Welcome to the NanoEHS Webinar Series

Lisa Friedersdorf
Director, National Nanotechnology
Coordination Office

>> Lisa Friedersdorf: Good afternoon. This is Lisa Friedersdorf, Director of the National Nanotechnology Coordination Office, and I would like to welcome you to our webinar.

This webinar is the latest in the nanoEHS series organized by the Nanotechnology Environmental and Health Implications Working Group. I want to thank our excellent webinar panel, who will share with you a sampling of the support for nanotechnology environmental and health research provided by the National Nanotechnology Coordinated infrastructure hubs, or the NNCI.

NanoEHS Webinar:

National Nanotechnology Coordinated Infrastructure (NNCI)

and

Environmental Research

National Nanotechnology Coordinated Infrastructure

Moderator:

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>> Lisa Friedersdorf: I now turn things over to our moderator, Dr. Larry Goldberg, Senior Engineering Adviser in the National Science Foundation's Directorate for Engineering. Larry?

NanoEHS Webinar Speakers

- Virginia Tech NNCI Site (NanoEarth)
  - **Marc Michel** – Asst. Professor, Geosciences
- Stanford NNCI Site
  - **Bruce Clemens** - Professor, School of Engineering

>> Larry Goldberg: Hello, everyone. It's my pleasure to introduce our two speakers for this session. The first will be Professor Marc Michel at Virginia Tech, who is a professor of geosciences and nanosciences, and the second speaker will be Professor Bruce Clemens from Stanford University, professor in the school of engineering and professor of photon science.

We will have a presentation by each followed by a question and answer session. I'd like to remind you that you can submit questions either here in the box that you see online or by email to webinar@nnco.nano.gov. We will queue these questions at the end of the presentations. So please do use the method that we suggest, and we will try to have a good discussion.

NNCI Overview

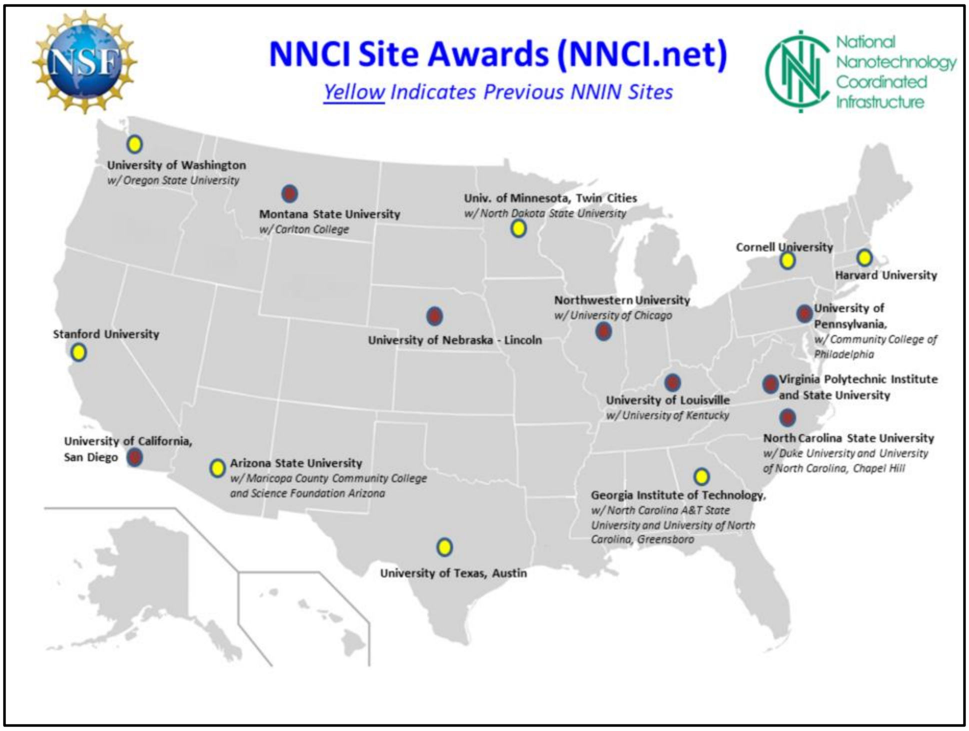
The National Nanotechnology Coordinated Infrastructure (NNCI) was established by NSF in 2015, as successor to the National Nanotechnology Infrastructure Network (NNIN).

NNCI is comprised of 16 user facility sites, their affiliated partners, and a Coordinating Office at Georgia Tech.

The NNCI sites provide researchers from academia, small and large companies, and government with access to university user facilities with leading-edge fabrication and characterization tools, instrumentation, and expertise within all disciplines of nanoscale science, engineering, and technology.

>> Larry Goldberg: First I would like to give you a very brief background of the National Nanotechnology Coordinated Infrastructure, the NNCI. The NNCI was established by the National Science Foundation in 2015 as a successor to the National Nanotechnology Infrastructure Network, the NNIN. The current NNCI is comprised of 16 user facilities sites, affiliated partners, and a coordination office established at Georgia Tech.

The NNCI sites provide you as researchers from academia, from companies, small and large, or from government, as well as internationally, with access to their user facilities and the leading-edge fabrication and characterization tools, instrumentation, and expertise that they have within virtually all disciplines of nanoscale science, engineering, and technology.



>> Larry Goldberg: Here is a map of the 16 NNCI sites. They're distributed across the country. Those in yellow were previous parts of the old NNIN, and those in the darker color are the newer sites that have been established. I suggest you go to their website, http://nnci.net/, and you will find considerable information on their capabilities and how you as users can gain access.

Role of NNCI Coordinating Office

- Enhance the impact of NNCI as a national infrastructure network
- Establish comprehensive web portal (NNCI.Net) for the user community of overall tools, instruments, and capabilities at all NNCI sites.
- Guide users as to which site(s), instruments, and processes would enable them to complete their projects most successfully.
- Coordinate and disseminate:
  - national-level education and outreach programs.
  - instruction in social and ethical implications (SEI) of nanotechnology.
  - computational modeling and simulation across sites and interactions with nanoHUB of the NCN at Purdue.
  - laboratory safety and training procedures and best practices.

>> Larry Goldberg: The coordinating office has a very specific role. Because we selected these sites independently from individual proposals, we needed to have a coordinating method. And this coordinating office enables us to enhance the impact of the sites as a national infrastructure network.

The office has established a web portal, NNCI.net, in which you as the user community can learn about the tools, instruments, and capabilities that are available at all sites. This website also will guide you as a user as to which site or sites you may wish to access, and what instruments and processes they have that could enable you to complete your projects most successfully. Further, the coordinating office will coordinate and disseminate national-level education and outreach programs. There will be instruction in social and ethical implications of nanotechnology. And if you are interested in computational modeling and simulation, the coordination office will indicate how you can also interact with the nanoHUB at the Network for Computational Nanotechnology, at Purdue University, http://www.ncn.purdue.edu/. Finally, the role of the coordinating office also includes disseminating information about laboratory safety and training procedures, and best practices.

>> Larry Goldberg: At this point I would like to introduce our first speaker, Professor Marc Michel.

>> >> Marc Michel: Thank you, Larry. Hello, everyone. Thank you for your attention and interest in NNCI. I am calling today, as Larry said, from Virginia Tech, which is located in the southwest part of Virginia. So if you look at the map that is shown on my first slide here, you'll see in the lower left corner, we are one of the stars located in the nodes that are on east coast of the U.S.

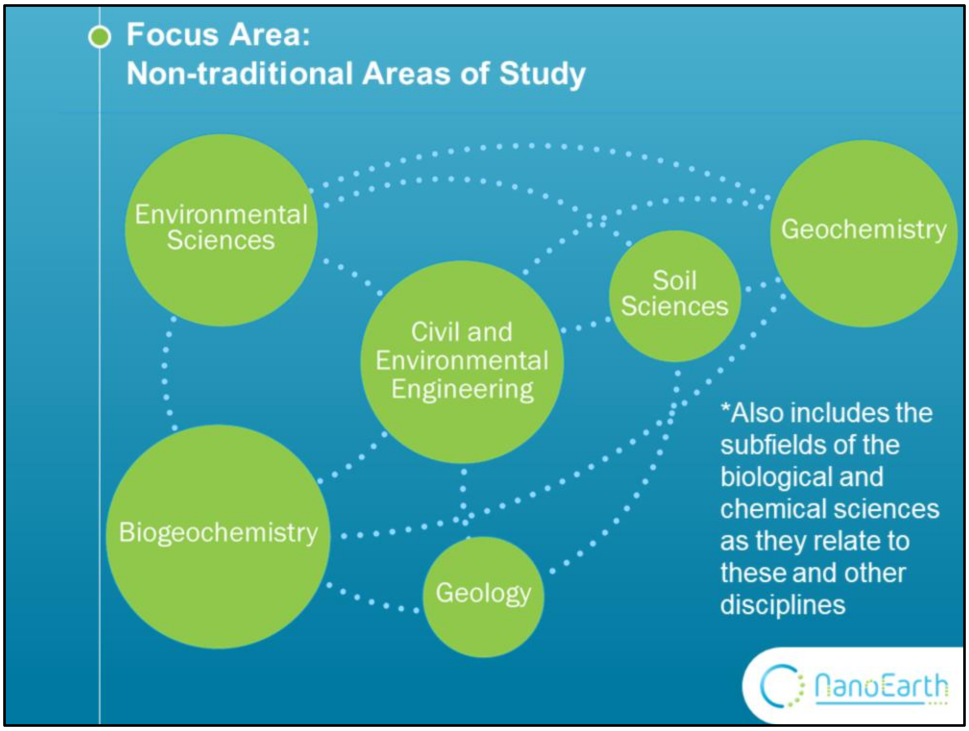
I am one of four co-PIs in the Virginia Tech National Center for Earth and Environmental Nanotechnology Infrastructure, which we shortened to a more convenient title called NanoEarth. And so you'll see in the lower right corner there our web address at nanoearth.org.

>> Marc Michel: So who are we? In the broadest sense we are a group of scientists, engineers, technical, and administrative staff that conduct and support earth and environmental nanoscience and nanotechnology research. So our specialty is understanding the roles that nanosized particles, whether natural or anthropogenic in origin, play in earth and environmental processes. In practice this means that we're skilled in two main areas. The first is doing field work, which is how we collect and preserve nanoparticles from the environment. So you can see in the upper left corner sampling from sediments from a river, for example, or in the lower right some work on atmospheric particles and assessing sites from the air with a plane.

Our second area of expertise is in performing synthesis and other types of laboratory experiments aimed at understanding the reactivity and other behaviors of natural nanoparticles. In doing all this work, we use cutting-edge nanoscience tools to study and understand nanosized materials. And one thing you should keep in mind, that I think is unique about our center: the samples that we mostly study, which in many cases are collected from the natural environment, like soil, sediments, water, and air, are especially complex. I'm going to demonstrate this a little bit later in the talk with some examples of our work.

>> Marc Michel: So finally, why is this type of research important? Well, natural nanoparticles are hugely abundant in the environment, and we know that they influence a vast number of different processes. For example, how contaminants and nutrients cycle in environmental systems.

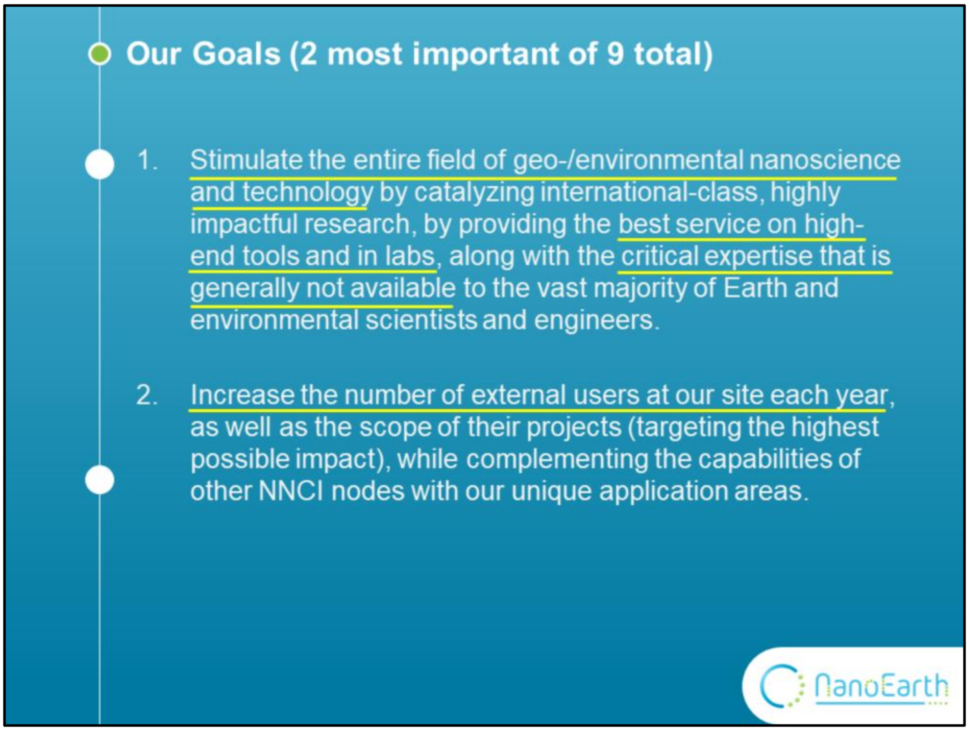
In addition, with the expansion of nanotechnology and nano-enabled products, more and more engineered nanoparticles will be released to the environment; both of these directly impact living things, including humans.



>> Marc Michel: So this graphically shows the specific areas we represent, and the size of the circles don't actually mean anything. They just need to fit on the slide. As mentioned previously, we are a group that includes scientists and engineers, and this is a unique strength of the center, because it allows us to tackle problems related to the intersection of the natural and engineered world. And because this also includes sub-fields of the biological and chemical sciences, it's actually a really big umbrella that encompasses our scope of work.

