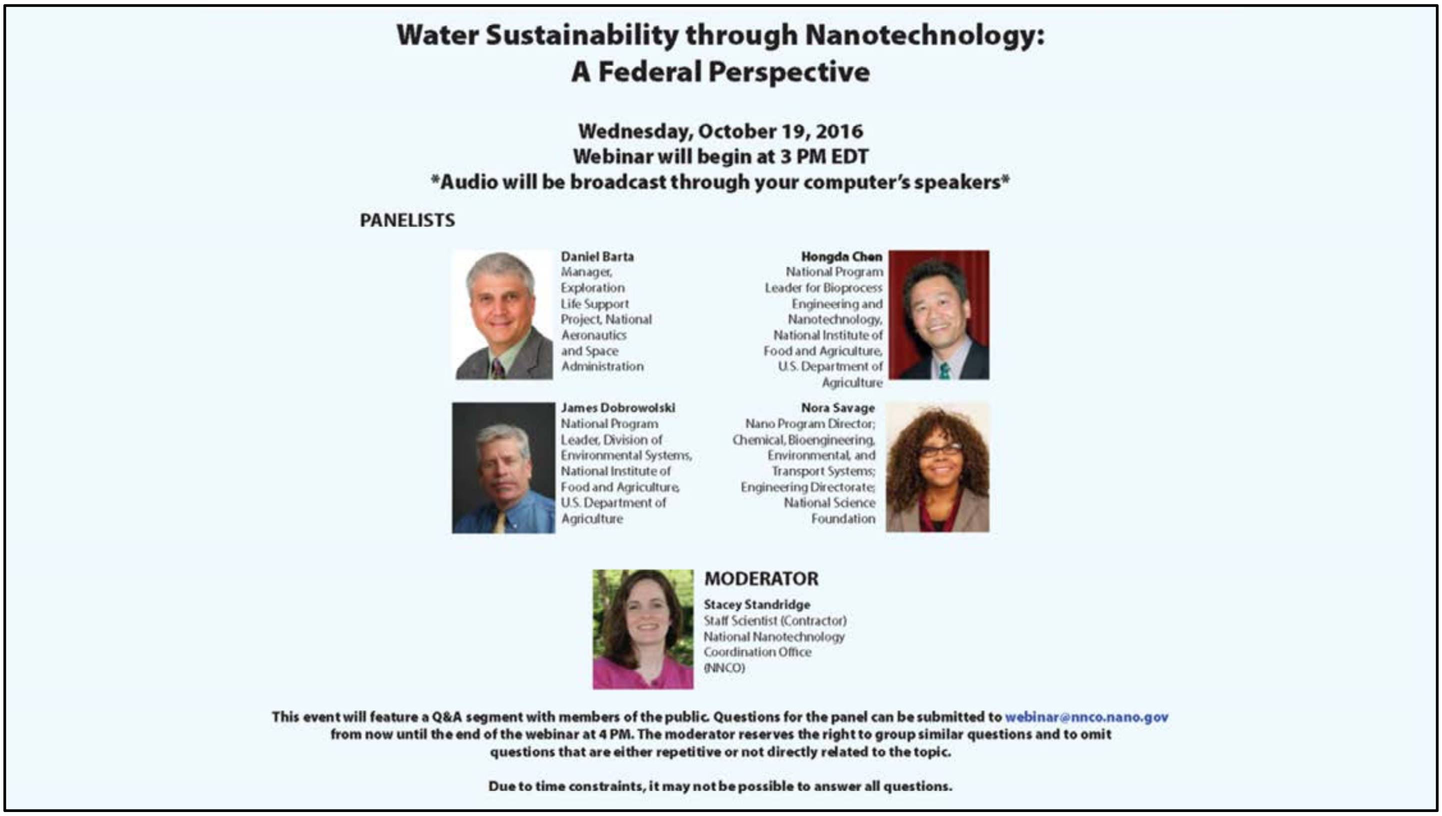
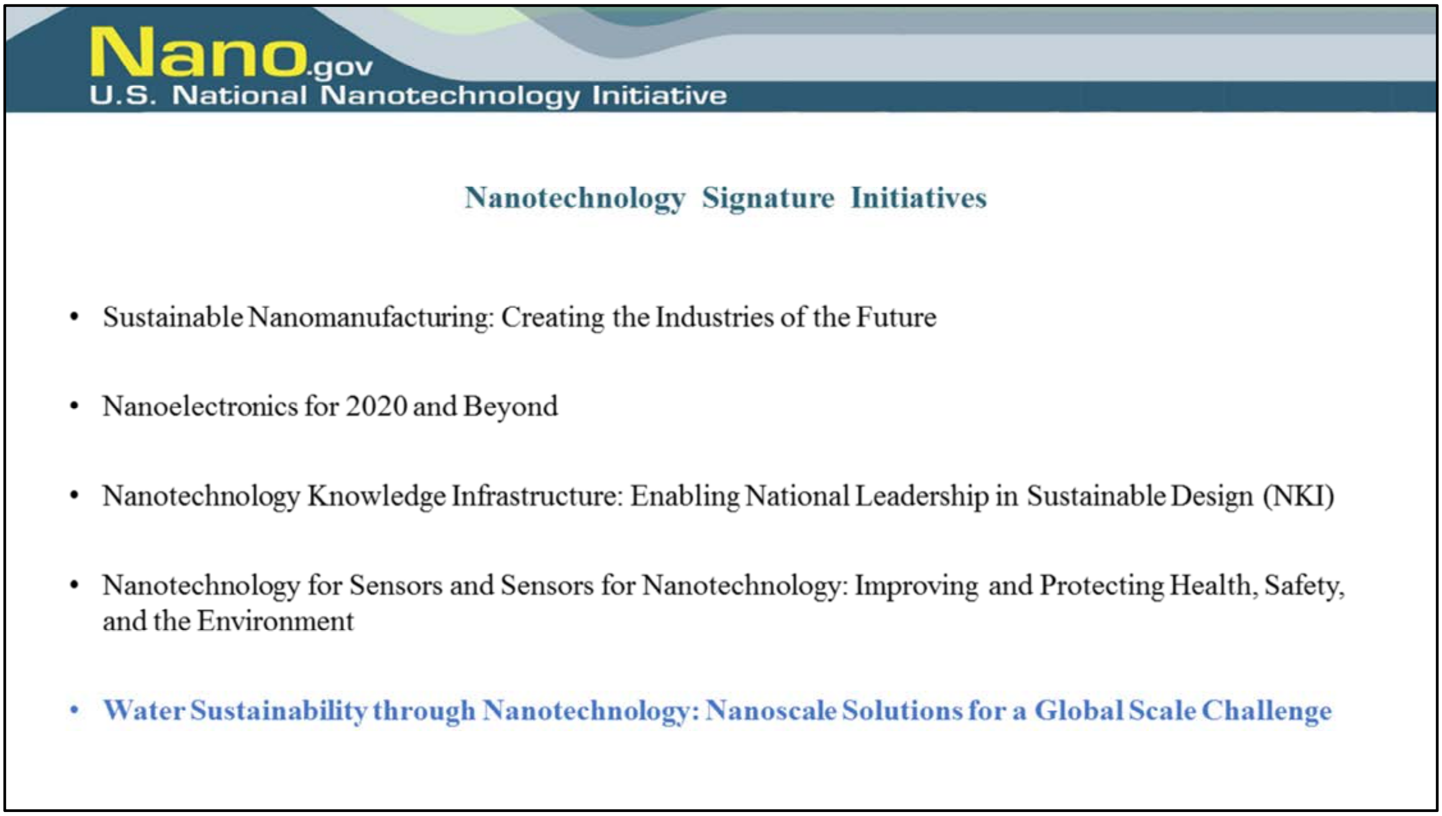
