BOBBIE MIXON: Give me the high sign when you're taping. NSF Science and Technology Centers have some varied beginnings. What was the original vision for your center?

HAROLD CRAIGHEAD: Well, our center intent was to bring together a community of researchers and really work closely together before, people from physics, from engineering, from physical sciences and those from biological sciences to try to see what new opportunities would emerge from that. We had some particular topics we thought would be relevant, but basically we wanted to bring together these communities to develop new concepts and explore new research directions and develop some new tools that would enable that research.

BOBBIE MIXON: Nanobiotechnology, was that—what was that original thought for nanobiotechnology?

HAROLD CRAIGHEAD: Well, that was a combination of our form of nanofabrication, which was the ability to manipulate matter and devices and objects at the sub micron level, so down to a few nanometers, the scale of molecules, down below a micron so it's easily accessed at the cellular level. So, it was our idea of micrometer and smaller dimensions that we could use to access systems, and then bringing that together with biological problems and biotechnological applications.

BOBBIE MIXON: How successful do you think you've been in achieving that?

HAROLD CRAIGHEAD: Well, in some sense, we were more successful than we imagined. I think we were part of a growing effort that opened up that direction as a very fruitful one, and so now I think that interfacial area of research is widely recognized as an important one. So, I think we were slightly ahead of the curve in understanding that that had opportunities and I think we built some of the intellectual resources so people could communicate. We also developed some specific facilities so the techniques that were largely in use in the physical sciences could be used in the biological community. So, I think we built up a lot of the infrastructure and showed people some ways, at least one pathway, that was fruitful in that interfacial research area.

BOBBIE MIXON: What advice would you give a researcher thinking of establishing a science and technology center?

HAROLD CRAIGHEAD: Well, my suggestion would be to come up with what you think is a new opportunity and bring together a community, and don't think just of a science and technology center, but really focus on what you think the new opportunities are, and then science and technology centers are one avenue, but I really think there's a growing importance in those interdisciplinary efforts. And the science and technology centers are one. There are other programs at NSF, but I think the really key thing is to identify what you think the important issues are and then go after them, finding whatever vehicle is appropriate for your concept.

BOBBIE MIXON: Well, rather than asking you what you think is your center's most important achievement, what's its most significant achievement to you?

HAROLD CRAIGHEAD: Well, to me, I think it's been the training in new areas that we provided to several generations of students, young students, graduate students, Ph.D., training which is in the form of post-docs. So, I think we've provided them skills at a time when it was very critical for the development of new capabilities in academic and industrial institutions. So I think we really helped provide training that wasn't available in individual disciplines at that time, and then we also allowed to do some new research, which was a vehicle for, you know, moving them into their own specific jobs, but I think that interdisciplinary training at a critical time in the development of the field was very important.

BOBBIE MIXON: Now, was that important to you? What made that so satisfying?

HAROLD CRAIGHEAD: Well, it's always satisfying working with students. I think that's the basic reason why we're at universities rather than an industry. So I think working with the individuals and seeing them develop and become capable of their own independent activities, I think that's a reward that we have in university. I think if we can couple that to our own personal interests and research and see not only our own ideas develop, but that spread into a broader community, that's extremely rewarding.

BOBBIE MIXON: What's the biggest question left over from your research?

HAROLD CRAIGHEAD: Well, I think we've certainly opened a more—opened up more questions than we've answered. When you move into a new area, you find all sorts of things that you didn't anticipate, opportunities and also questions. So I think the closer we look at biological systems, the more we realize we don't understand, and so I think there are now specific questions that people are asking. We were asking general questions about how a cell would interact with a surface or how we might analyze a small amount of material. Now we want to know very specific questions. So now we understand that we want to understand how this disease develops, how does this pathogen change in response to the environment that makes it resistant to treatments? So, they're very specific questions that I think now we think we can get out and so we want to probe those.

BOBBIE MIXON: What do you think the legacy of your center will be when folks look back at it another 10 or 20 years from now?

HAROLD CRAIGHEAD: That's always hard to predict because things change a lot in 10 years. But I hope it will be recognized as having helped foster these interdisciplinary research directions in general, but specifically the interface between biological, physical scientists and engineers. I think—I hope that that has impact in some areas that people recognize, maybe in healthcare, maybe in processing of green materials, or using bioprocesses rather than conventional industrial processes. So, I'm sort of projecting where the results of some of this basic research may be, but I think we were—I hope that we contribute to that fruitful direction.

BOBBIE MIXON: What is next for your center?