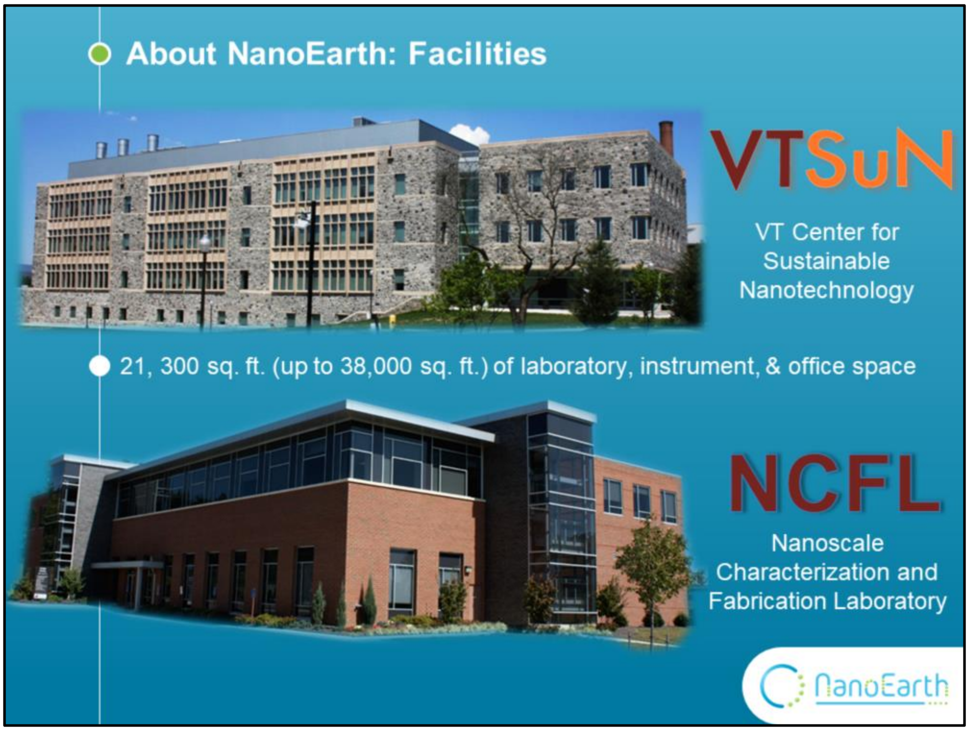
>> Marc Michel: I want to tell you a little bit about how we are different from the other NNCI nodes. This is language that was in our proposal to NSF. So I'm just going to read the part that is underlined there. Where it says that ”NanoEarth is designed to provide a network node to support external researchers who work with nanoscience and nanotechnology-related aspects of the Earth and environmental sciences, and engineering at local, regional, and global scales, including the land, atmospheric, water, and biological components of these fields.”

So what is important is that NanoEarth is the only NNCI node dedicated to the nanoscience and nanotechnology of Earth and its environment.



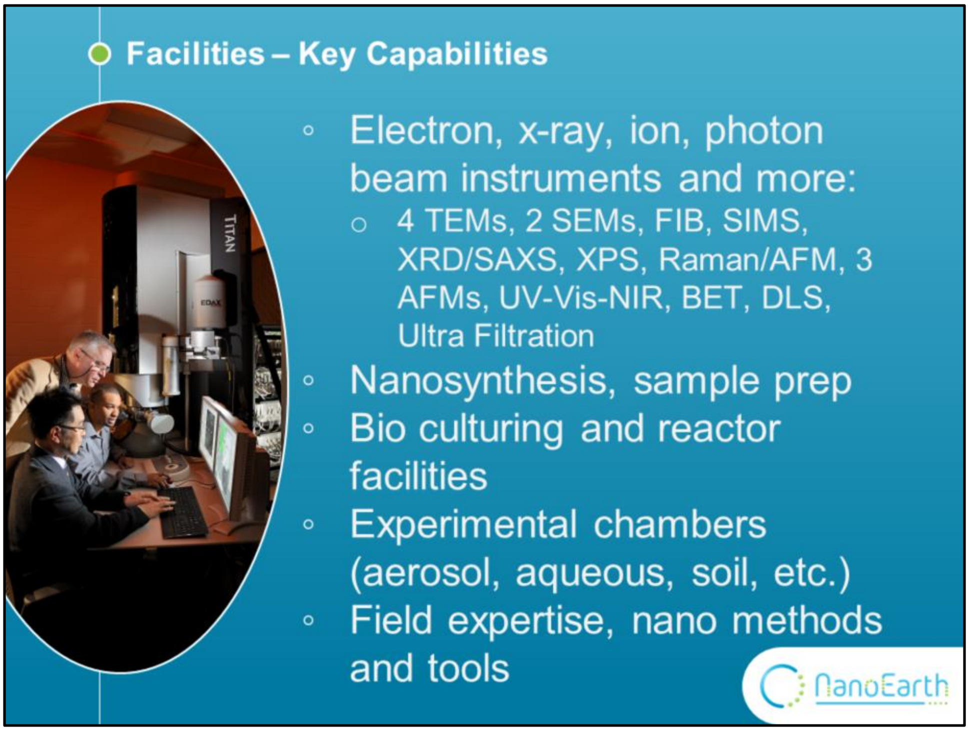
>> Marc Michel: So what are the goals of our center? I'm just going to talk about two of nine that we consider the most important. So the first is to really stimulate the entire field of geo- and environmental nanoscience and technology by providing the best service on high-end tools, and in labs, along with the critical expertise that is generally not available to researchers in this area.

The second major goal is to increase the number of external users at our site each year. And so for those of you watching the webinar today who are interested in the areas that I have been describing in terms of Earth and environmental nanoscience, this is really your invitation to come to Virginia Tech and work with us.



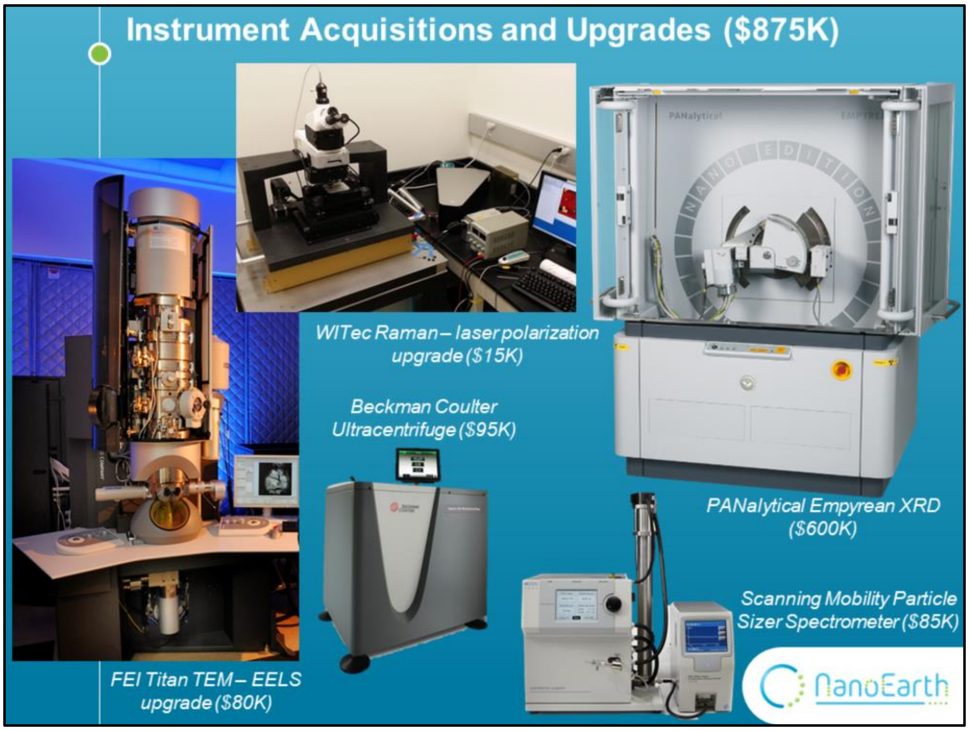
>> Marc Michel: So when you come to Virginia Tech as a user of NanoEarth, you'll work mainly in two facilities shown in the images here. One is VT Sun for short, which is the Virginia Tech Center for Sustainable Nanotechnology, and the other is called the NCFL or the Nanoscale Characterization and Fabrication Laboratory. We house instrumentation, lab space, and office space in both of these facilities. Together they comprise about 21,000 square feet.

I should point out that we are actually not a clean room facility; there are other nodes in the NNCI that specialize in clean room work. For the most part our samples are too messy to bring into a clean room.

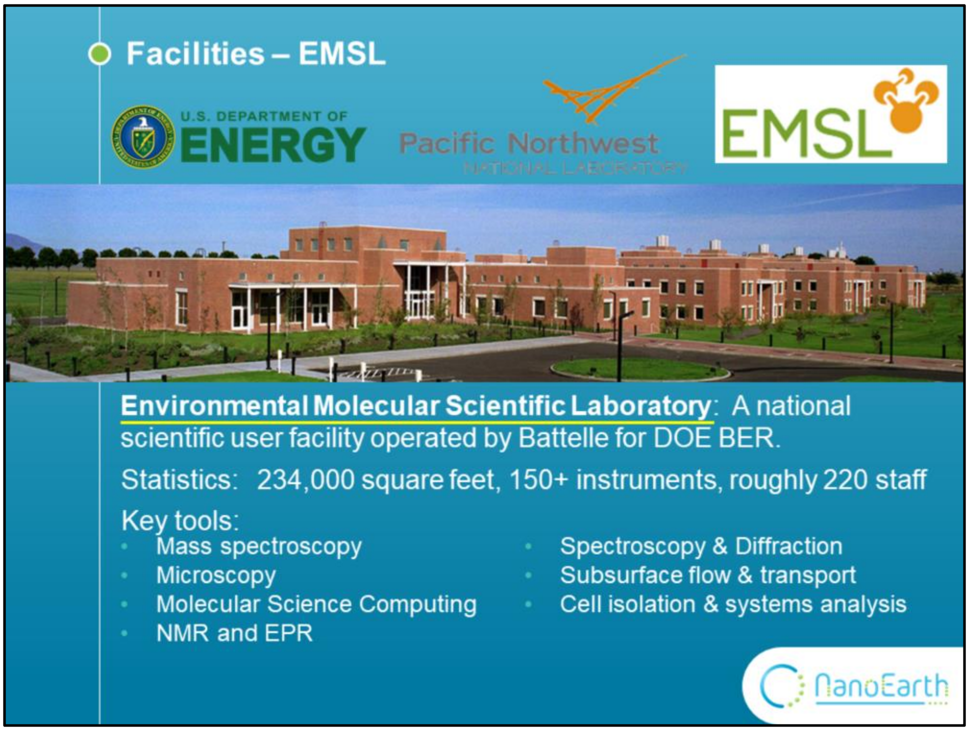


>> Marc Michel: Our key facilities involve materials characterization. So these include instruments like electron, x-ray, ion, photon beam instruments that conduct various types of imaging, spectroscopic, and scattering experiments. But we don't just provide analytical machines. We provide laboratories suitable specifically for the fields we cover, and especially provide experience and expertise in these fields.

This is often absolutely critical for our users, many of whom do not have prior experience or maybe even know that these different methods exist.

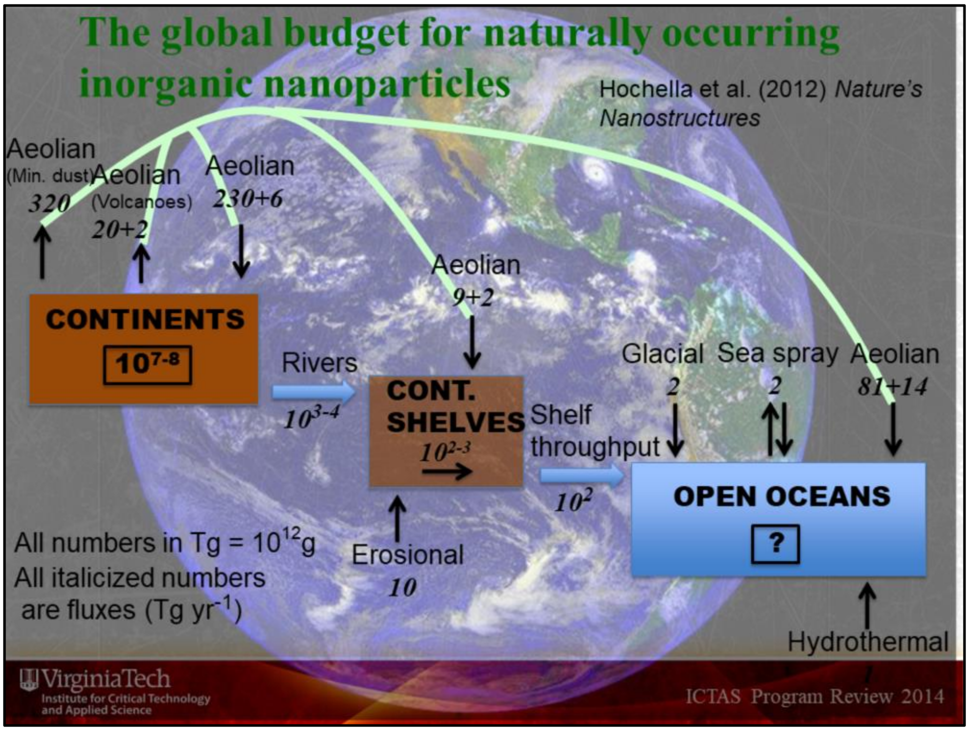


>> Marc Michel: Our capabilities have grown with time. Just in the last year we have acquired an upgrade of a number of instruments shown on this slide. A significant addition that I'll point out here was a new x-ray diffraction system shown in the upper right. It's made by the company Panalytical, and it facilitates different types of x-ray scattering experiments. So we just installed this in December of 2016. It allows us to do different types of scattering experiments aimed at understanding the atomic, structural, and physical properties of nanomaterials, and it really adds a beautiful complement to our other electron microscopy methods, and various other methods we have in our Center.



>> Marc Michel: We have one partner in our Center, and that is the Environmental Molecular Scientific Laboratory, or EMSL, located at Pacific Northwest National Laboratory (PNNL), which is in the State of Washington. And what EMSL (and PNNL) does for us is handle the things that we can't. For any users [who] need it. As you can see, this is a huge facility that is very well-equipped with both tools--and you'll see some of the key tools shown in bullets there--and also staff.