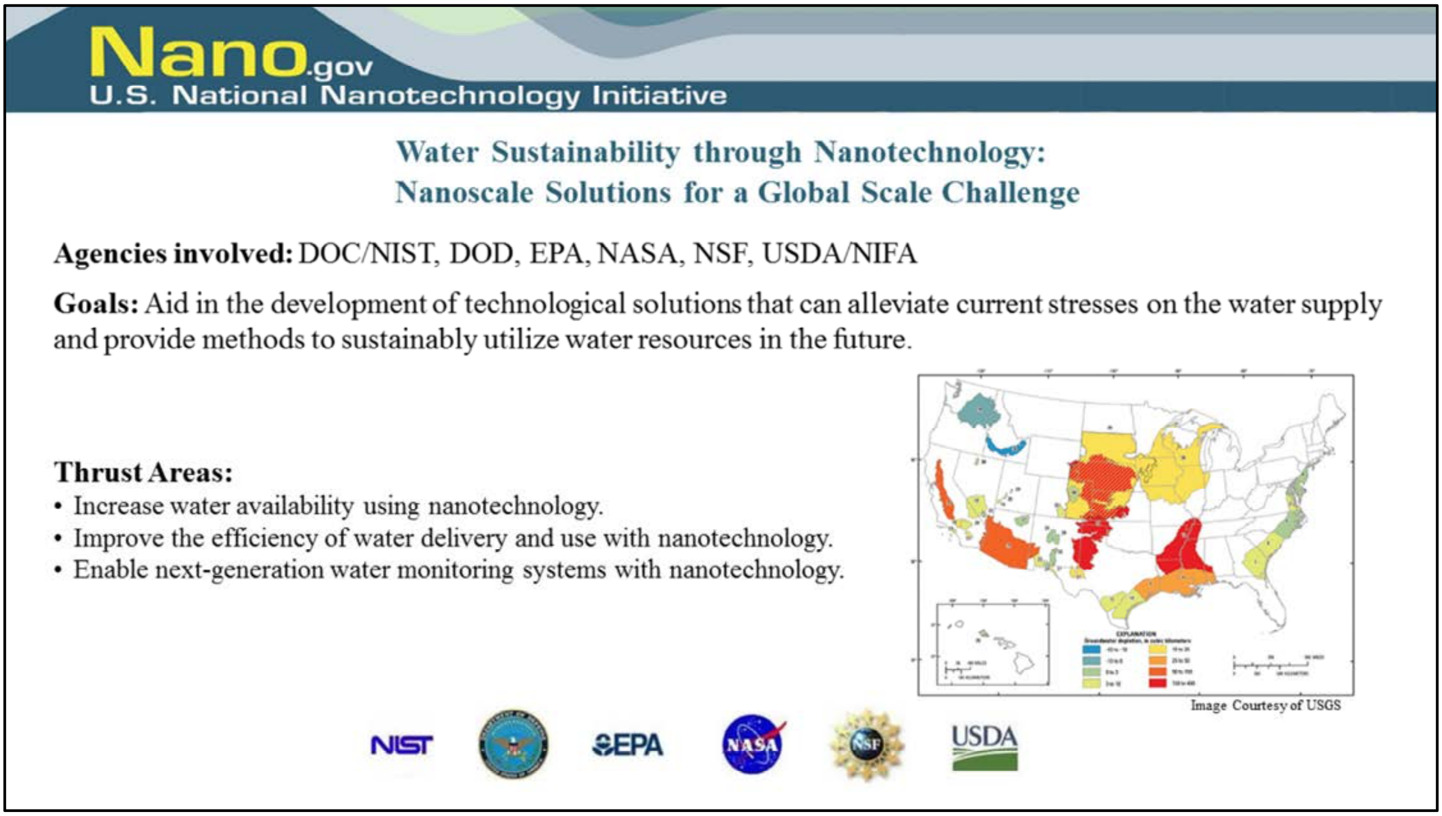