HAROLD CRAIGHEAD: Well, our center is obviously evolving. It was primarily an NSF-funded and driven activity and now we're broadening our mission. So I think we're taking on

more specific tasks, addressing some of these questions with more mission-oriented funding from other agencies like the Department of Energy and the National Institutes of Health, so I think we're moving into a more diverse, more mature form of where the research will be so we'll act as a umbrella organization to try to keep that interdisciplinary flavor, shepherd the educational activities that really span departments so that we have an ongoing need to have that sort of enterprise.

BOBBIE MIXON: Give me one specific task that you're looking at.

HAROLD CRAIGHEAD: Well, a specific task in that mission is we have a group of people, so it's a large task that's working on the issues of how cancer develops and, specifically, understanding the microscopic details of the environment of cells as that influences the progression and development of cancer. So, that's a targeted effort, it's a group effort, quite broad but it does utilize some of the skills, interdisciplinary training and approaches to interdisciplinary research, but also uses the facilities, the physical resources that we've developed in our nanobiotechnology center.

BOBBIE MIXON: When you originally started, did you know that you'd be looking at cancer and what causes it to develop?

HAROLD CRAIGHEAD: No. I think it was remotely conceived that we would be dealing with things that had healthcare outcomes, but I don't think we said, yes, in 10 years, we're going to do cancer. I don't think any of us thought that.

BOBBIE MIXON: So you've just been following where the science has been leading?

HAROLD CRAIGHEAD: Well, hopefully we've been opening up the doors that make those possible. So, we're following the knowledge that's developed across the community, but we're also developing some key resources. So, we developed some techniques that we can use, in our case, the ability to make engineered environments in which we can culture cells and also control that environmental detail. That's something that emerged out of our nanobiotechnology center capabilities and that's being used specifically to use that component to understand, in this case, cancer.

BOBBIE MIXON: A number of the techniques that you've developed are already being used in academic settings. Is that true?

HAROLD CRAIGHEAD: I think they are. I mean, we are using things that come out of our research, but also keeping abreast of what's available from any source, but I think, in house, we've certainly developed some local expertise and so that's something that we can capitalize from the experimental and theoretical treatment of what we do.

BOBBIE MIXON: Very well. Thank you so much.

HAROLD CRAIGHEAD: All right. My pleasure.

BOBBIE MIXON: What was the original vision for the Center for Behavioral Neuroscience?

WALTER WILCZYNSKI: Well, the original vision was threefold, and it was to tackle the big problems in neuroscience, the complicated behaviors that have been difficult to understand from a mechanistic point of view, things like social behavior, which requires you to understand how different individuals are interacting with each other. Much more complicated than how a single individual, for example, sees food or something like that. We're talking about things like reproductive behavior, communication, social bonding, cooperative behavior, things like that that are complicated. So, our vision in the research domain was to tackle these problems in a multidisciplinary way, to look at them at multiple levels from the behavior down to the molecular basis of that, and that's still going on. The second part of the vision was to train scientists in this collaborative model and that was a major part of what we wanted to do, was to train scientists at multiple levels, from junior faculty to post-docs, to graduate students to undergraduates to understand that science is a integrative process that requires people to look at things at multiple levels. It's a collaborative endeavor. Even if you're working by yourself, you're really working in the midst of a community of other scientists, and that was a big part of it. Then the third vision was to bring what's going on in the research domain out to the public to do outreach studies, do outreach activities, both in the community but also bring it to the public in a sense of impacting K-12 education, to train teachers to excite students at the middle school level or at the elementary school level, the high school level that science is really very interesting, that it's a career that they want to go into and that there are really interesting things going on at research universities.

BOBBIE MIXON: How successful do you think you've been at achieving those goals?

WALTER WILCZYNSKI: I think we've been real successful in all three. I think the CBN has really stimulated a lot of very interesting research. It's really pushed the envelope in trying to understand the neurochemical systems of the brain that are behind a number of very complicated activities like social bonding, for example. How do organisms recognize individuals it interacted with? How do they develop trust with them? We now have identified a number of different neurochemical systems, one of which is called vasopresssing, another one is called oxytocin. There are probably others that are involved that really interact with key parts of the brain in order to bring about this emerging property that we call affiliative behavior or bonding. I think that was a really big part of what we did. And I think there are other examples, too, in looking at sex differences and behavior, how males and females differ, looking at individual differences of behavior and how those are reflected in the brain at the genetic level, at the systems level, at the neurochemical level. So, research has been extremely productive at the CBN. We're now counting upwards of 2,000 published papers that have come out of CBN labs, equal number of presentations and invited talks. And so, I think it's been very successful there. The training that's been stimulated by the CBN is probably even more successful than this. As a function of the CBN and the CBN scientists then going out on their own, we've really made dramatic impacts on the curriculum and the programs at all of our member institutions from Spellman College, which really reorganizes biology curriculum from one that was a very standard pre-medical school model to one which is now an inquiry-based, much broader biological system, new graduate programs at Georgia State, for example. We just had a Ph.D. in neuroscience and now we're moving toward an undergraduate major in neuroscience. So that's been really good,