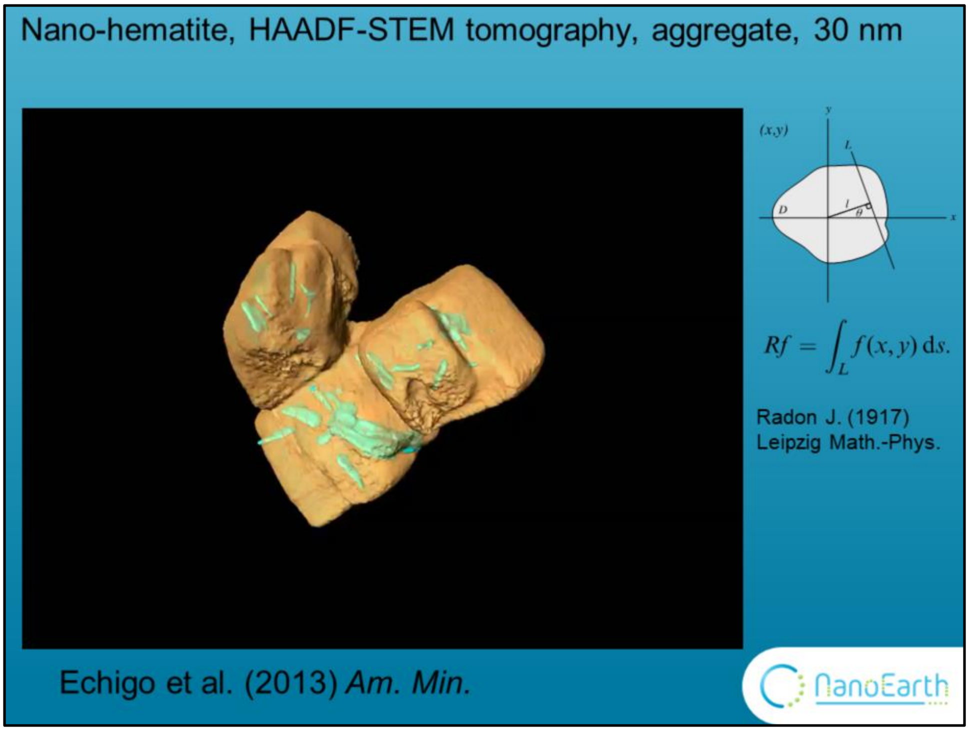
So what we do at NanoEarth for users is facilitate the connection with EMSL if it's needed. We also do work for PNNL, and this has gone both ways. We can send users to EMSL, and PNNL staff can also use our facilities, and both have happened to date.



>> Marc Michel: So this is the first of five slides of a diverse set of examples of work that NanoEarth can and has supported. So in this slide we're showing the estimated global budget for naturally occurring inorganic nanoparticles as determined by us. By the way, no one has attempted this before or since this paper was published in 2012 (http://www.crcnetbase.com/isbn/9789814364218).

All the numbers shown on this slide are in units of teragrams. So if you're not familiar with a teragram, it's 10^{12} grams or 1 million metric tons. The numbers shown in italics corresponding with the arrows between the different boxes are fluxes, and so what we're talking about are the masses of nanoparticles moving between the different reservoirs, shown here as the continents, continental shelves, and open oceans.

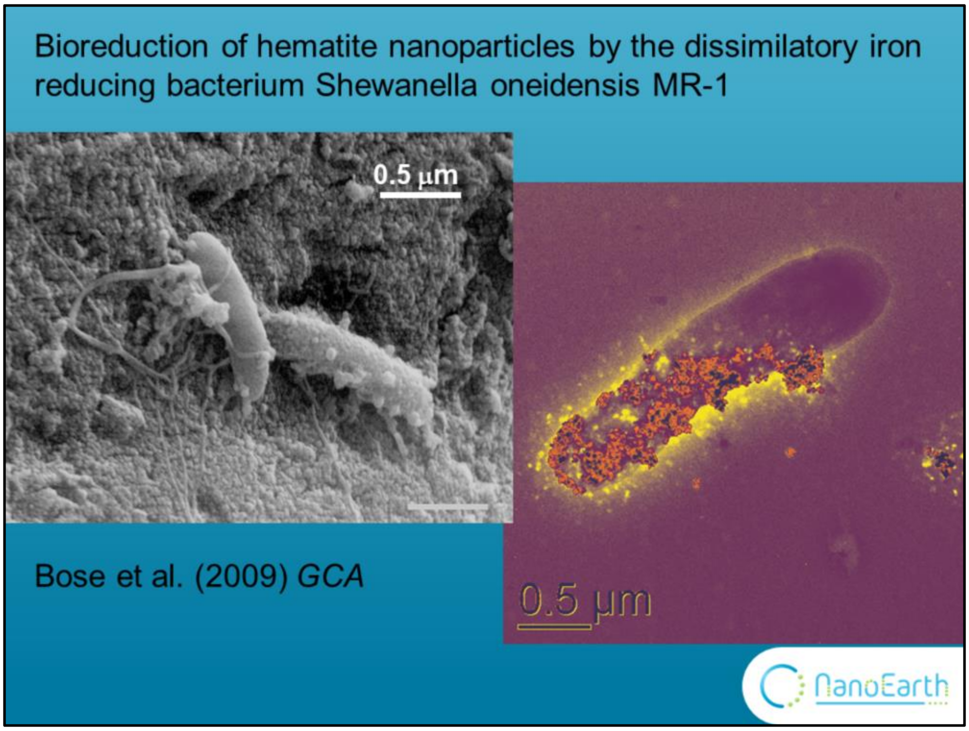
There are a lot of details in the slide and I don't want to get bogged down with it. I just want to make one point. The Earth produces naturally an enormous quantity of nanoparticles and many of the processes related to their formation, transformation, transport, and fate, as well as what roles they play in environmental processes, remain under-studied or entirely unknown. So my message to our audience is there is a lot of opportunity here.



>> Marc Michel: An area that we specialize in is imaging complex nanoparticles. So this slide gives just one example of the state-of-the-art work that we can perform in terms of imaging complex nanoparticles. The abbreviation at the top you see there, HAADF-STEM, stands for "high-angle annular dark field scanning transmission microscope tomography". So it's a fancy transmission electron microscope technique.

What you're seeing in the video is an aggregate consisting of some small nanosized synthetic hematites that are aggregated into the structure that is maybe 30 nanometers in diameter. What was unexpected in this experiment, and only possible to see using this type of method, is that this hematite nanoparticle actually contains internal void spaces. These are false colored in green there. So these green colored tubes are internal to the crystals and have diameters of about three to five nanometers.

What is important about identifying and characterizing these features is that they help to explain unusual behavior of this material during its reductive dissolution. Basically the rate of dissolution was higher than predicted because it was particularly rapid where the nanotubes intersected the hematite surface. This is an example of how some nanoscale characteristic of a material can influence its bulk behavior.

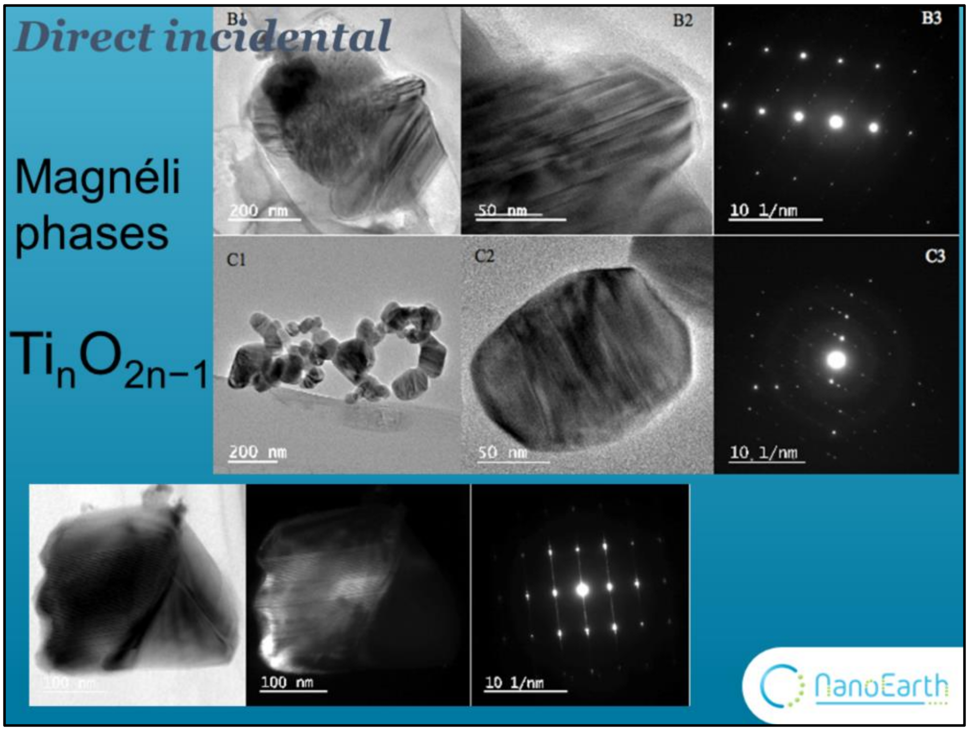


>> Marc Michel: One unique aspect of Earth and environmental nanoscience research is that it often involves the intersection of inorganic matter and life. What is shown here is an example of a microbial organism, specifically *Shewanella oneidensis,* interacting with iron oxide nanoparticles much like the one you saw in the previous example.

The picture on the right is from laboratory experiments that are described in the paper referenced, and the image on the left shows the same type of interaction in a natural soil sample. The elongated sausage-like shapes are individual microbes. And what they are coated in, that is sort of speckled in the image on the right, and are attached to, are minerals, including many nanoparticles.

Many types of microbes use nanoparticles for respiration when no oxygen is present. This process involves electron transfer where there is an electron donor, usually organic carbon and an electron acceptor, in this case iron oxide. Here the researchers showed that the size of the nanoparticles was critical to the efficiency of the microbial respiration process. This is important for understanding various processes related to, for example, soil fertility or the treatment of wastewater, among others.

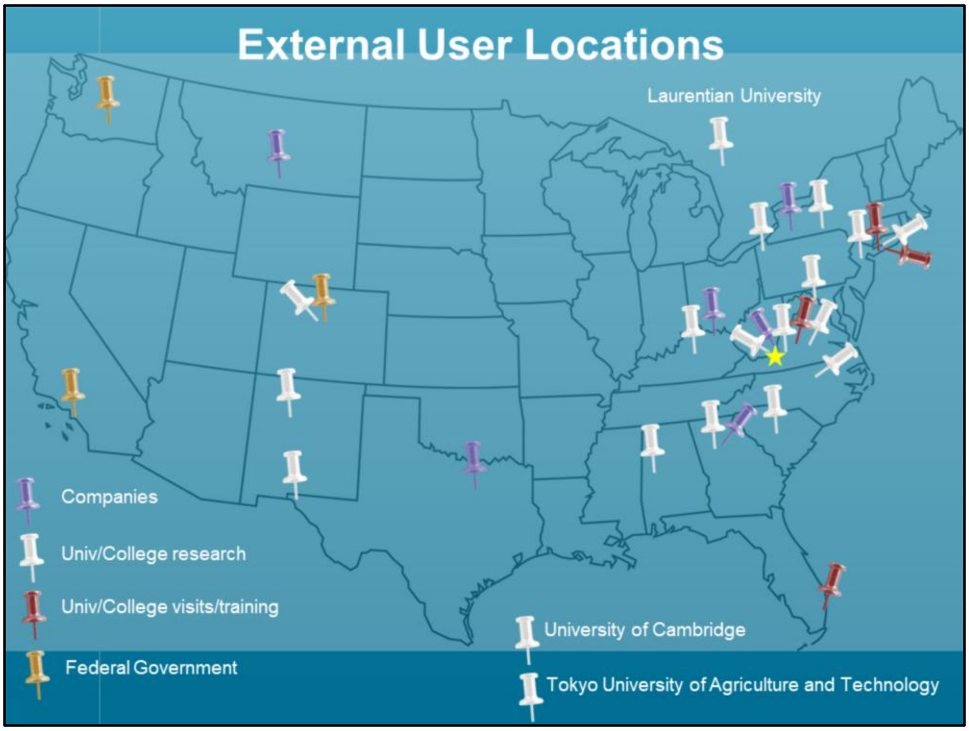
>> Marc Michel: This final example involves the recent study on the combustion products of coal. And as a reminder, coal remains a leading fuel for producing electricity worldwide. Despite environmental controls, waste products of coal combustion including particulate matter and coal ash, which contain many toxic elements, are continuously entering the environment through emissions and unintended releases. This study looks at what types are present in coal ash from sites in the U.S. and China.



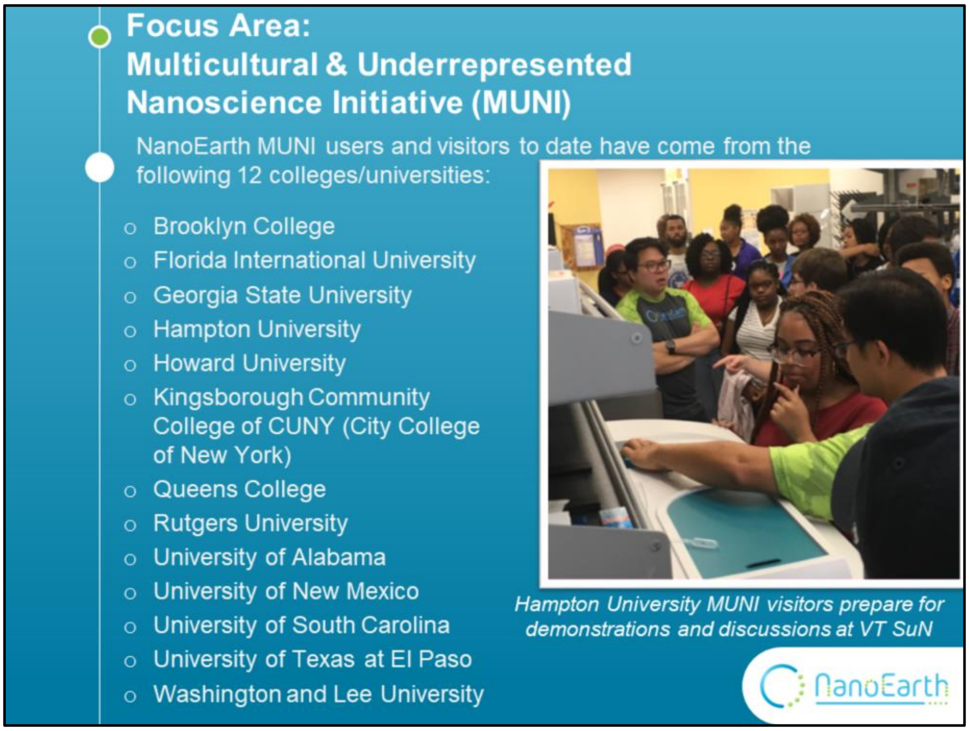
>> Marc Michel: So using TEM or transmission electron microscope methods, what the researchers were surprised to find were nanosized varieties of a rare type of titanium oxide known as a Magnéli phase. What you're seeing in these images are different size Magnéli-phase nanoparticles, and you can tell they're this particular rare phase because of that wavy-like, sort of alternating dark and light stripe appearance.