>> Stacey Standridge: Good afternoon. Welcome to today's *Water Sustainability through Nanotechnology* webinar. My name is Stacey Standridge, and I'm a Staff Scientist at the National Nanotechnology Coordination Office. I will be the moderator today. We have a great panel of speakers, and I invite you to read their bios on the webinar webpage. By way of brief introduction, Nora Savage is a program director at the National Science Foundation, and she likes to lounge at the beach at the water's edge. From the USDA's National Institute of Food and Agriculture, we have Jim Dobrowolski, National Program Leader for Water, and Hongda Chen, National Program Leader for Nanotechnology. Jim loves sailing, and his permanent home is in the Chesapeake Bay watershed on the western shore. And Hongda's favorite water sport is watching Olympic swimming. And finally, from NASA we have Daniel Barta, Manager of the Exploration Life Support Project, and I just learned that he swims two miles a week.



>> Stacey Standridge: This webinar is hosted by the National Nanotechnology Initiative's Signature Initiative, *Water Sustainability through Nanotechnology.* The National Nanotechnology Initiative, known as the NNI, was established in 2001 and is a collaboration of 20 Federal agencies with shared interests in nanotechnology research, development, and commercialization. These agencies have established five Nanotechnology Signature Initiatives in order to enhance interagency coordination and collaboration in targeted areas of national importance. The signature initiatives leverage resources and capabilities of the NNI agencies to maximize progress and provide a forum for ongoing communication.

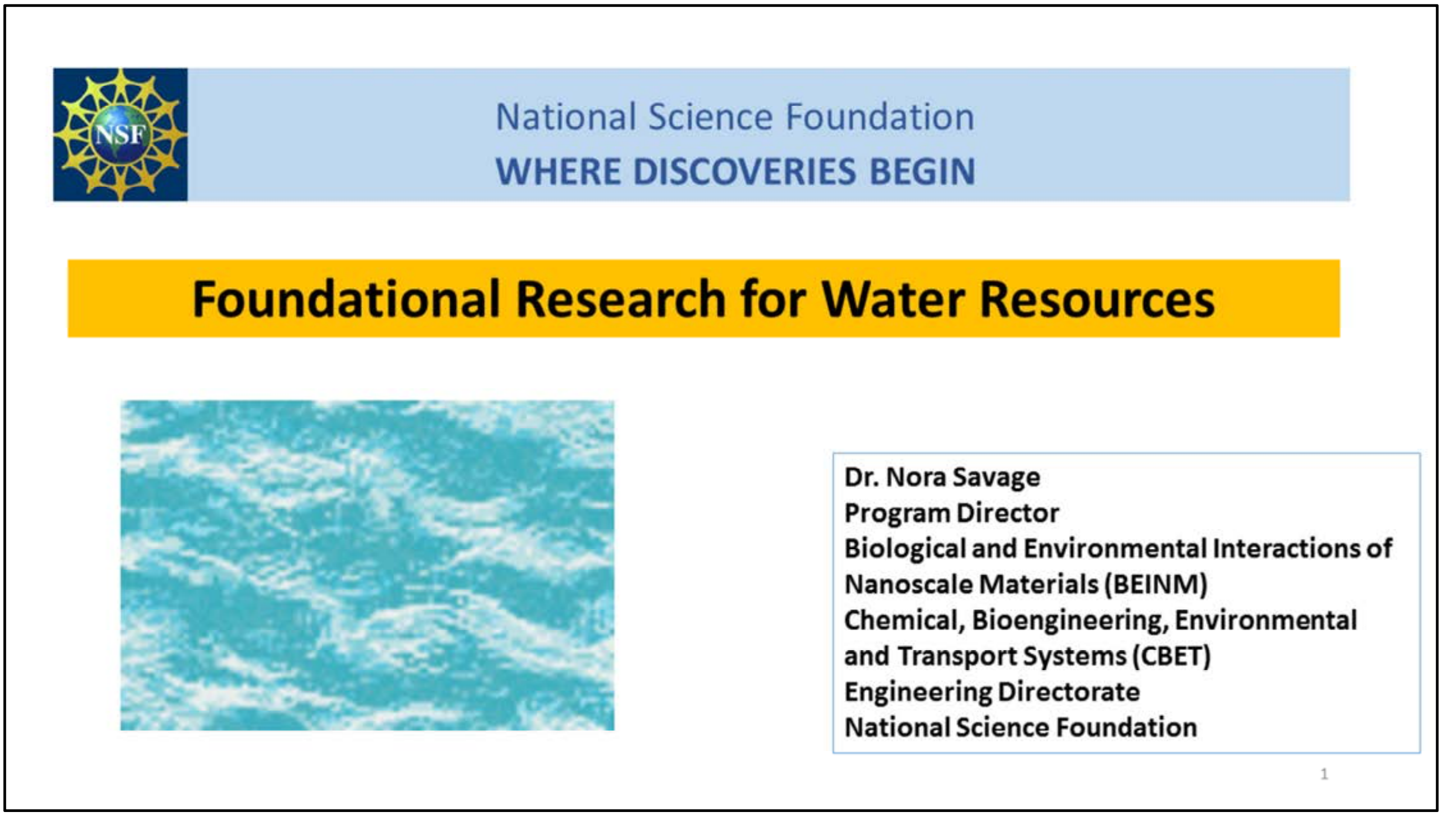
The signature initiatives are not intended to be a purely Federal activity, but to catalyze communities of interest that extend into academia and industry. More information about the NNI and the Nanotechnology Signature Initiatives is available on www.nano.gov.



