. That's right, Phil Sharp. So we had went through a whole second search. So I spent a full year working with a lot of people from the central administration, as well as other faculty on that search. We ended up, I think with a very terrific candidate, Chuck Vest. So I got to know him before he was president through that process. Then I was asked by, I guess by Paul Gray to lead the group that would organize the inauguration and all the activities around it. We had a lot of activities, including -- we decided this would be an opportunity to kind of celebrate MIT, symposia, and there was a book published. There was all kinds of things. And I sort of led that group. So I guess I had come on the radar screen by that time as someone who at least won't mess up too much in working with other people around the Institute.

INTERVIEWER: Our time is running down, so I'd love to get a quick take on the physics department and how that's changed, and what the astronomy, astronomers or astrophysics role was?

CANIZARES: Well, of course, when I came here there was really very little astronomy. There was an astrophysics -- at the time there was a group of people in physics, and actually in mathematics, as well as atmospheric and planetary sciences who were kind of an assemblage, and there was a place in the catalog where you could look under astronomy I think, and you would see courses in these various departments.

INTERVIEWER: Even there was no department.

CANIZARES: Even though there was no department. There was a kind of an organizing principle. I can't even recall if it was called a division or something of that sort. But there were almost no traditional astronomers here.

INTERVIEWER: Are there now?

CANIZARES: And now there are. I mean we've hired a number of really wonderful people who you would say would've, in the past, might have been in an astronomy department. Many schools, by the way, have astronomy and physics or have decided they wonder whether astronomy should be a separate department. But I think MIT's always had a very physics-based department.

On the other hand, I come from more of the traditional physics -- as an elementary particle physicist. So I was totally at home in this department. It was a great place. We had just wonderful people. I think one of the things about the physics department that I noticed when I got here, although I didn't really know how important it was until time passed, was how everybody really supported each other and got along well, which is actually remarkable. It was a big department. It was probably 90 faculty when I got here. It's now smaller. It's shrunk somewhat over the years. But it had absolutely outstanding people. Of course, the first Nobel Prize that MIT ever got was in physics, Sam Ting. So the -- I believe that's right.

INTERVIEWER: What about the teaching of basic physics? 801 and 802 are required courses at MIT. Do you think they ought to be, and there have been changes in how they're taught? Do you have any particular take on that, whether they're good or bad?

CANIZARES: My sense, and I haven't been involved in the new ways of teaching physics, the TEAL in particular, which my astrophysics colleague, space physics colleague, John Belcher really helped get going here. But I'm a strong believer that physics, and I hope it's not only because I'm a physicist, but I think maybe because I appreciate how physics is really a way of thinking about the world in an analytic way that it is an excellent foundation for any scientist, in fact, almost any human being, as a way of thinking. Even if it's not the way you're going to end up thinking most of your life. So, I think a foundation in physics is something that I expect will be in our curriculum for a long time to come.

INTERVIEWER: Two semesters?

CANIZARES: I'm not going to quibble on whether it's one semester or two semesters, because I think they're--. But I think because I think there are lots of ways to teach the physics, and it may not be in a course that's called 801 or 802, but it should be there. Just like I think you need the mathematics, at least two semesters worth of mathematics. We haven't talked much about teaching, but I really loved teaching here. That's one of the things I had to give up in order to do as much administration and keep my research going as I've done. But some day I might go back to it.

INTERVIEWER: What about the telescopes down in Chile? Has that changed? MIT became part of a consortium?

CANIZARES: And I spent a lot of time on that over the years. I was one of the people who really helped get that going. It is one of the things that has really made us more connected in a way to mainstream astronomy. So it is a very important part of what we do.

INTERVIEWER: And do you see any major new projects on your plate in the coming year in all these jobs -- physics or associate provost or VP?

CANIZARES: Well, there are a lot of things on my plate. In my research, we're still hoping that there will be a next generation of x-ray astronomy satellite and they will play a significant role. I won't be the leader, I suspect, but I'm trying to foster that. We have a lot of things going on at MIT in terms of this research infrastructure, our international engagements, our relations with all our major sponsors in these big initiatives. So I'm not worried about getting bored any time in the near future.

INTERVIEWER: Well, thank you for talking to us today. Thanks for the interesting conversation, and keep having fun.

CANIZARES: Well, I intend to, and I appreciate the excellent questions. Thank you so much.

INTERVIEWER: Thank you.