Shown on the right and at the bottom are electron diffraction patterns that were used to confirm their structural identity.

The researchers showed that these phases form during the coal combustion process, and this is significant because these phases are actually extraordinarily rare in nature. So what they realized is that these phases can actually be used to track where coal waste goes in the environment. In addition, the study also showed that these incidental nanoparticles may have significant toxicity. This paper is just about to come out in *Nature Communications*, and it's my opinion this is going to really prompt a lot of new research in this area.



>> March Michel: This slide is just to tell you the webinar audience that even though we have only been operational for less than 2 years, our users have already come from all over the country, to the yellow star, the geographic location of Blacksburg, VA. We have dozens of external users from 18 states across the U.S. and 3 other countries, using thousands of hours of instrument and lab time.

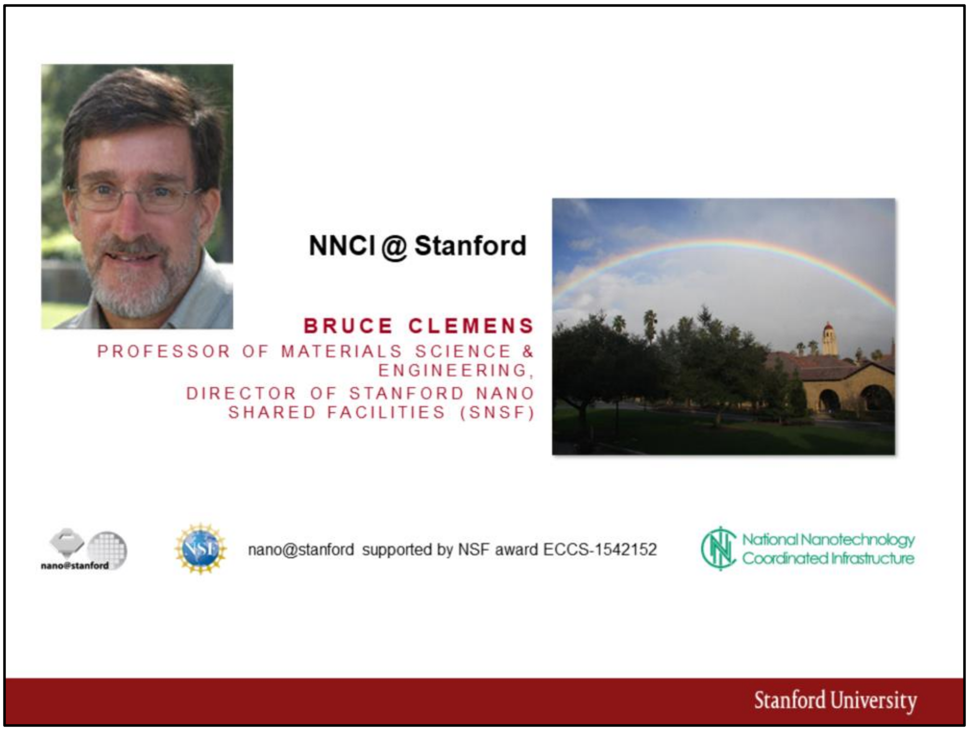


>> Marc Michel: A focus area of NanoEarth that I want to highlight is called the Multicultural and Underrepresented Nanoscience Initiative, or MUNI program. This program was designed to make our facilities and staff accessible to African American, Hispanic, Latino, and Native American students and researchers.

To date we have had users from 12 schools and ten states, and these are shown here in bullets on the slide. What you should know is that for students and researchers coming from under-represented groups, we pay for all of their experiences out of our budget. That includes travel, lodging, food, instrument, and staff time.

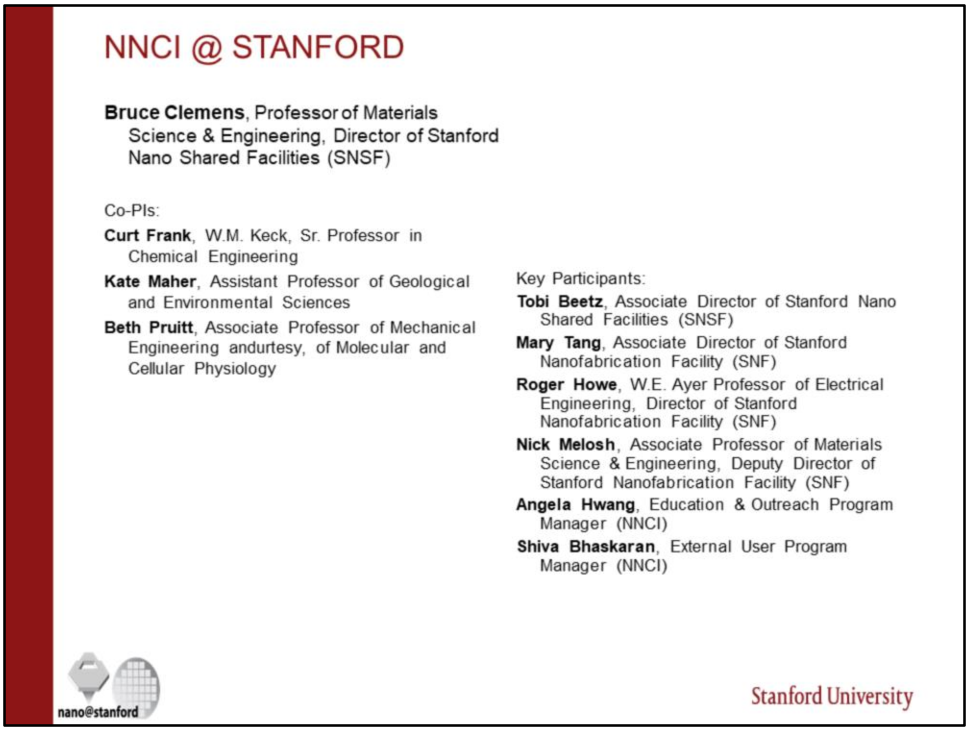
Finally I just want to say, new users are welcome and it's really easy to get started in our Center. If you go to www.nanoearth.org you will see a *Getting Started* tab on the home page, and from there you can submit an *Access Request*, a one-page document that will let us know what your research interests and needs are. And what follows from that is a dialogue that starts between our staff and you about getting your research underway.

And finally my thanks to the National Science Foundation for supporting our center and to our webinar audience today for your attention.



>> Larry Goldberg: Thank you very much, Marc. Again, I would like to encourage our listeners to send in questions to us in the question and answer period; we will try to have as many of those answered as possible. The next speaker is Professor Bruce Clemens from the NNCI site at Stanford University.

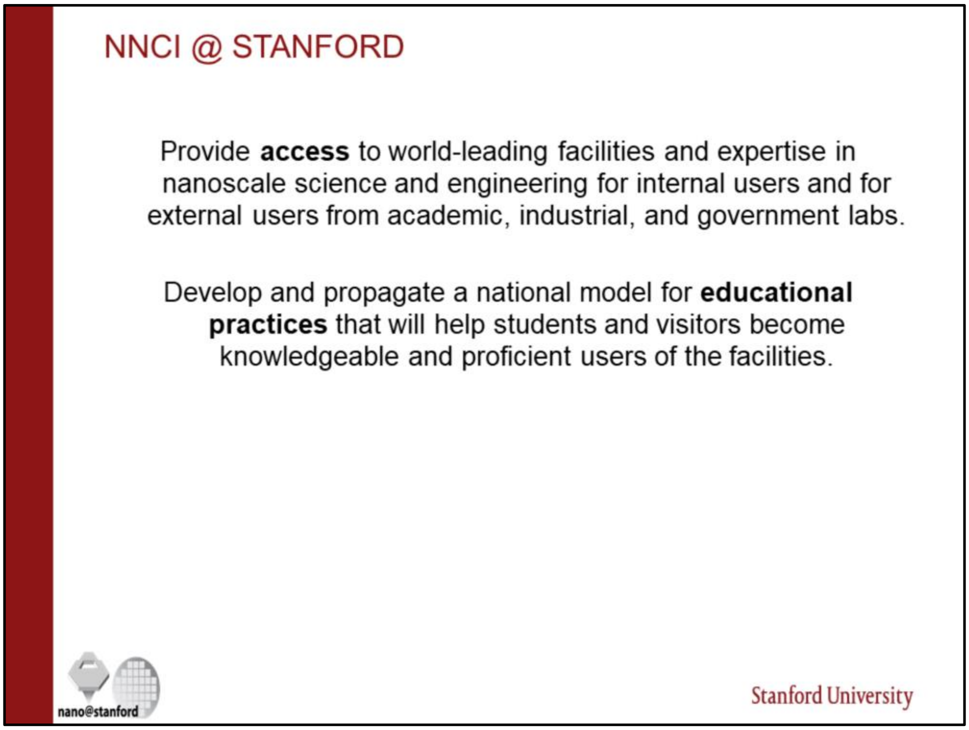
>> Bruce Clemens: Hello. Good morning. And good afternoon to all you guys who are out there. I want to start by thanking Larry and the organizers for this opportunity to talk to you today and also thanks to Marc for getting us off to such a good start with an interesting talk. I'm going to talk today about our work at Stanford, our center at Stanford centered around the National Nanotechnology Coordinated Infrastructure. I actually am in the Department of Materials Science and Engineering, but I also do have a joint appointment with Photon Science.



>> Bruce Clemens: Just to give you an idea who is involved –

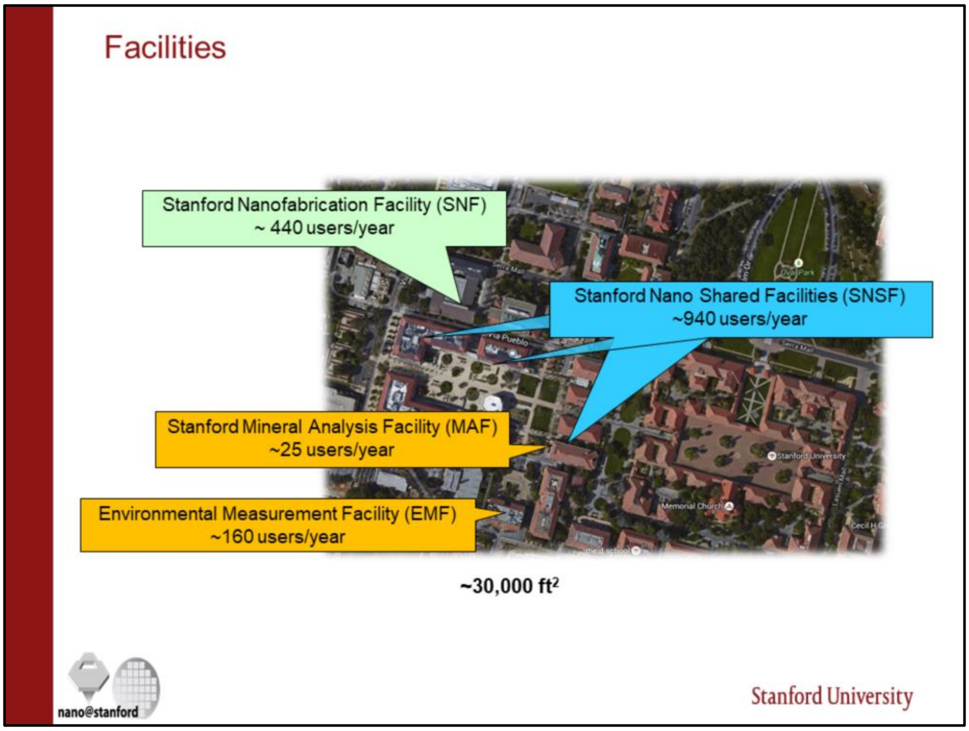
I'm Professor Bruce Clemens, and the NNCI grant at Stanford has three other co-Pis: Curt Frank in Chemical Engineering, Kate Maher in Geological and Environmental Sciences, and Beth Pruitt in Mechanical Engineering. We have a host of staff, and I'll mention several of them here. Toby Beetz works with me, and what I'll explain in a minute, is at Stanford Nano Shared Facilities, and Mary Tang is his equivalent over in the Stanford Nanofabrication Facility.

Both these facilities I’ll explain in a little bit, and both are part of an NNCI at Stanford. Roger Howe and Nick Melosh are my parallels as faculty directors, and Angela Hwang and Shiva Bhaskaran are both NNCI-related employees. Angela is head of education and outreach, doing a lot of interesting work that I won't have time to talk about. And Shiva is the guy you want to contact if you want to get into using our facilities. So he's tasked with helping external users get going at Stanford.



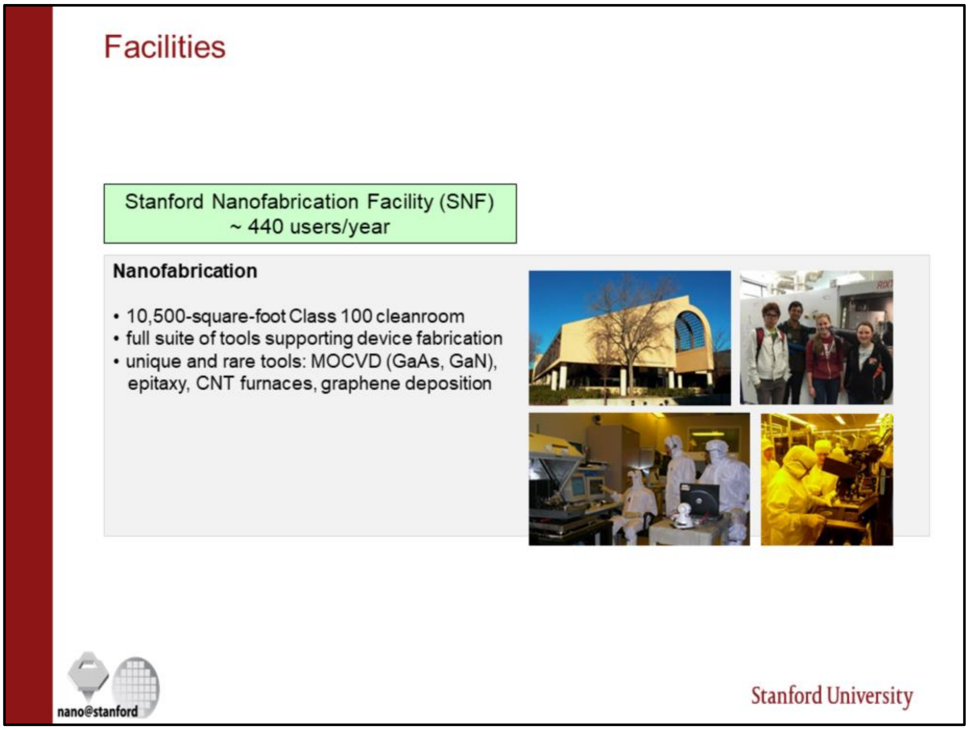
>> Bruce Clemens: Our goal is to provide access to world-leading facilities and expertise in nanoscale science and engineering for internal users, and also external users from every possible source.