>> Stacey Standridge: The *Water Sustainability through Nanotechnology Signature Initiative* was announced earlier this year with six participating agencies. The goal is to support the development of technological solutions to water supply issues and to provide methods to sustainably utilize water resources. The white paper for this signature initiative is available at www.nano.gov/node/1577, and it outlines three thrust areas with related technical objectives. The thrust areas are to increase water availability, improve the efficiency of water delivery and use, and enable next-generation water monitoring systems.

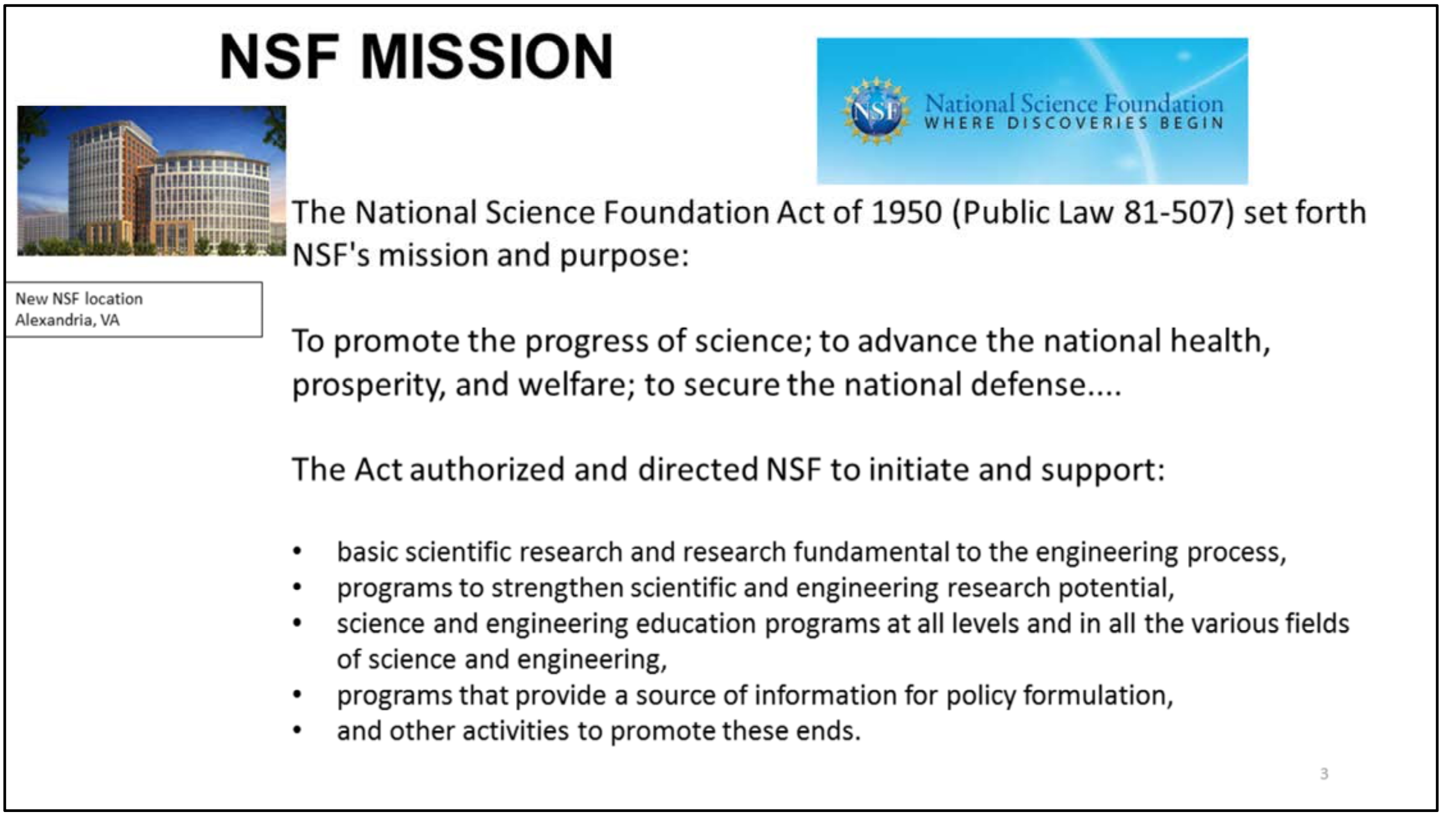
Today's webinar will be the first in a series of events designed to engage the water community broadly and the water/nanotechnology community more specifically. This first event will introduce the *Water Sustainability through Nanotechnology* Signature Initiative, as well as some of the participating agencies' interests at the intersection of water and nanotechnology. Three subsequent webinars will each address one of the three thrust areas in more technical detail. As the specifics of these webinars are finalized, registration information will be posted at www.nano.gov/publicwebinars.