and we've put together a system and a culture where students can go back and forth between different institutions. I'm at Georgia State, for example. I've often had students from Morehouse College come to work in my lab. Students from Georgia State have worked at Emory labs, and so that has really been part of the success of CBN. And then the outreach, just in terms of numbers, has been great. We had the two, a post-doc and a graduate student, just win the Next Generation Award from the Society for Neuroscience for their outreach. We calculated that they've run programs over the last ten years that have reached 27,000 middle school students in their classrooms. So, I think we've been really successful at all of those. And even more successful in just integrating them together so that it's become part of the culture that scientists do outreach, people who are involved in education are bench scientists. It's a very vibrant and, I think, hopeful situation.

BOBBIE MIXON: Now, the Center started ten years ago.

WALTER WILCZYNSKI: Uh-huh.

BOBBIE MIXON: Looking back on it, are there any goals that you would change or emphasize more than another?

[repetition]

WALTER WILCZYNSKI: That's a really good question. I've been with the Center now for just four and a half years so I wasn't there at the beginning. The goals that were there, I think, were good ones and were appropriate for the institutions. I think if there was one goal that may have been better articulated and that we might have put more emphasis on was looking more towards knowledge transfer in the terms of spin-offs of products. It was very difficult to do that in a basic science department because we're not engineers and we're not physical scientists, but the one thing I think that we should've paid more attention to, and is an issue, I think, as we're going forward, is how do we spin-off what we're doing to the medical field, to the pharmaceutical field, to biotech, and in the last few years, Elliot Albers, who's the director of the Center, has made enormous progress in making relationships with the biotech industry in the region, and I think this is really a direction we'll really be paying a lot of attention to. And, in concert with that, incorporating that into the training programs. The training of graduate students, I think, now is much different than it was ten years ago because in the one sense, they have many more options. There's a real need for trained scientists in industry and policymaking, and in a lot of ways, our traditional graduate programs don't address that. We're training bench scientists, which is good. We try to support people who want alternative careers, but we need to make it to the next step in developing right in—as an integral part of our graduate and undergraduate programs, what the skills would be for alternative careers that are not academic science careers.

BOBBIE MIXON: You mentioned Spellman and Morehouse, two historically black colleges. Did the Center make a special effort to involve those universities?

WALTER WILCZYNSKI: They were there from the very start, and I wasn't there at the time when all this was worked out and there were some discussions that had to be made because we

were trying something that was really difficult. We were trying to meld together institutions which are extraordinarily diverse. Spellman and Morehouse are elite undergraduate institutions that primarily serve African-American students. Their main goal is the preparation of these students for life, it's undergraduate education, it's mentoring and it's training them in research, and their graduate and their faculty do research. We had to look at their goals and their aspirations and try to integrate them with an institution like Morehouse School of Medicine, which is a research-oriented medical school which doesn't interact with graduate students at all, and Emory School of Medicine, which is an enormous research-driven enterprise, and clinically driven enterprise. And so there was a lot of effort in the first few years to try to understand how you make this work. And I think we've learned a lot from that. We learned that we can't go into this with a "one size fits all" mentality. It's not the case that everybody has to have the same goals and every institution has to have the same goals. What a center has to do is figure out how the center could work for those institutions. And I think we've done a lot for Spellman and Morehouse and they've done a lot for us with their expertise in mentoring, with their expertise in how to reach out to diverse populations, their sensitivity to how to meld diversity into a unitary direction, which is not just an issue for student diversity, but it's an issue for how you do that for diverse institutions. And I think they really helped us in that regard. They helped us with developing our education and mentoring programs and I think we had a really good and now do have a very good interaction with them that allows their students access to many more research labs, their junior faculty resources in other institutions, and allows our post-docs to get training in teaching at high-quality undergraduate institutions. So I think it's been good for both of us.

BOBBIE MIXON: I think most people think of the human complexities when they think of behavioral neuroscience, but your background comes from animal. How did you go from that to behavior neuroscience?