And we also want to develop and propagate a national model for educational practices, and, again, I won't have time to talk about that today, but it's a big thrust of our NSF-supported effort here, to develop educational resources that are widely used, and widely useful for a wide range of nanotechnology users.



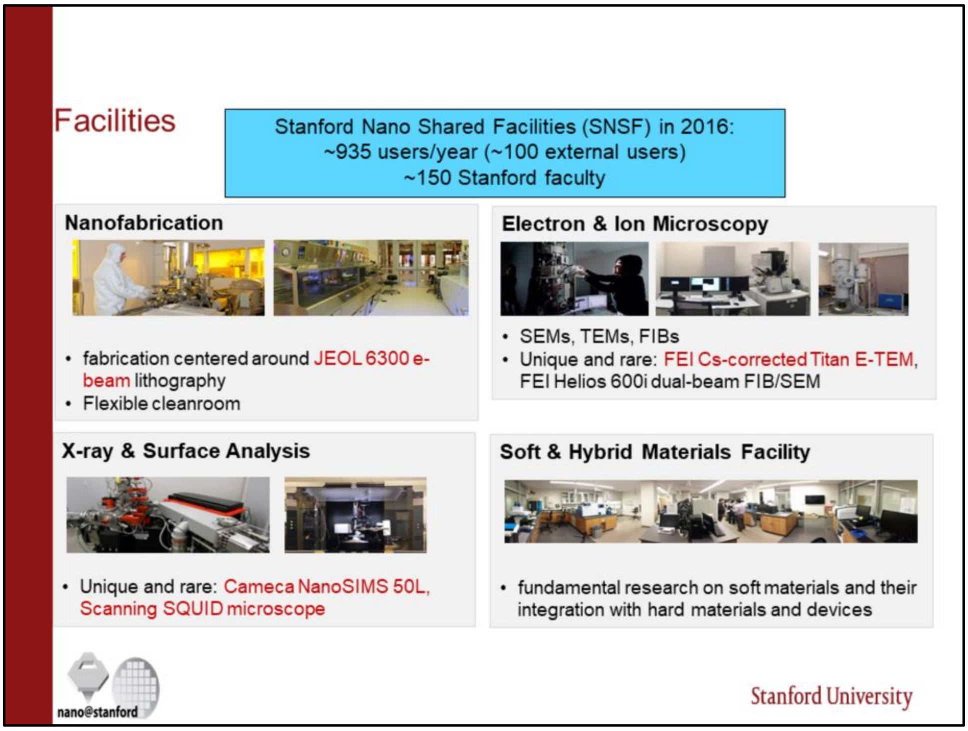
>> Bruce Clemens: So [among] the facilities that are in the NNCI at Stanford is the Stanford Nanofabrication Facility, SNF. I'll talk more about that in a little bit. We get about 440 users a year there. The Stanford Nano Shared Facilities, SNSF, of which I am the director, gets about 940 users per year.

And then we also have the Stanford Mineral Analysis Facility, and the Environmental Measurement Facility. Both of these are in the School of Earth here at Stanford and are focused on studies related to geological and earth-based materials.



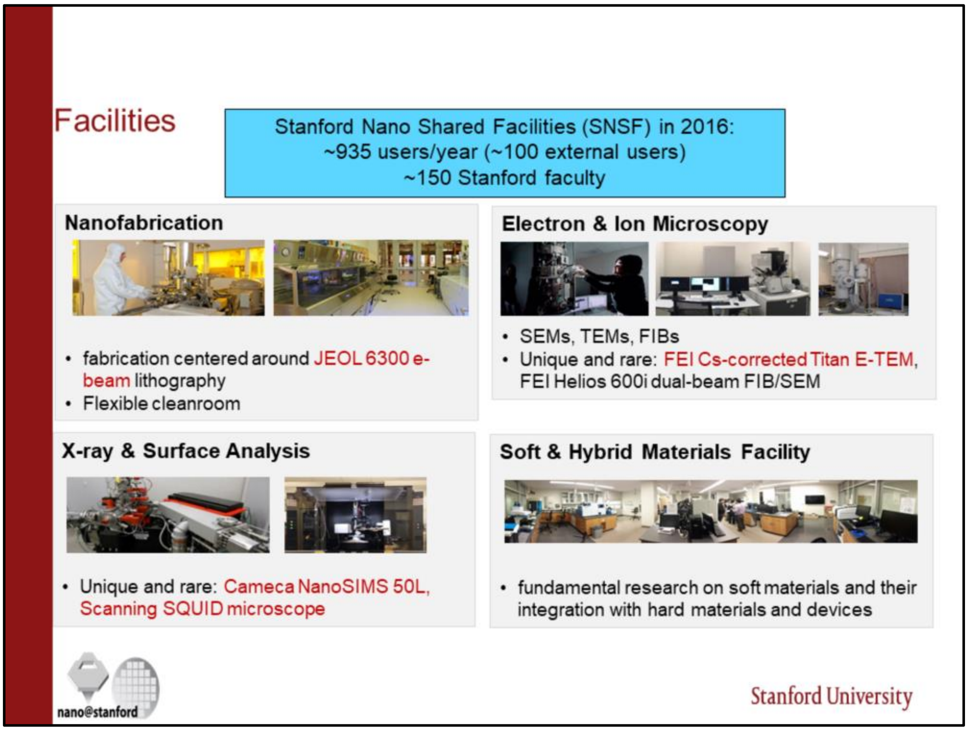
>> Bruce Clemens: The Stanford Nanofabrication Facility is a clean room; a 10,500 square foot, Class 100 cleanroom with a full suite of tools to support device fabrication. It's completely open to outside users, and we have a large number of outside users that use SNF. We have some unique tools in terms of their access from NNCI, and among those are MOCVD [metal-organic chemical vapor deposition], of both gallium arsenide and gallium nitride.

We have two different machines that outside users can use. And we have run a recent workshop on Atomic Layer Deposition (ALD) MOCVD that focused on getting people familiar with our capabilities here.



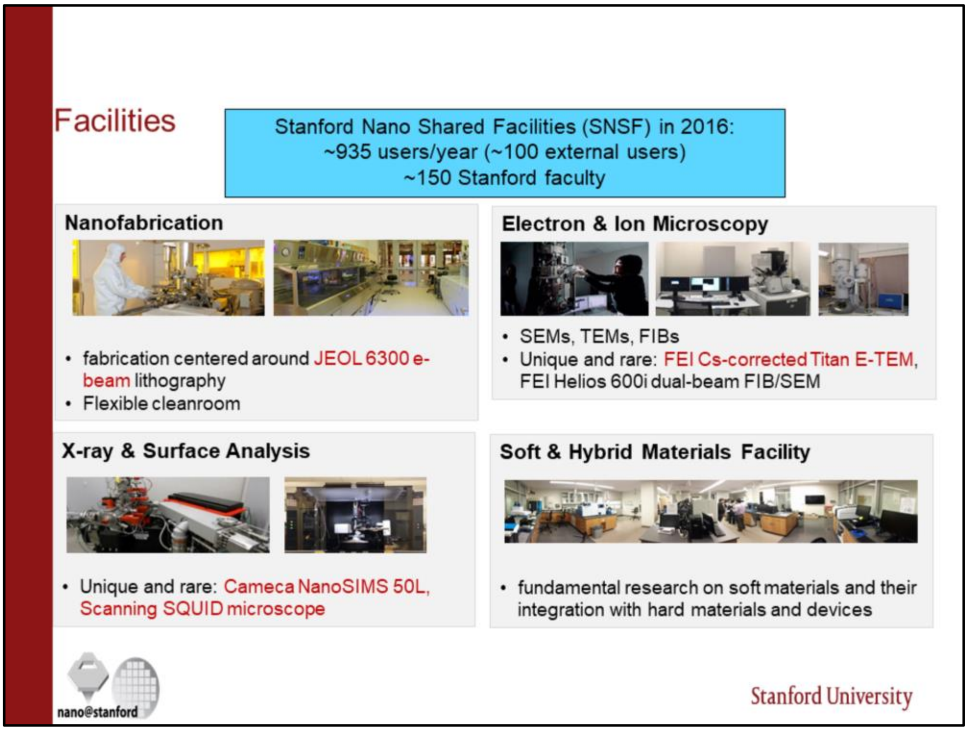
>> Bruce Clemens: We also have epitaxy and carbon nanotube furnaces and graphene deposition, and a new X-FAB, which is a more open cleanroom, open to a wider variety of material sets than a traditional cleanroom. The Stanford NanoShared Facilities itself consists of four facilities. First is nanofabrication, and these [facilities] are centered around electron beam lithography. Here we have a JEOL6300 e-beam lithography system that is state of the art for producing small patterns for devices.

We also have what we call a flexible cleanroom that is similar to X-FAB in that it allows you to do lithography on a wider range of materials, and particularly small samples. A lot of people developing new materials technologies don't have a full-size wafer, which is what traditional cleanrooms are set up to handle. We're set up to handle small little bits of things [that] you may want a pattern.



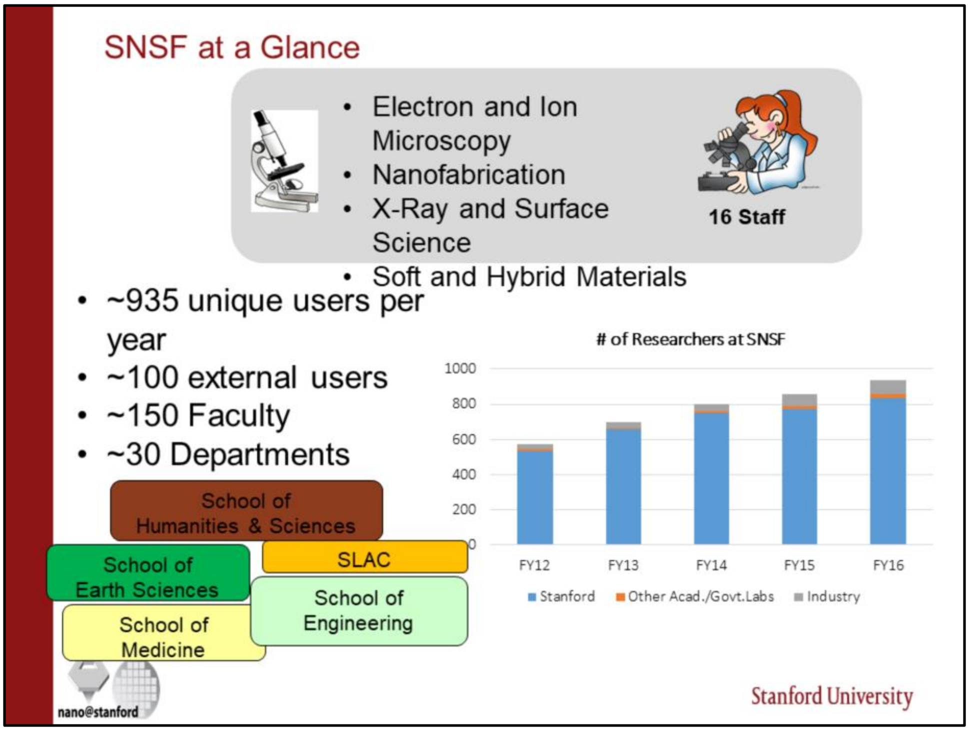
>> Bruce Clemens: The X-ray and Surface Analysis facility has several x-ray diffractometers, with some *in situ* capabilities, and we also have a Cameca NanoSIMS tool that we'll talk more about in a minute, because I think it is unique in the NNCI, just one of the few in the country, and it has remarkable capabilities. Another unique apparatus we have is a scanning SQUID microscope that allows you to take magnetic measurements on a nanometer scale. And not listed here is also an x-ray tomography tool that gives high-resolution 3D non-destructive images of minerals and other materials.

In the electron and ion microscopy facility, we have aberration-corrected Titan electron environmental TEM that allows you to do high resolution imaging while exposing your sample to a variety of gases. We also have a large number of sample holding cells that allow you to look at materials *in situ* and *in operando* in liquid or up to atmospheric pressure, and gases up to high temperatures. And we also have a dual beam FIB SEM for preparing TEM samples and other types of work.

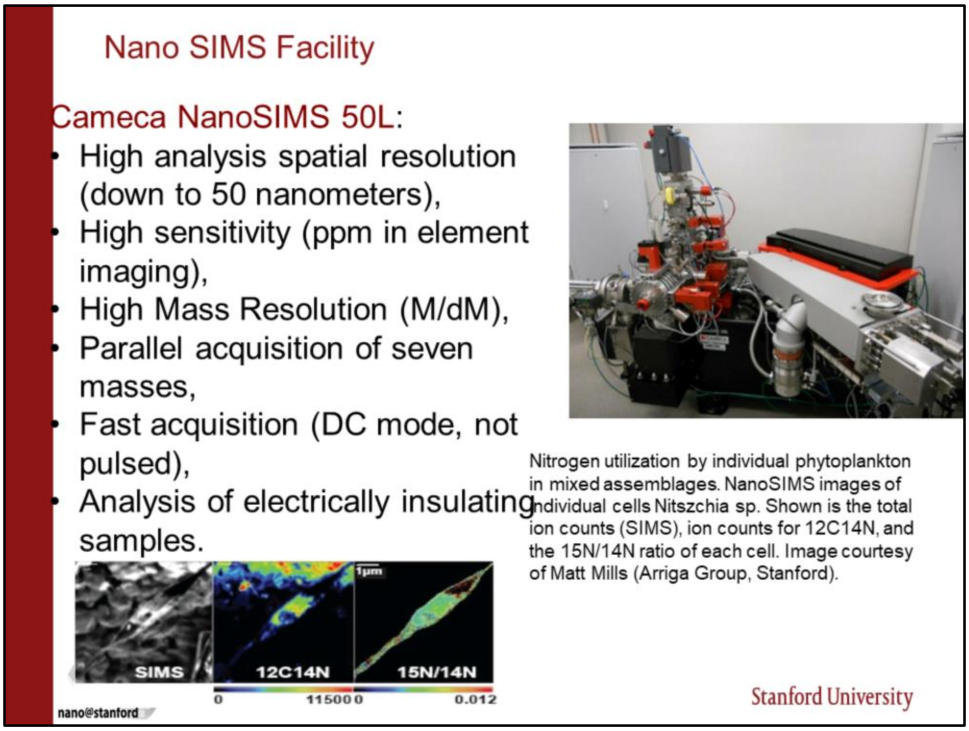


>> Bruce Clemens: The fourth facility in SNSF is the Soft and Hybrid Materials Facility, and this facility focuses on soft materials, obviously, and we have maybe a dozen or two dozen different pieces of apparatus all available to researchers, both inside Stanford and the outside world. It's a fairly powerful collection that is well-maintained and has expert trainers and users. By the way, [for] all these facilities at Stanford, we train you to be the user. So if you want to learn how to use the facilities, we'll train you how to do it and then you can use the facilities to do your research.