>> Stacey Standridge: As I mentioned, we have a great set of talks for you today. We're going to start at the basic science end of things with an NSF talk from Nora. Then we are going to move to more applied challenges in the field and then into space. Jim and Hongda will discuss agricultural challenges, and Dan will discuss NASA's water needs for astronauts in space. With that, I will hand the floor over to Nora.



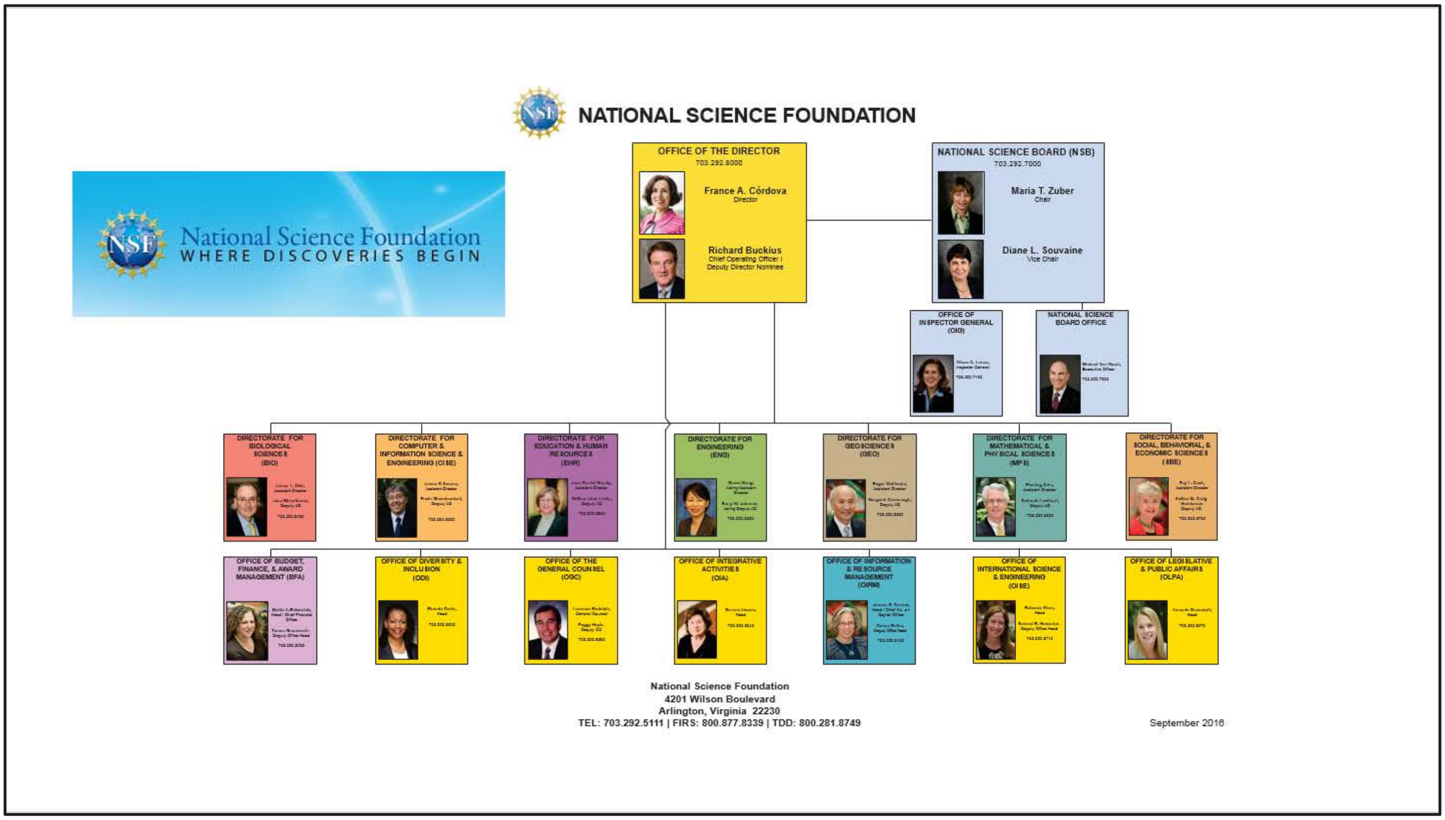
>> Nora Savage: Thank you, Stacey, and good afternoon, everyone. As Stacey mentioned, I am with the National Science Foundation.