WALTER WILCZYNSKI: Well, most of neuroscience, especially mechanistic neuroscience, that looks at the cellular, molecular or systems level mechanisms of complex behavior orients towards animal models of this because we don't do experiments on humans and, in many ways, our tools are not available—more available now than they were ten years ago—to image what's going on in the human brain. And humans are more complicated. And we can't really, you know, discount that factor in trying to understand this. So, for those of us in behavioral neuroscience in general, we tend to work on animal models because many of the fundamental systems level organizations with a brain, a lot of the—certainly the molecular and cellular levels are really common between us and even invertebrates. There's a lot of work, for example, done on the genetics of behavior, which uses fruit flies, and that's because the genetic endowment that we have is really very similar to those in terms of what the genes are. What our challenge is to understand how what we do in animals relates to humans, both to clinical conditions, which I think is important, but equally important, how it relates to normal, healthy, human behavior so that we can understand what really makes us good people, healthy people, people who are fulfilled in their lives, and a lot of that does have to do with the kind of social behaviors that the Center for Behavioral Neuroscience looks at, things like social bonding, cooperation, empathy, altruism, reproductive behavior, even things like fear and aggression are normal parts of us and if we can understand that, we can understand something about the human condition.

BOBBIE MIXON: If you can assess it, what's the most important achievement of your Center?

WALTER WILCZYNSKI: I really do think that the most important achievement for the Center is showing that you can get diversity at all levels, from diversity in the student population to diversity in the levels from middle school students to post-docs, to diversity among institutions to work together to solve a big problem in neuroscience, or at least to work on big problems of neuroscience. I don't want to say that any of our STCs, and certainly not the Center for Behavioral Neuroscience, has solved all the problems in its area of study. Now, what we have done is put together a test case for how you would get people together to work on collaborative projects that are big issues, and how we get them together with the sensitivity to the idea that just doing the research is not enough. The research has to be done in the context of training the next generation of researchers, has to be done in the context of communicating those findings to the general public, to school kids, to undergraduates and to other faculty members, and I think the biggest accomplishments are our achievements in doing that and developing our institutions within the Atlanta area into a very cohesive, cooperative group of institutions.

BOBBIE MIXON: Was that also the biggest challenge you had to overcome?

WALTER WILCZYNSKI: That was the biggest challenge, and I'm a little relieved that I came in after the big challenges were over. I came in in year six of the center and a lot of the challenges, of course, were even before the center was formed because it was preceded by at least two years' of discussion by representatives of all these institutions, faculty of all these institutions to figure out how to do this and the first couple of years, I think, there were missteps and people tried to work their way through something that really hadn't been done very successfully before. It was a big challenge and a lot of the challenges were really solved on the personal understanding level is getting an understanding of what it means to cooperate, what it really means to take into account the goals and missions of diverse institutions and just trying to figure out, on a personal basis among the participants, how best to deal with this.

BOBBIE MIXON: Ten years from now or 20 years from now, what do you think the legacy of the center will be?

WALTER WILCZYNSKI: Well, I think the legacy is going to be the research that we did and the process that we did for doing that research. The research, I think, really does stand out. There are areas from the basic mechanisms of how we learn to be afraid of things, to how we deal with stress and we're resilient to stress, to how reproductive behavior works and how develop and unfolds, and how behavioral interactions early in development change the brain in fundamental ways that are echoed well into adulthood. I think there are some fundamental findings that are going to go out there. I think the big legacy is that we actually pioneered a way to get groups of people together across institutions and a mechanism for stimulating this kind of novel research, and the mechanism is, in retrospect, things which, you know, maybe become obvious once you start doing them, is getting people together to talk, having something of a carrot in the sense that we would support innovative research that bolted up out of this kind of combination of competition and cooperation among people, how we got education an integral part of this so that in order to be part of the CBN, it was kind of expected that you would

participate in these outreach and as being a part of CBN then, you also get resources for your research when you did it. it was never a quid pro quo and I think we learned early on that you can't force people to do this, but if you get people together and show them that there's some meaningful outcome that comes out of this, it's rewarding, that it's fun, that they get an intellectual benefit from it, people come about to do this, and I think, you know, 10, 20 years from now, what we're going to have among our institutions is a culture of cooperation multi-institutional exchanges that's probably not gonna go away.

BOBBIE MIXON: What's next for the center?