So we have 90 members of the audience today, I understand. I'm hoping that we get 90 new external users, so you're all welcome to contact me or Shiva and we'll help you get set up.

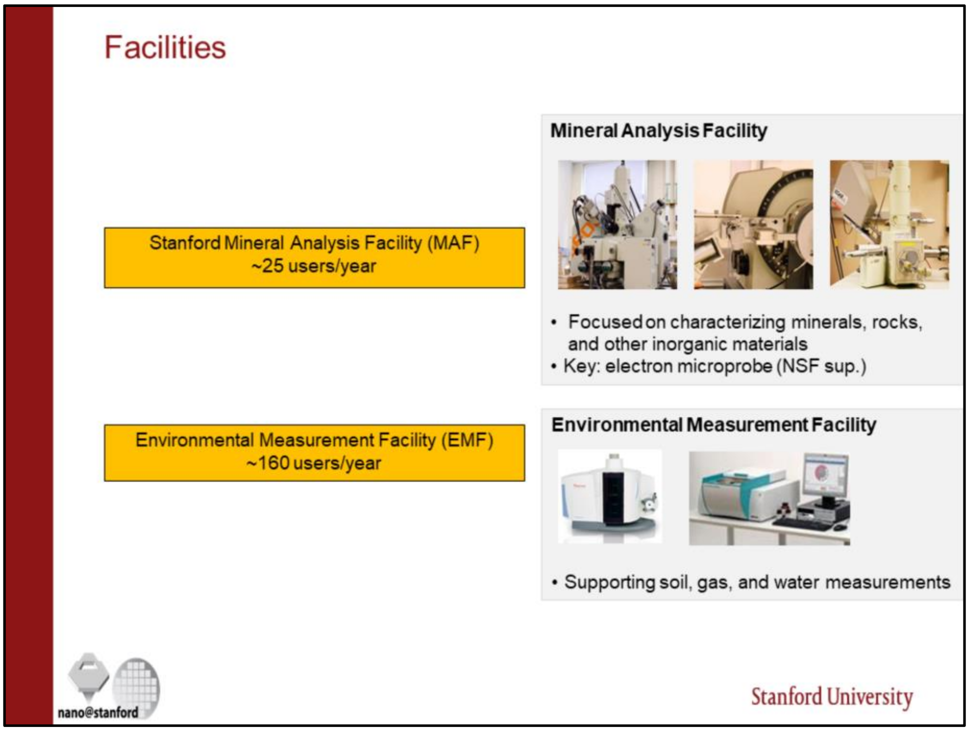


>> Bruce Clemens: Just to give you an idea, a little bit more about SNSF, as I mentioned we have about 940 users per year. We're growing so much I like to think that we're going to have 1,000 this year. I've challenged the staff to see if we can get a nice round number of 1,000 this year. We have about 150 faculty groups that use it, and 30 different departments, [from] five different schools.



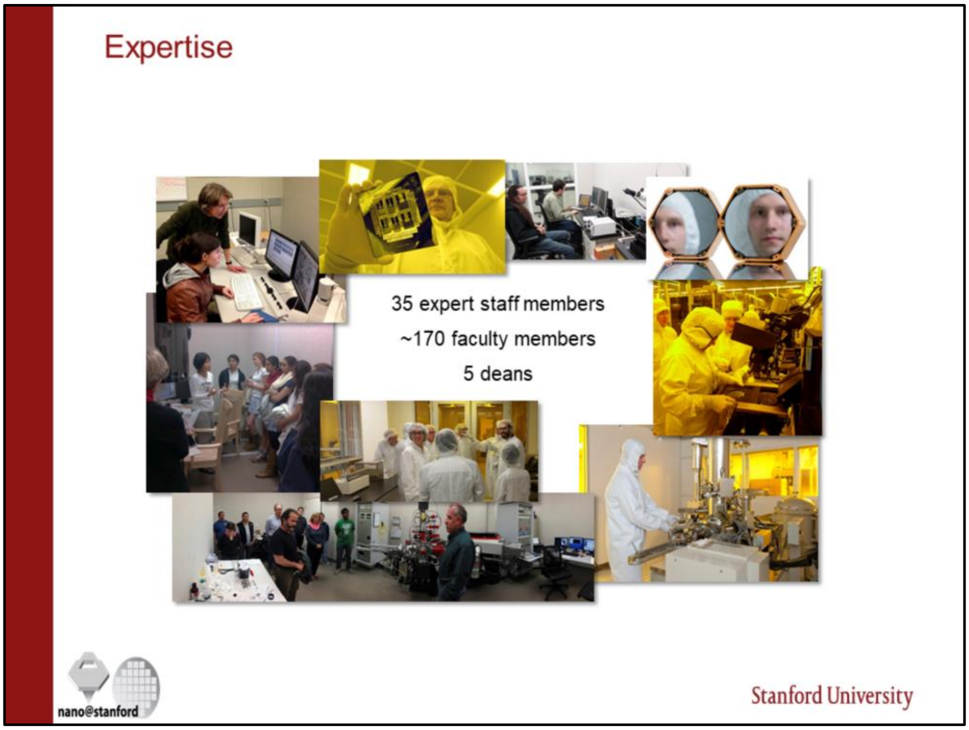
>> Bruce Clemens: So just a little bit more about the NanoSIMS facility, it's a Cameca NanoSIMS 50L, which is a state-of-the-art piece of equipment. It has high resolution, down to about 50 nanometers. It has high sensitivity, high mass resolution. You can [do] parallel acquisition of seven different masses with fast acquisition, and you can analyze insulating samples.

Shown here is an example from our work at Stanford here, where they've looked at nitrogen uptake and microbes, and this is an individual phytoplankton showing different nitrogen isotopes in different locations in this creature.



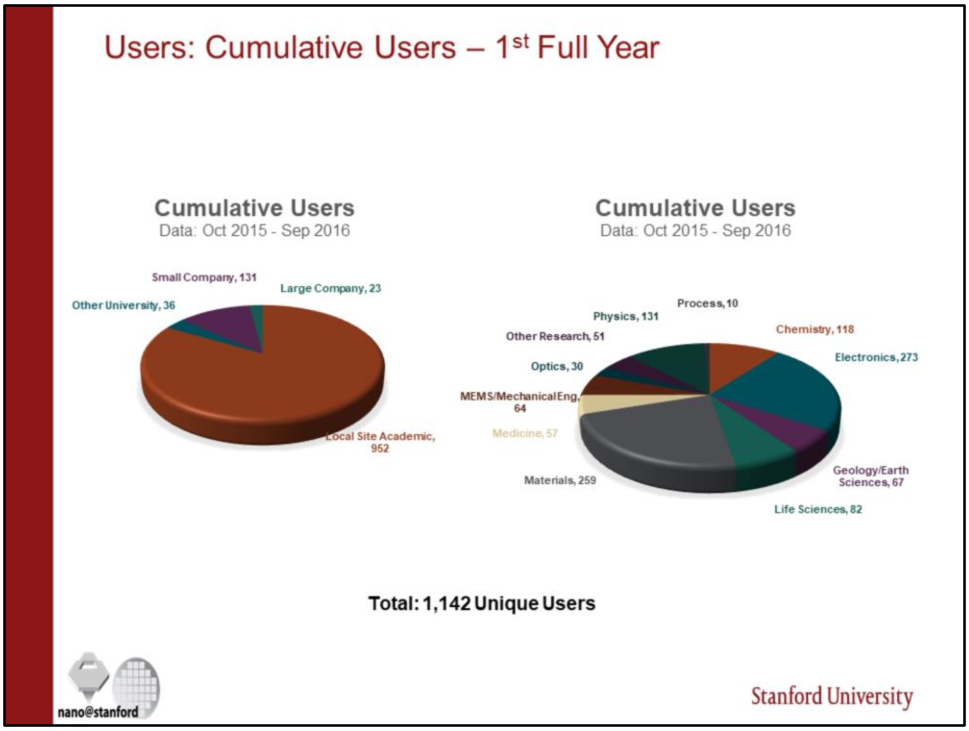
>> Bruce Clemens: Back to the last two facilities, the Mineral Analysis Facility has x-ray diffraction, SEM, and electron beam microprobe all aimed at focusing on minerals. I'll show some results from this capability when we move on.

And then we have the Environmental Measurement Facility, which has things like inductively coupled plasma [ICP] for measuring concentrations both in liquid, and also we use it in my group, for example, to measure accurately the composition of films that we grow. You just dissolve the film in an acid and run it through an ICP, and that gives us accurately the composition.



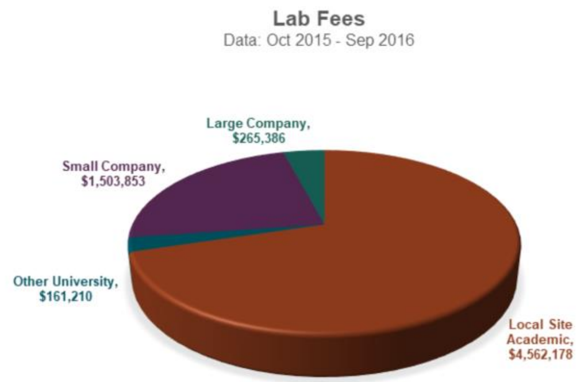
>> Bruce Clemens: So we have about -- between these four facilities we have about 35 expert staff members, 170 faculty members, and 5 deans. We also have a large number of student staff members we hire to do training. Once the students become expert enough and later on in their grad school careers, [if] they want to experience the interesting opportunity to teach people, they can also become trainers.

We run a large number of workshops and also outreach events for a local and more remote under-represented universities and colleges.



Just to give you an idea of the numbers, here is our first full year of use. We had a total of 1142 unique users from a wide range of disciplines. Including materials, life sciences, geology, electronics, chemistry, physics. So a huge number of disciplines from different places, academic, other universities, small companies, and large companies.

Users: Lab Fees – 1st Full Year



Total: $6,492,627

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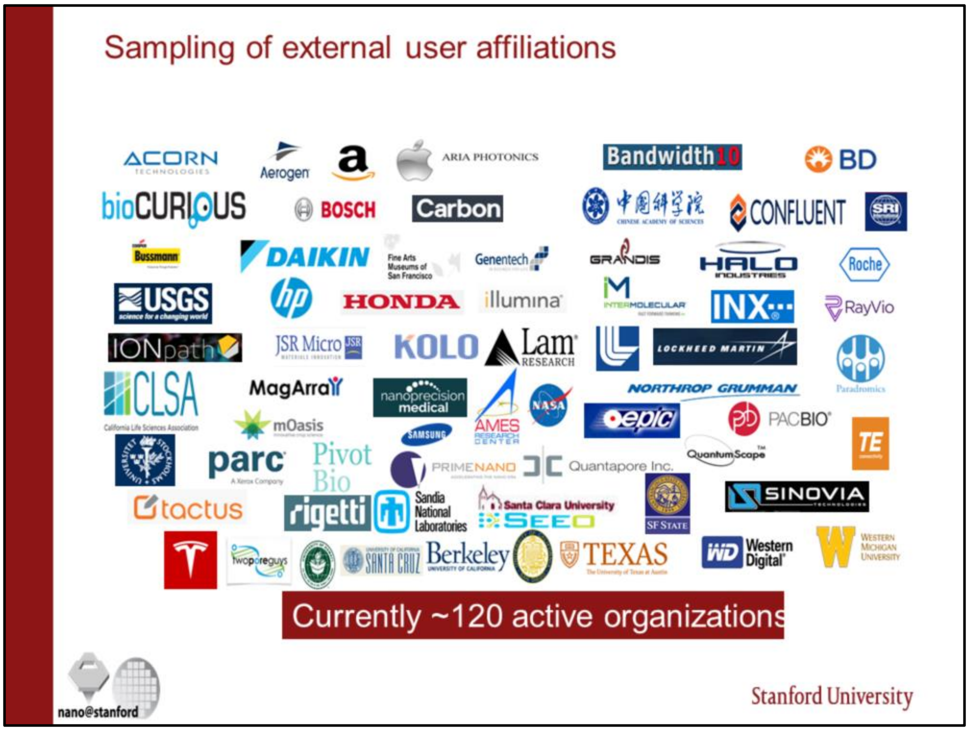
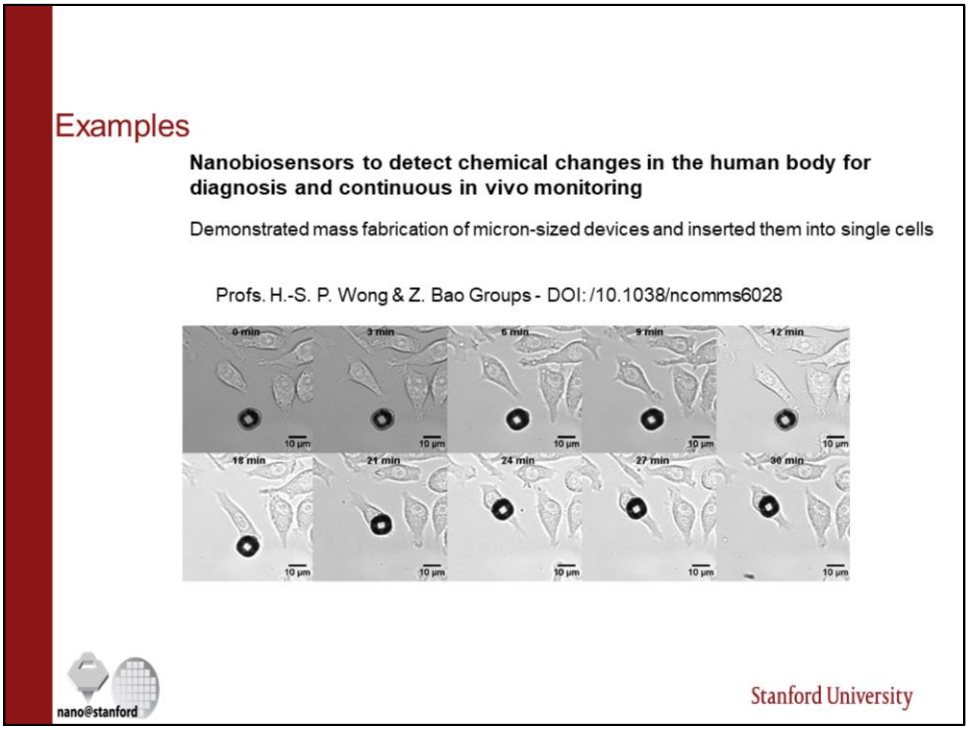
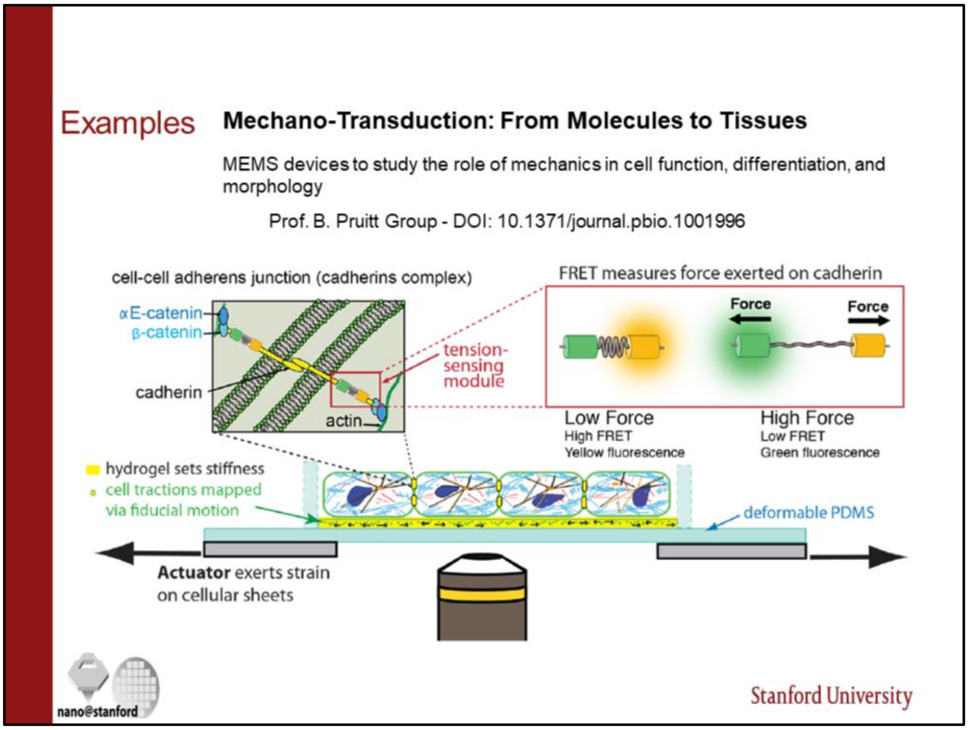
This gives you an idea of our budgets, in total about $6.5 million.