>> Nora Savage: To give you a flavor for what I'm going to talk about today, I have a little outline, and I'll talk a little bit about NSF's mission and organization, how we're organized. And then I'll go into some of the fundamental science areas and research strategies that I think will fit nicely within our nano water signature initiative.

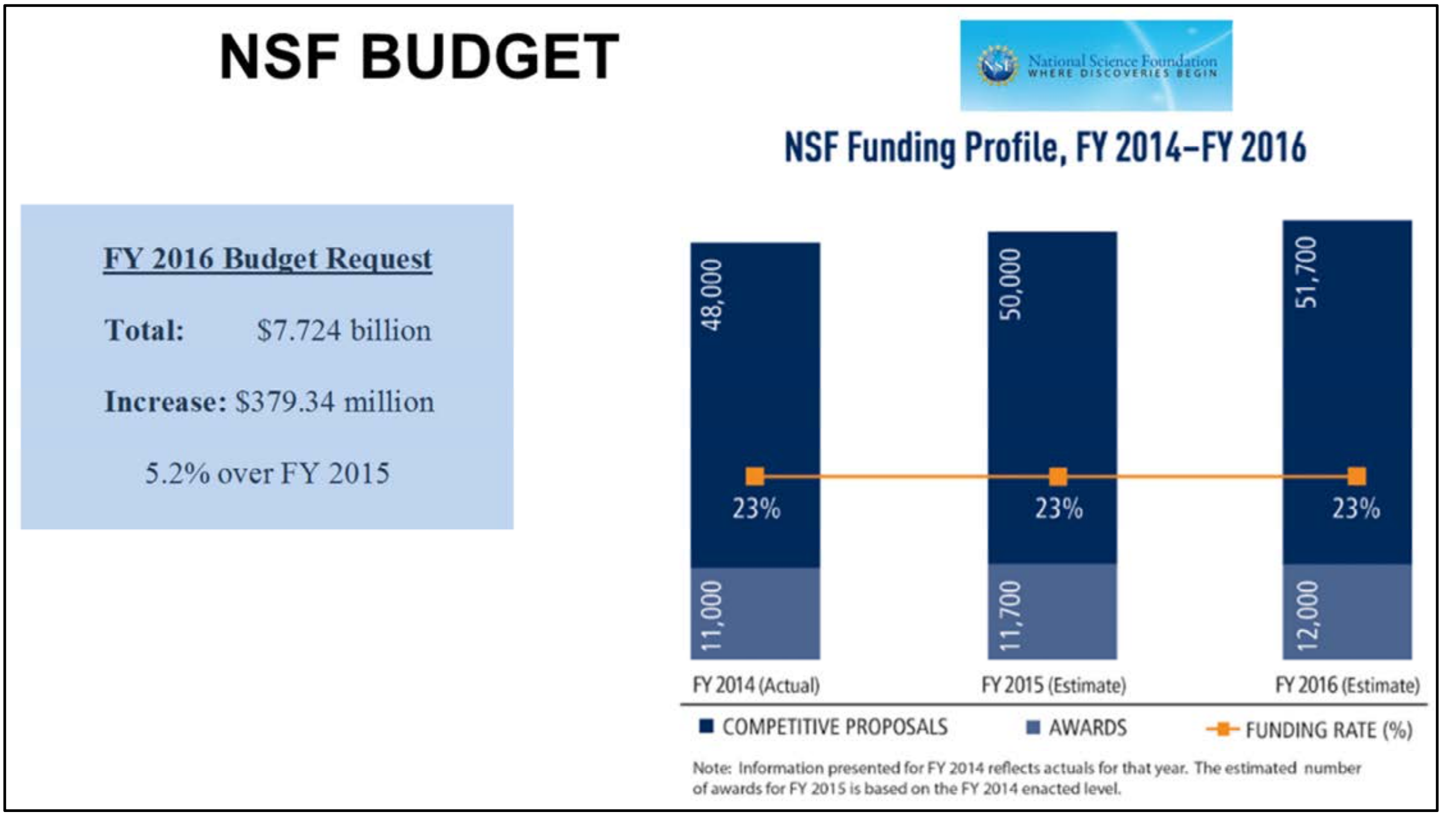


>> Nora Savage: NSF was founded in 1950. And the idea was to promote the progress of science to advance the national health, prosperity, and welfare to assure our national defense and make the nation number one in science and technology. The goal is also to strengthen science and engineering within this Nation and to support science and engineering education at all levels. We don't just support grad students through our grants, we support post-doc, early career faculty though our CAREER grants. We support K-12 students through the work that our PIs do with our grants. We do education at all levels.