WALTER WILCZYNSKI: Well, next for the center is both, you know, the mundane nuts and bolts and for a period of trying to figure out exactly what we're going to do. I think next for the center is moving forward to get the resources that will continue this kind of cooperative behavior. Especially in this economic climate, it's very difficult for everyone to maintain their research and education programs. So we have to find a way to do this, but we're looking at ways that will continue to excite people's interest. One way is to try to more directly understand the relationship between the basic science that we're doing and human problems and human conditions, the idea of translational research, trying to break down even more the barriers between what goes on in very basic biology and what goes on in biomedical sciences. I think that's going to be a big part for us. One of the big areas in science, in neuroscience in general, is the area of genomics. How do our genes affect our brain and how does that affect behavior? We now have the tools to look at that and I think one of the big questions that something like the CBN can look at with its multilevel approaches is the question no one's really answered yet, that is how do we move from various levels? For example, we know that genes have a very big impact on our personality, but what does that mean when we say that there's a genetic mechanism for something? We know that there are differences in genes, but we know that genes don't code directly for personality and they don't code directly for behavior. How do you get from one level to the next? That's a very, very difficult question and in some ways, we don't even have the tools yet to look at. And also, I think to move forward with models of training students in new ways, especially in getting our students in the basic sciences and the biomedical sciences more skills that will make them competitive for multiple jobs that will come about, but also to better integrate their training with training in what we now know about education in the stem fields.

BOBBIE MIXON: Do you have folks at the Center looking at the ethical aspects of genomics?

WALTER WILCZYNSKI: You know, that's an interesting question. One of the things the CBN has done is provided a model and resources to start these things and one of the areas at Georgia State University, for example, that happened very unexpectedly was that the Philosophy Department took a great interest in neuroscience and on their own, with some help from us and with some help from the brains and behavior area of focus at Georgia State University hired a number of new faculty members who are people who specialized in the philosophy of mind, who specialize in ethics, and who specialized in what we can call biomedical philosophy. What are the philosophical implications of mental illness, for example, in dealing with mental illness. It

hasn't been a big part of the CBN but I think it's one of these things that, at all centers, you can never predict that now is going to be part of what we're doing.

BOBBIE MIXON: Thanks so much for taking the time to talk with us.

WALTER WILCZYNSKI: Thanks for having me.

LILLY WHITEMAN: We're rolling now, so I'm going to hit you with the first question. Can you explain why an ever-increasing number of world regions are or might soon be considered semi-arid?

SOROOSH SOROOSHIAN: Well, I think the question is an interesting one. It's still very unclear because, so far, one-third of the continental landmass is considered to be arid or semi-arid and there are different definitions of what qualifies them as arid, semi-arid. It's more in terms of the amount of rain that they get as well as the vegetation cover. OK?

LILLY WHITEMAN: Can you explain why ever increasing number of world regions are or might soon be considered semi-arid?

SOROOSH SOROOSHIAN: Yeah. It's interesting question. In general, about one-third of the continental landmass is considered to be arid, semi-arid and the definition that has been provided by UNESCO or some of the other agencies is based partly on the amount of precipitation, rainfall, that these regions get, and the second part of it is the vegetation cover that these areas have and, naturally, rainfall is critical for that. It is—I'm not so sure if it is entirely correct that the amount of arid regions are increasing climatologically yet, but definitely over-grazing that is taking place because of requirements of the human population in terms of, you know, cattle, etcetera and mismanagement of the land may have exasperated the problem. Shifts in precipitation might cause that too, but so far, in the scheme of things, when you look at the history of Earth being billions of years, we only have a very short period of data that we can judge to see how the conditions were in the past. So, the summary answer to this is that I'm not so sure exactly that landmass that is going to be arid, semi-arid is going to increase except for the part that is due to human activities.

W. JAMES SHUTTLEWORTH: Although one of the big projections of climate change is that wetter place will get wetter and drier will get drier.

SOROOSH SOROOSHIAN: That is true and also the variability is going to be a factor in terms of precipitation. Globally, we might see an increase in precipitation that we think, well, why should areas get more arid, but it's these shifts that are so uncertain at the present.

W. JAMES SHUTTLEWORTH: That's absolutely true.

JUAN B. VALDES: And also that climate change is just one of the drivers, population and Soroosh was saying, over-grazing is a problem but population growth, especially in the southwest, has been a major driver of the water demand.

LILLY WHITEMAN: So, is that why water management and policy issues are particularly important now, because of the population increases?

SOROOSH SOROOSHIAN: You're precisely right. I think that the population of the Earth that's almost getting close to 7 billion as compared to what it was some 40 years ago, of 4 or 5 billion, so we are now seeing more pressure on the water resources that are not necessarily increasing on a regional basis to the significant level to keep up with the population. So, we are putting more emphasis on extracting water from the groundwater regions that was relevant to this particular center, SAHRA, because it was semi-arid regions. So, more and more then you better have better policy in place of controlling or regulating how the usage takes place. Otherwise, these are hidden catastrophic issues that are going to face many regions of the world.