>> Bruce Clemens: This is just a slice of some of the external users we have. I'll talk some more about a couple of these in particular, but you can see we have quite a range of companies, from some of the largest companies in the world to some of the smallest companies in the world. And all of them find our facility useful, and also universities and other external entities, national labs, and so forth. We think that having this vibrant culture of external users is important for us to keep on top of what is going on throughout the world in the area of nanotechnology.

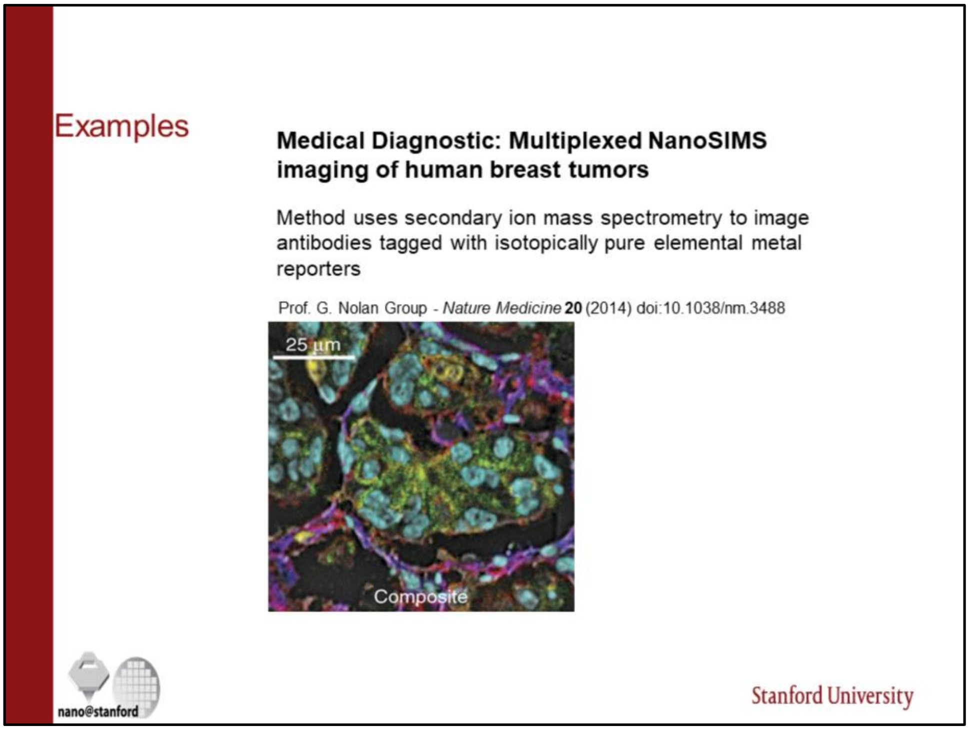


>> Bruce Clemens: So I'll turn to some examples, and this is an example from Stanford where they're making sensors. And among the sensors they're making are chemical sensors that can go in individual cells, but also they make extremely small pressure sensors that can be implanted inside a body and sense remotely to measure, for example, blood pressure. So they can do this with a sensor that is as small as 1/10th of a cubic millimeter to remotely sample and send out signals about blood pressure.



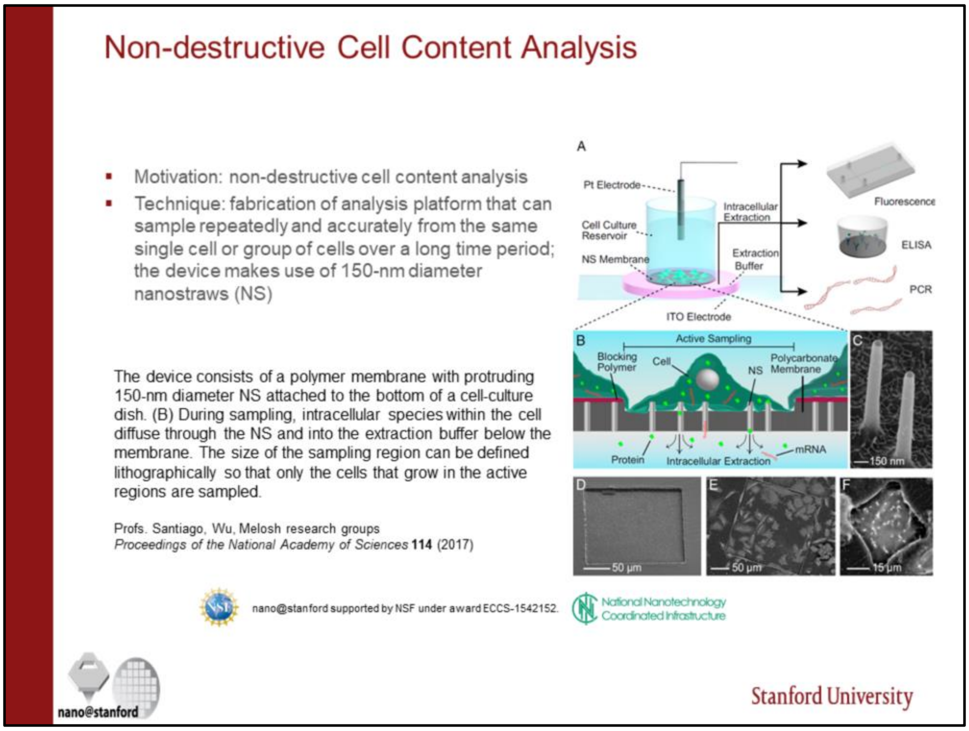
>> Bruce Clemens: This is [an] example from Beth Pruitt, who is one of the co-PIs in the NSF NNCI Stanford grant. Her work is in understanding the role of force on biological processes. So force can arrange the way cells, change the way cells are arranged, change the way cells are developed, change the shape of cells and their interaction with each other, and it can also change the way individual proteins are conformed. So Beth has an array of sensors that she uses at a lot of different length scales to investigate the effects of force on biological processes.

See https://doi.org/10.1371/journal.pbio.1001996.g004

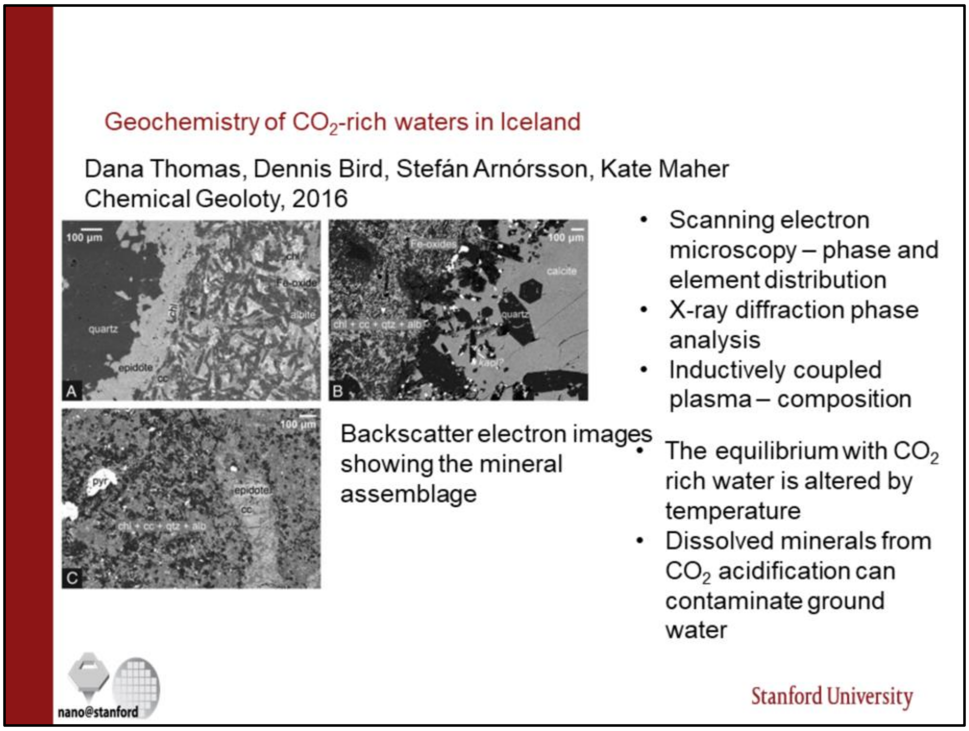


>> Bruce Clemens: This is an example -- I'll talk about it a couple times, actually, because it's both a collaboration with an internal group from Professor Nolan, but also an external group that is interested in similar things. And this is this technique of using our NanoSIMS to tag antibodies with isotopes and then you can track where antibodies go within a cell.

This is an example of a breast cell cancer, looking at how different antibodies move around. And the nice thing about using a NanoSIMS is you can multiplex by tagging different antibodies with different isotopes, and then track their location with the SIMS.

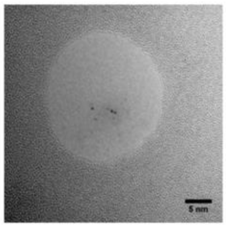


>> Bruce Clemens: Another life sciences [project] that is going on here is a collaboration between three Stanford professors, Santiago, Wu, and Melosh. What they're doing is developing nanostraws that can sample a cell environment. So they use patterning on a variety of different length scales, including down to just a few tens of nanometers across in the nanostraws, but also they pattern the nanostraws, so they pattern the substrate upon which the nanostraws are made, so they can control where on that substrate cells are sampled, and then they can put cell and cell environments on top of the nanostraws and draw material in and out of the nanostraws to sample it in the environment and even control the environment by putting in, you know, proteins, for example, through the nanostraws.



>> Bruce Clemens: This is an example from Kate Maher, who is also one of the co-PIs of the NSF/NNCI grant, and she's interested in how CO_2 affects chemistry and geochemistry, and she's found an interesting place in Iceland where there's naturally CO_2-rich environments. And she and her collaborators have studied the effect of this CO_2 on the equilibrium that results in these environments, and also its effect on groundwater. And so she uses scanning electron microscopy and inductively coupled plasma and x-ray diffraction and a host of techniques to look at this equilibrium as well as doing detailed modeling of the processes, and they find that [in] the CO_2-rich water, first of all, the equilibrium is altered by temperature. In fact, in Iceland, the temperature is lower than many other environments. But they also find that the CO_2 acidification can result in dissolved minerals and contaminate groundwater with undesirable things such as arsenic. So this has big implications for CO_2 storage in the environment.

SRI INTERNATIONAL



TEM image of a nanopore made in a thin silicon nitride membrane using the electron beam of the TEM

Research at SNSF/SNF – Fabrication of electrophoretically drive nanopore device to count particles or molecules

Reason using SNSF
Stanford facilities has better capability than SRI's in-house tools

Instrument Used:
Fabrication – TEM, HF Vapor Etch, Wet benches
Characterization - SEM

Company Profile
- Nonprofit – Research center serving government and industry partners
- Research focus – Biomedical, materials, earth and space systems, energy and environmental technology, sensing and devices.