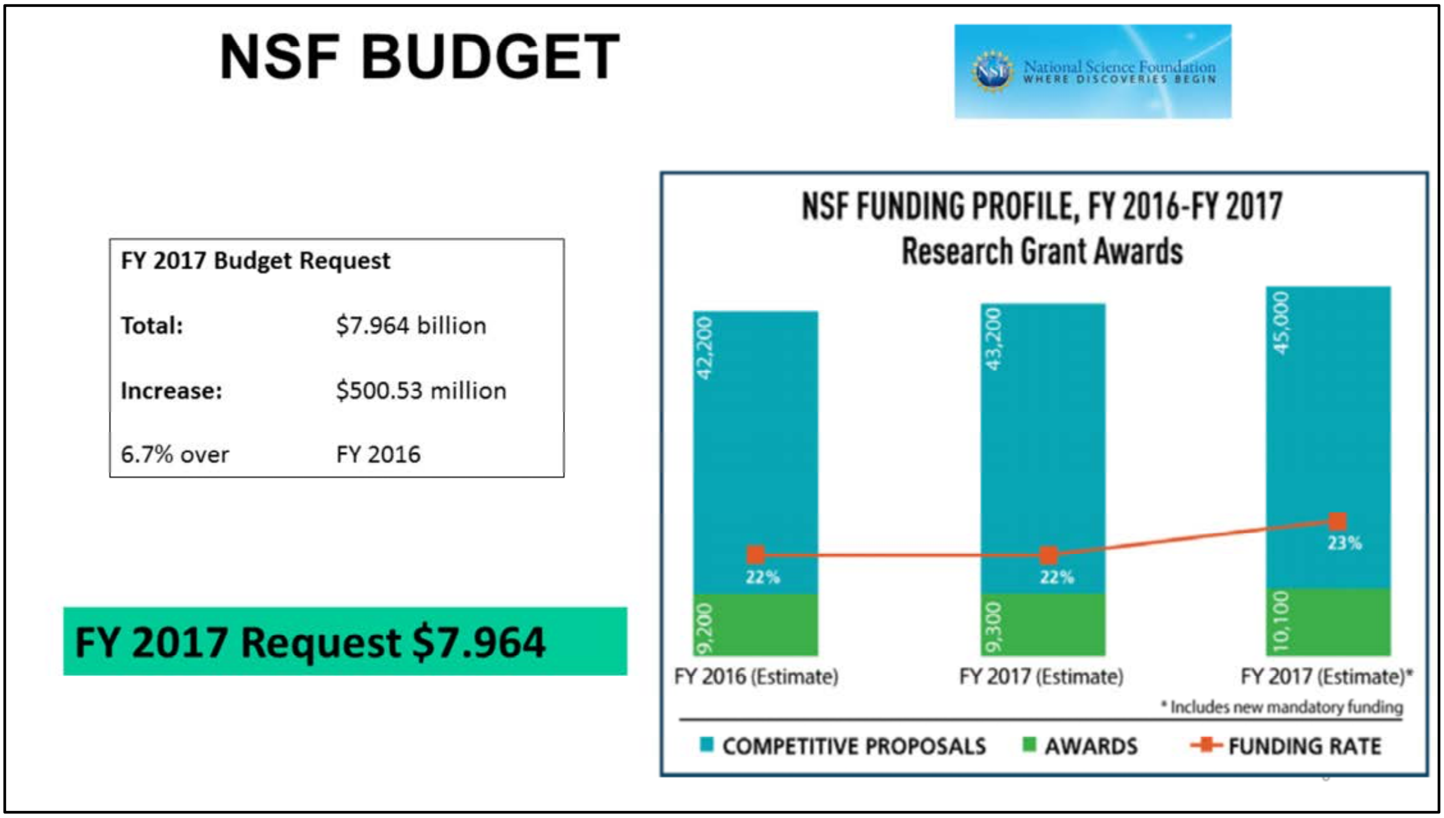
We do not do policy, but we do provide fundamental science that can be used by policymakers.