LILLY WHITEMAN: And has your center impacted policy…?

SOROOSH SOROOSHIAN: Definitely. At least in the scope of the activities of the center in the southwest United States, lessons have been learned that we hope will translate to other regions of the world. Do you agree?

JUAN B. VALDES: Yeah, and I think one example I want to discuss later will be to salinity, not just on the climate and aridity, but some of the other aspects that our center has addressed.

LILLY WHITEMAN: You can address that now.

JUAN B. VALDES: Well, you know, one of the results that really came out of the research by SAHRA personnel was there was a lot of concern about the salinity on the lower Rio Grande and middle Rio Grande between New Mexico and Texas. And, of course, that deteriorated the water quality of the river, and Texas was concerned that that was due to a [inaudible] in New Mexico. After some isotopic research conducted by SAHRA personnel, it was determined that most of the source of salinity was from upwelling, from natural sources of salinity in that water. So now, New Mexico and Texas are working together to try to prevent that salt to reaching the main river. I think that is the direct result of the research of SAHRA that has tremendous impacts on policy and decision-making by water managers.

LILLY WHITEMAN: Any other examples you'd like to…?

SOROOSH SOROOSHIAN: Other examples—A good one is a continue in the—sort of research that determined that the southwest U.S. vegetation has changed over the past five decades or so, or six decades, going from grasslands more towards shrub lands. And that change of vegetation has had an impact on the amount of water that infiltrates into the groundwater aquifers, and the original rates at the desert floor were estimated to be at 2 millimeters per year on the average, which would have—if I'm not wrong, and I remember my numbers right—in the Rio Grande basin, which includes the city of Albuquerque and is for almost 70,000 households, that amount of water per year. And then, later on, because of the change of the vegetation and the analysis that was done by one of our partners, New Mexico Tech, it was determined it wasn't 2 millimeters per year, it was two tenths of a millimeter. And that translated in terms of water availability is not for 70,000 households, but for 7,000 households. So you suddenly have this

tenfold difference in the amount of water availability. And those are, I think, important knowledge gaps that existed that the center has been able to fill.

LILLY WHITEMAN: Can you give that example of the Rio Grande again? Because there were technical difficulties.

JUAN B. VALDES: Sure. In the middle Rio Grande area, which goes between the states of New Mexico and Texas, is under a contract, an agreement, a binding agreement, between New Mexico and Texas, not just on quantity but also on quality. The salinity was one of the major concerns of the quality of the water of the river. So it was thought that most of the salinity was coming from the irrigation sites on the New Mexico state that were contaminating or increasing the salinity of the river. And that put some discussions or conflict between New Mexico and Texas. The research conducted by SAHRA personnel, the isotopic analogy that determined that most of the salinity was coming from upwelling of groundwater, very salty groundwater. So it's a natural cause, not irrigation cause. And…

LILLY WHITEMAN: How does that influence policy?

JUAN B. VALDES: Well, because now Mexico—New Mexico and Texas are working together to try to prevent that the salinity reach the main river.

LILLY WHITEMAN: And how is having a center on your topic help catalyze or speed advances in a field that without a center wouldn't have happened or would have happened more slowly?

W. JAMES SHUTTLEWORTH: I think the most significant aspect has to do with communication. What is sustainability is a very difficult, complicated process and involves a lot of different types of people being involved, and not just a physical sciences, hydrology, atmospheric sciences, geosciences and that sort of thing, but also social sciences, economics, law, policy people. And one of the major outcomes of the SAHRA center is that, over the years, we have learned to not just speak together but to work together and to find tasks that we can address together. And that is certainly already going to facilitate the more effective response to user problems in the future.

LILLY WHITEMAN: So, do you think that's part of the legacy of the center?

W. JAMES SHUTTLEWORTH: It is. In my opinion, it is probably going to be the most important part of the legacy in terms of a long-lasting impact. I predict that if you come back in five years, come back in ten years, and you look at universities in the southwestern USA, and you find where there is good, multi-discipline or science going on that is relevant to stakeholders, to people who need the science, and you trace back where that started from, very often you will find that it started in SAHRA and it was nurtured in SAHRA.

JUAN B. VALDES: What I would like to add to what Dr. Shuttleworth just mentioned is that one difference between individual researchers and the center type research is that the total is larger than the sum of the parts. If the three of us get different projects, we may get at different

times, maybe go to work in different sites. A center type allows us to work on the same site at the same time, and so the progress was much significant that would have been with the same amount of money, would have been given to three researchers or more researchers.

W. JAMES SHUTTLEWORTH: Is this working?

LILLY WHITEMAN: There was another problem, sorry.