Images courtesy of Dr. Dr. Matt Puster

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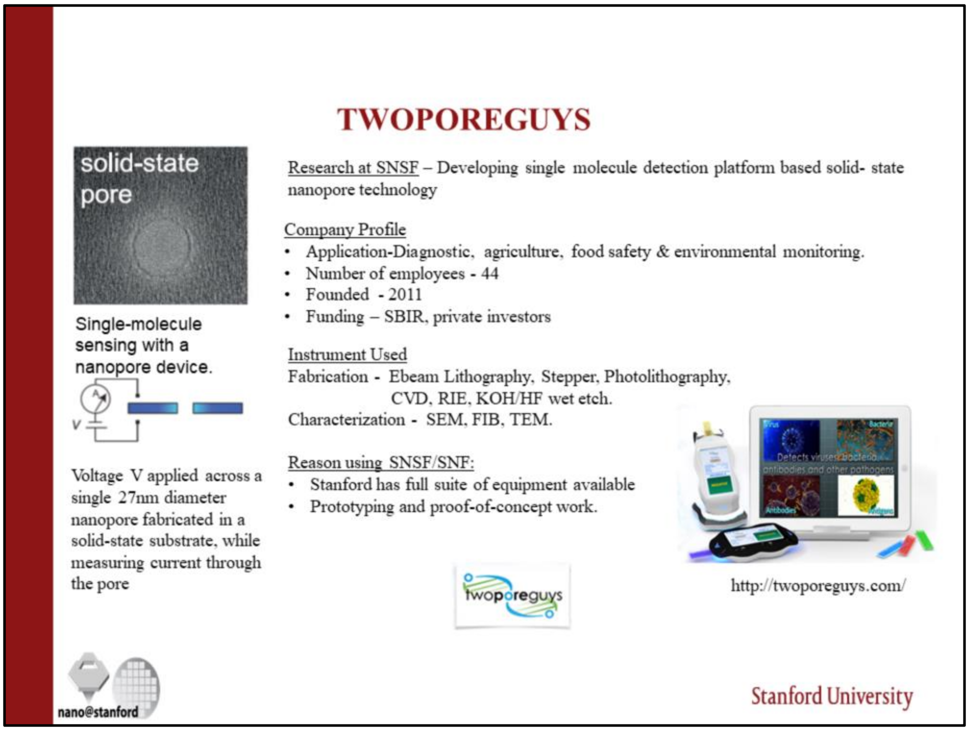
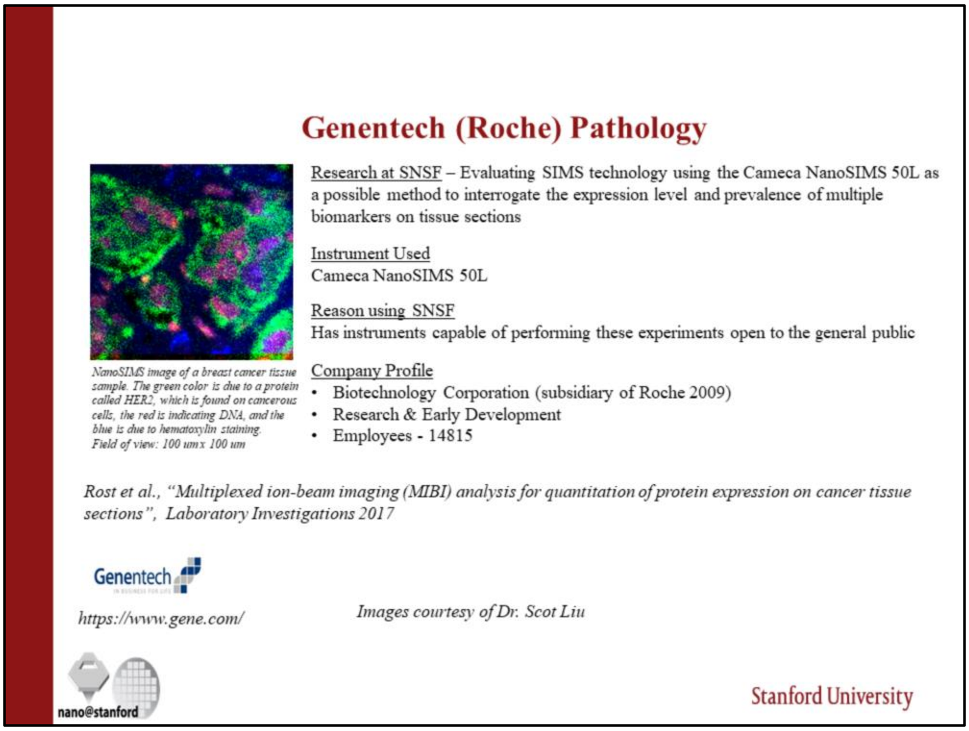
>> Bruce Clemens: Turning to some of our external collaborators. SRI International finds our facilities useful.



>> Bruce Clemens: As does a small company, Two Pore Guys, who are manufacturing nanopores, and they’re looking at individual molecules going through these nanopores for a variety of environmental and safety agriculture applications.



>> Bruce Clemens: And then Genentech; I already mentioned this example where they're using SIMS to look at this multiplexed, high-end beam imaging.

>> Bruce Clemens: So with that, I'll wrap it up and say thank you again to the NSF for [its] funding. It's been tremendously helpful for us to integrate these four facilities here at Stanford through the common envelope of the NNCI funding as well as to interact with the 15 other sites, and I think it's a great program and we are really proud and happy to be part of it.

And thank you to the audience for your interest in my talk today on our facilities network.

Q&A Session

Q: *I am from South Dakota and far from the SNSF. Is there an option where we can ship samples in and request the facility to deposit nanoscale coatings?*

>> Larry Goldberg: Thank you very much to both speakers. I would like to start with some questions. We've got a number of them from our audience. For Bruce, the first one is we have an interested user who said, *I am from South Dakota and far from the SNSF. Is there an option where we can ship samples in and request the facility to deposit nanoscale coatings*?

>> Bruce Clemens: We do some [of] what we call service work, where our main mode of operation, as I said, [is] we train users, and we would like to see you here as a user. But for some cases, we are able to help people do things that can't be done elsewhere. One thing in our service work that we call "service," where we do work for other people, we try to avoid doing things that can be done commercially. So if there's a commercial outfit that can do it, it's usually easier and faster for the people to go and work with them. But in cases where we can provide a service that is not available commercially or elsewhere, then we do try to accommodate them.

So I would encourage you to contact me or Shiva and ask about your particular application, and we'll try to get you an answer one way or another as quickly as possible, and hopefully we'll be able to help you out.

Q&A Session

Q: Does the Virginia Tech Center work with the Center for Environmental Implications of Nanotechnology on analysis of ENMs in wastewater residues used as agriculture fertilizer? And what kind of soil science experiments have been conducted with your infrastructure?

>> Larry Goldberg: Another question we have, this one for Marc. *Does the Virginia Tech Center work with the Center for Environmental Implications of Nanotechnology on analysis of ENMs [engineered nanomaterials] in wastewater residues used as agriculture fertilizer? And what kind of soil science experiments have been conducted with your infrastructure*?

>> Marc Michel: Thank you for the question. The short answer is, yes, absolutely. The Center for Environmental Implications of Nanotechnology (CEINT) is headquartered at Duke. It's nearing the end of a ten-year run, and Virginia Tech is one of the affiliated universities with that NSF center. So many, if not all, of our co-PIs actually have done or actively are doing work within CEINT, and so in terms of what is mentioned, ENMs, (engineered nanomaterials), samples have been collected that have been analyzed at Virginia Tech, and that includes soil samples.

So one thing that Duke has that we have leveraged with our centers: they have what are called mesocosm facilities, basically small boxes containing a simulated environment that is exposed to the atmosphere and to rain and so forth.

Q&A Session

Q: Does the Virginia Tech Center work with the Center for Environmental Implications of Nanotechnology on analysis of ENMs in wastewater residues used as agriculture fertilizer? And what kind of soil science experiments have been conducted with your infrastructure?

>> Marc Michel: And so we've been doing experiments down there looking at, for example, how cerium dioxide nanoparticles of different sizes move through a sediment and an aqueous environment and can get taken up by organisms, flora and fauna. So the samples that are prepared at Duke in many cases have been brought back to Virginia Tech for detailed characterization work, especially using the electron microscope capabilities that we have here.

Q&A Session

Q: *Could you comment on your Center's collaboration with the Department of Energy's Pacific Northwest National Laboratory?*

>> Larry Goldberg: Marc, I would like to ask a question to fill out some of the capabilities you have. You have a collaboration with the Department of Energy's Pacific Northwest National Laboratory on the West Coast. Could you comment on that?

>> Marc Michel: Sure. So when this center was conceived, Mike Hochella, who is the director of the center, put together this relationship with Pacific Northwest National Lab [PNNL] and their Environmental Molecular Scientific Laboratory [EMSL], and it's [a] place he had done work during his career prior to this. So he knew very well their instrumentation and knew many of the researchers who work in that facility, some of whom have expertise in the kinds of materials that are of interest to the researchers and users of our center here.

Q&A Session

Q: *Could you comment on your Center's collaboration with the Department of Energy's Pacific Northwest National Laboratory?*

>> Marc Michel: So I think in sort of the big picture terms, EMSL has tools in their facility that very nicely complement what we do here at Virginia Tech, as I described. What they have there are different types of, for example, mass spectroscopy, and they have nice EMR (electron magnetic resonance) and EPR (electron paramagnetic resonance) facilities. They do some high-end computing, and then have some other sorts of labs that specialize, for example, in sub-surface flow and transport and things like cell isolation and systems analysis, so things we don't necessarily specialize in at Virginia Tech.

Again the users of our facility can, through our relationship with PNNL and EMSL, get sort of fast-tracked access to that facility. Most access for external users from academia to national lab facilities like PNNL, or Argonne or Stanford and so forth, have to go through a proposal process that usually takes three months or more before you actually can get in the door to do your experiment. And so our relationship with them will fast track that in most cases.

Q&A Session

Q: *is the NanoSIMS a user facility for external users, and if so can you share a contact person for* it?

>> Larry Goldberg: A participant asked*, is the NanoSIMS a user facility for external users, and if so can you share a contact person for it?*

>> Bruce Clemens: Yes. First I want to clarify something that was mentioned by Marc. The Stanford Synchrotron Laboratory does operate by a proposal-based process, but our facility does not. We try to avoid that, so we have people come in – if you have work you want to do that makes sense at our center, then we'll get you in as a user. And it doesn't take three months.

>> Larry Goldberg: That is the case for all the 16 NNCI sites.

>> Bruce Clemens: That's right. Yes. I wanted to be clear that was the Stanford Synchrotron Radiation Laboratory that operates that way, which is a great facility too but operates by a different mode. The NanoSIMS facility, definitely; it's open for external users and we would be happy to have you come as a user if you're interested in using it.
Shiva, whose name was mentioned in the first slide in my talk, he's the person, or you can contact me directly, and I'll get you hooked up with the people who can get you going as a user of the NanoSIMS, and that's a facility [where] we're very happy to have external users, as [at] all our facilities. And so, please, contact me or Shiva and we'll get you going.

Q&A Session

Q: *Are there exchange programs for students from other universities to get trained and to use these facilities?*

>> Larry Goldberg: All right. A question that probably either of you could answer: *Are there exchange programs for students from other universities to get trained and to use these facilities?*

>> Bruce Clemens: We don't have a formal exchange program except with a few universities. Let me just start by saying every student from any university is welcome to come and use our facility. In fact our charging structure is, if you come from an external university or a national lab, we charge the same rate as we charge our internal users. So we're very welcoming to any student from any university who can come and use our facilities, and we'll train you to use whatever techniques you want to use and get you going as a user.

We do have specific programs with Cal State East Bay and also Cal State Long Beach, which serve a large number of under-represented minorities, and part of our outreach program is to reach out to them and offer them special programs to come and use our facilities.

Q&A Session

Q: *Are there exchange programs for students from other universities to get trained and to use these facilities?*

>> Larry Goldberg: Marc, do you have a different situation at Virginia Tech?

>> Marc Michel: Yes, our situation is a little bit different. While we invite users to come if financially they're able to, because it really can help with the analysis of their samples. We don't normally train users explicitly as we do when it's someone internal to Virginia Tech. And I believe, and I may be wrong in this, but I think it has to do with insurance reasons. In any case, if a user comes with their samples to do experiments, they will sit side-by-side with one of our trained technical staff people to analyze their samples and even go to the next steps of not only collecting data but also, you know, processing data, analyzing data, in order to get them walking away with answers to their questions, not just data that they may or may not know how to deal with.

So as far as formal exchange programs, like Bruce, we don't really have anything that is formal, and I don't know that that's going to change any time soon.

Q&A Session

- Q*: Do I need to visit the center to submit the samples? How does this work? Finally, what if we do not have funding for the research? What can you tell this individual?*

>> Larry Goldberg: Okay, there are several related questions. The person asks*: Do I need to visit the center to submit the samples? How does this work? Finally, what if we do not have funding for the research? What can you tell this individual*?

>> Marc Michel: We actually are happy for people to send their samples in. In the end, it saves money for both the researcher and for us, in many cases. The key there is sort of knowing specifically what the researcher is after in terms of the information they are desiring on their sample, and then also we just need to know that the samples that they would be sending are safe to handle. Those are two key aspects. But, yes, we absolutely invite people to submit samples by mail, but they need to go through the channels that are outlined on our website, and it's detailed on the nanoearth.org website how to go about it once you have access to submit a sample.

Q&A Session

Q: *Are there REU programs where undergrads would have access? What departments are they affiliated with at your universities?*

>> Larry Goldberg: There's one other question that actually I'm going to answer, because it relates, I think, well to the entire NNCI network of sites. And the question is: *Are there REU [Research Experiences for Undergraduates] programs where undergrads would have access? What departments are they affiliated with at your universities?*

Well, most of the NNCI sites, or a good number of them, have active REU programs, and this is being expanded as the years go [by]. I would encourage you to look at the NNCI.net website for information on the REU programs. Each of the universities, each of the sites, I should say, has their own program, but we're trying to coordinate this in a more effective way.

And now Treye Thomas, co-chair for the NEHI Working Group.

>> Treye Thomas: Thank you all, and again, my name is Treye Thomas from the U.S. Consumer Products Safety Commission, and it's really a pleasure and a privilege to thank our excellent panelists on behalf of the Nanotechnology Environmental and Health Implications [NEHI] Working Group of the Nanoscale Science Engineering and Technology Subcommittee [of the National Science and Technology Council]. This has been an excellent presentation. Again, thank you to our panelists. Thank you to Dr. Larry Goldberg of NSF for serving as our moderator. And also the NNCO (National Nanotechnology Coordination Office) staff for their excellent coordination and support of this webinar. We're really pleased that our Federal partners, the National Science Foundation and others, are supporting of this research. It's so important for us to have this data available to address implications of nanotechnology. So thank you to our partners at NSF.

I encourage all of our participants; thank you for your participation, and please go to the nano.gov website for more information on research, on the NEHI, as well as [on] upcoming webinars. We really enjoy this opportunity to engage with our stakeholders, so thank you for taking the time to engage with us. With that, I will end the webinar, and everyone please have a great afternoon.

Thank you.