W. JAMES SHUTTLEWORTH: From where? I hope it wasn't my bit, because I thought I was rather good.

[audio pause]

…on the same place.

JUAN B. VALDES: OK.

LILLY WHITEMAN: Are we ready to start? OK.

JUAN B. VALDES: I wanted to add to what Dr. Shuttleworth just mentioned is that one of the great advantages of working in the center type rather than individual researcher is that the total is larger than the sum of the parts. And at the same amount of money spent on individual researchers, like, for example, the three of us will not be working at the same time, at the same place. And the ability to work together on the same place on the same time, the results are much larger than individual projects.

LILLY WHITEMAN: Well, speaking of your achievements, can you tell me why your center won the 2007 International Great Man-Made River Prize from UNESCO?

SOROOSH SOROOSHIAN: Yeah, well, of course, we have to leave that question for the people who judged SAHRA. In addition to SAHRA was another center that I have the pleasure of directing now at the University of California Irvine, called Center for Hydrometeorology and Remote Sensing, which, by the way, is an extension of SAHRA. Once I moved from Arizona, I created this center because, through the research in SAHRA, we identified that one of the biggest gaps was lack of good-quality precipitation, rainfall, around the globe. And using satellite technology to help with NASA, we've been able to fill that gap to some extent. And I think the UNESCO, having been involved with some of the work that both of these centers are doing in arid, semi-arid regions, decided that the work was significant enough to deserve to be recognized, and we were pleased that both centers were acknowledged.

W. JAMES SHUTTLEWORTH: Fundamentally, it was to do with outreach, wasn't it?

SOROOSH SOROOSHIAN: Absolutely.

W. JAMES SHUTTLEWORTH: Effectively trying to transfer what we've learned in the USA into semi-arid regions elsewhere in the world.

LILLY WHITEMAN: What are some of the regions you have…?

SOROOSH SOROOSHIAN: Anyplace that has arid, semi-arid environments of less than 400 millimeters of rainfall have found value in the data that is being posted. You know, we have tried to put most of the information on the Web. And it's accessible to people, real-time data on rainfall. They can download it, whether it's North Africa, in the Arabian Peninsula, Iran, South East Asia, in some regions that are requiring it. And, luckily, it becomes much broader than that; even regions that are not arid are taking advantage of the information.

LILLY WHITEMAN: Now, I know that problems dealing with water management are particularly contentious. Can you tell me how, in some way, that SAHRA helped reduce the contentiousness of these issues?

W. JAMES SHUTTLEWORTH: Well, the way that we do that is to establish a position where we become the common center of knowledge between the two parties between which the contention exists. A major step forward is when both parties agree to do that, and then we can effectively help to quantify, for instance, the amount of water resource available. We can recommend to both parties alternative ways of going forward. We can implement what we call decision support systems, essentially computer programs, that can allow them to experiment with alternative scenarios in terms of the way that they want to develop and manage the region in which they are. But, fundamentally, it is the impartiality between the two contentious parties that we fulfill.

LILLY WHITEMAN: Is there an example of an advancement the center facilitated that affects people's daily lives that they might not even know about, or improves their daily lives?

JUAN B. VALDES: Well, I think that one of the examples is, following up with what Dr. Shuttleworth mentioned, and this is a [inaudible] support system, is, the work that was done with the Upper San Pedro Partnership. The San Pedro is a river that originates in Mexico and ends eventually on the Colorado, but it's the only riparian corridor between [inaudible] flow from Mexico to the U.S. and back. So there was a lot of internal preserve in this riparian corridor. But also there is a lot of pressure that was mentioned before with Dr. Sorooshian of population moving to the southwest and demanding and also some military installations at Fort Huachuca. So, how to combine those, at the same time preserving the ecosystem, was this Upper San Pedro Partnership, which is a consortium of 19 federal and state, local and NGOs that try to do that, and SAHRA developed the system support system that allowed them to evaluate the scenarios that Dr. Shuttleworth just mentioned.

SOROOSH SOROOSHIAN: I'll maybe add a little bit to that. Also, the type of information we try to make available, as I said, rainfall information is important for flood forecasting in many regions. And there are regions of Africa that we don't have any gauging stations for which the data is provided. Now through this remote sensing work that we're doing, it's easily accessible to the hydrologic services in these parts of the world, and indirectly, at first, a villager in sub-Sahara Africa would not be aware of it, but the ability of their hydrologic

services to try to issue warning and get them out of harm's way is a definite advantage that people wouldn't know where it came from.

LILLY WHITEMAN: Now, during the center's lifetime, climate change has become a much more prominent issue. How has, if in any way, has that affected your work?

W. JAMES SHUTTLEWORTH: Initially, our focus, really, was on climate variability. Climate variability is very important in water management, particularly at the multi-time scale. That's why we build dams, after all. Progressively as we went through the ten years, of course, the climate change issue became more apparent, and so we changed the focus to still have a big interest in variability but superimposed on change. And that actually stimulated us to invest fairly substantially in a task in which we developed scenarios for the desert southwest that could be used by water managers. So that's certainly one of the ways that we responded to that. And I think we learned a lot in that process. We learned how to discriminate between the numerous different projections that the climate models make. We learned how to, in a sense, make corrections, some of those on the basis of existing data. And we learned how to down-scale those data so they become more relevant at the level at which they're needed.

LILLY WHITEMAN: Now, I know a lot of the centers work [inaudible] regions. Why are those regions so important?

W. JAMES SHUTTLEWORTH: Well, 90% of the species that exist in the desert southwest live within tens of meters on either side of the rivers flowing through the desert. Also, many of the rivers actually flow north-south, and they act like kind of bird interstates, you might say. The birds fly up and down those systems. They take water, they take food as they do that. So, losing those systems would, first of all, remove most of the biodiversity types of species available, and secondly, would cut off high flight, if you like, North America from South America with respect to the bird migration. The issue is that those vegetation systems are supported by continuously flowing water, which comes from below. It comes up from the groundwater and, unlike other river systems, if the groundwater falls because the human beings pump the water, even by a few meters, you lose the vegetation, you lose the biodiversity, and you lose all of the economic value that is associated with that through tourism, through influence on property. All of those things are linked to the availability of those rather obstructive regions in the desert.

JUAN B. VALDES: I would like to add that, you know, following up what Dr. Shuttleworth said, that EPA in addition to NSF funded a study that tried to do this evaluation of the market and non-market evaluation of riparian ecosystems. And that was done through surveys to—after building the model of the riparian systems, doing service or trying to see how people evaluate those resources. So that was very helpful.

LILLY WHITEMAN: We're getting close to our time, so I just want to give each of you an opportunity to say anything about your center's achievements, future, past that we haven't been able to get to. If you could each take a minute, if you'd like.

SOROOSH SOROOSHIAN: Yeah, sure. I'll be happy to. Of course, a center like ours, as well as the other four that were the class of 2000, as they're now called, were created with the

major support coming from the National Science Foundation, which gave us the ability to partner with other institutions to advance the science that we promised were critical, and that's why panels judge that. One thing that I've learned is that one should not completely rely on NSF as the only source of support. And entrepreneurial and creative ways by which we can engage other federal agencies as well as local entities was really one of the things that I take a lot of pride in, our center being able to have done that. As I said, I moved to the University of California four years after that and was able to take a certain aspect of it that wasn't necessarily under the research priorities of the center when we started SAHRA, but then I was able to convince NASA that it was crucial enough to support it. So, essentially, it's almost like branching out into different areas, and I think that's really a key message for all the new center directors.

JUAN B. VALDES: I would like to mention something that, unfortunately, I didn't have time to say before, is that, in addition to all this understanding of the physical and ecological process, we also look for economical and social value. And like one of the questions presented today about our water banks—are water banking and water leasing feasible, we also look to the economic access of water, both market and non-market. And like I mentioned in the presentation, that prototype of water leasing market was done so well that now the Office State Engineer of New Mexico is using that to implement on the Mimbres River in New Mexico. The other thing I would like to mention is that, from the very beginning, we have the collaboration of certain Mexican institutions. We felt that we have a lot of affinity with the northern part of Mexico, which is as arid, and the southwest, and we work with both the National Water Commission of Mexico City and the Mexican Institute for Water Technology, in addition to some people in the state of Sonora, which is the state across the border from Arizona. So, those are the two things I wanted to mention on this.

W. JAMES SHUTTLEWORTH: The SAHRA Center was, I think, the first STC that's focused on the public good. And a huge part of its activities and mission was related to education and outreach. Thirty percent of the budget systematically over the years has gone on that. And our primary target was always water managers and water professionals, because they have the ability to enhance the sustainability. But at the same time, we invested strongly in public education, and we invested strongly in educating students and young people, the idea being that the water managers can enhance sustainability, but they have to have the support of the population and, ultimately, if the sustainable program itself is to be sustainable, then the upcoming generations have to be invested in it also.

LILLY WHITEMAN: [inaudible] This is great, thank you so much.

JUAN B. VALDES: Thank you.

SOROOSH SOROOSHIAN: Thank you.