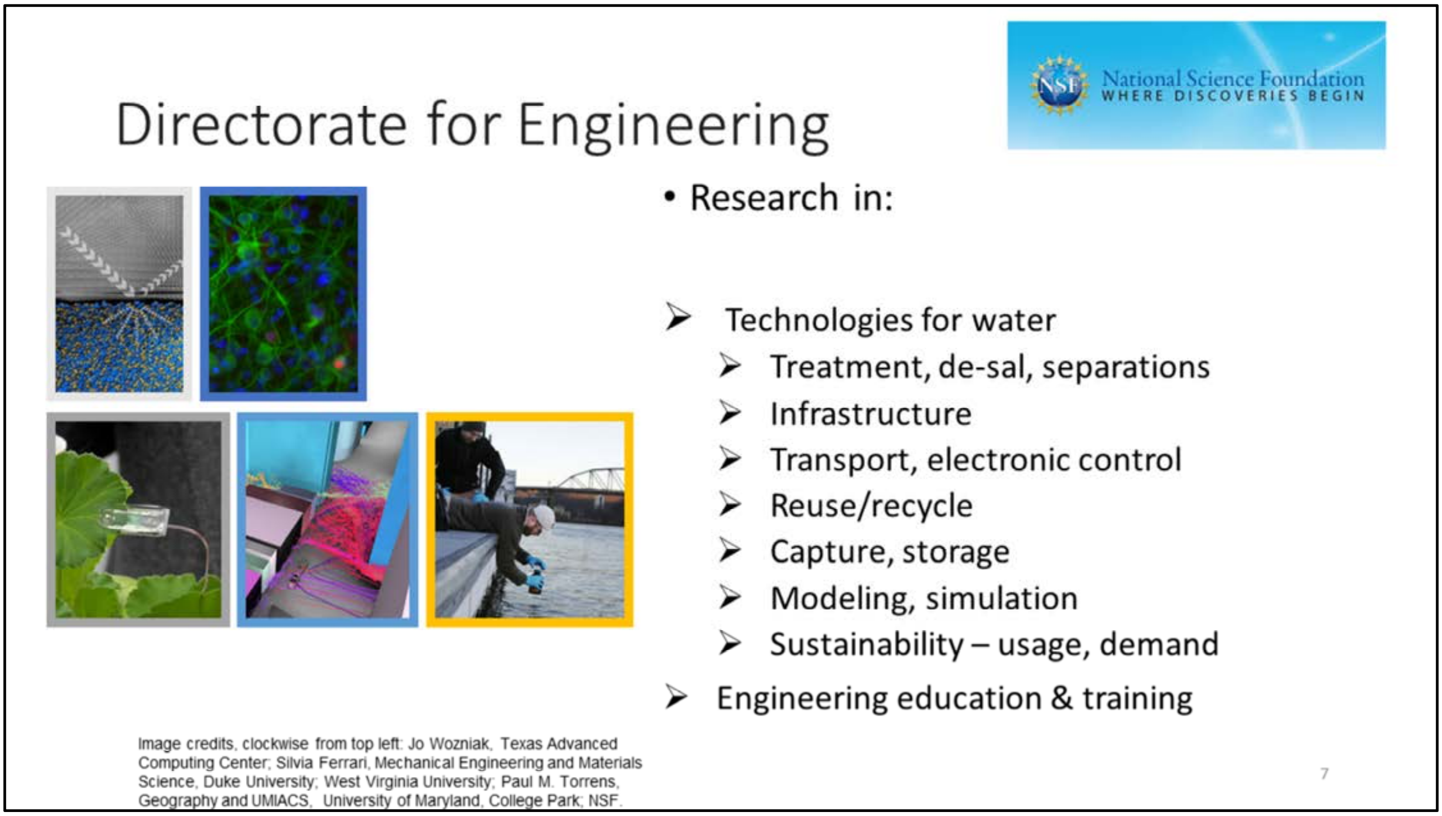
>> Nora Savage: So at NSF, if you look at the top to your right, you'll see the Director is France Cordova in yellow. Looking below at some of the directorates, I will also talk about the Directorate for Engineering; that's in green. And the Assistant Director for that directorate is Grace Wang.



>> Nora Savage: Now, to talk a little bit about our budget, the numbers. So NSF in FY ’16 had a budget of approximately a little over $7.7 billion, which was about a 5.2% increase from FY ‘15.



>> Nora Savage: And then going to FY ‘17, our request was about $8 billion. And it's approximately 6.7% we're hoping to increase from FY ‘16.



>> Nora Savage: Next, I thought I would look at three specific directorates and talk about potential areas where I thought science and nano could impact this water signature initiative. One of the things that I think the Engineering Directorate could help us do is understand how to develop novel infrastructure. We have an aging water infrastructure, and we need to have ways of retrofitting and developing new infrastructure that is much more resilient and sustainable. Treatment and desalination and separation technologies. Ways of transporting water, especially with low energy. We have a lot of energy that's used in transporting water. We need to develop better ways of transporting and controlling the release and accumulation of stored water. How can we better reuse and recycle water, and when is it appropriate to do that? For example, you don't necessarily need potable water to wash your car or to flush a toilet. When is brown or green or gray water useful for that and not potable drinking water? Again, storage and capturing water. We really should get more innovative at capturing rain water or melting water so that we can have more clean sources of drinking water and improve some of the water quality that we have. Also sustainability: How do we equalize the demand with the use? So, for example, you want water for recreational use, but you also want to have water for drinking, cooking, showers. We have to balance these uses and needs. And then engineering education and training, of course, is one of the NSF's primary mandates, as I mentioned before.

Directorate for Social, Behavioral & Economic Sciences (SBE)

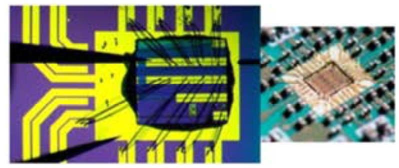
National Science Foundation
WHERE DISCOVERIES BEGIN

Research on:

- Human behavior
  - Water use, reuse, valuation
- Social organizations
  - Water distribution, water clubs, urban farming
- Social, economic, political, cultural, and environmental influences
- Across spatial and temporal domains – patterns of change, behavior

>> Nora Savage: So now talking about the social sciences directorate, SBE. So what SBE can do in this arena is look at human behavior. How do we use water? Why do we use water? How do we value water? And how can we really understand why we do the things that we do with water, so that we can make smarter choices with the water. How do we develop social organizations that also manage and maintain water, for example, water clubs, water organizations, even urban farming, that are developing more and more across the Nation? So social, economic, political, cultural influences, how do those influence what we do, how we manage, how we sustain the water quality resources? And the SBE Directorate does this across all spatial and temporal paradigms so that we can begin to understand both patterns of behavior and the way the behavior changes. So that we can do a better job of designing how we use water and how we acquire water.

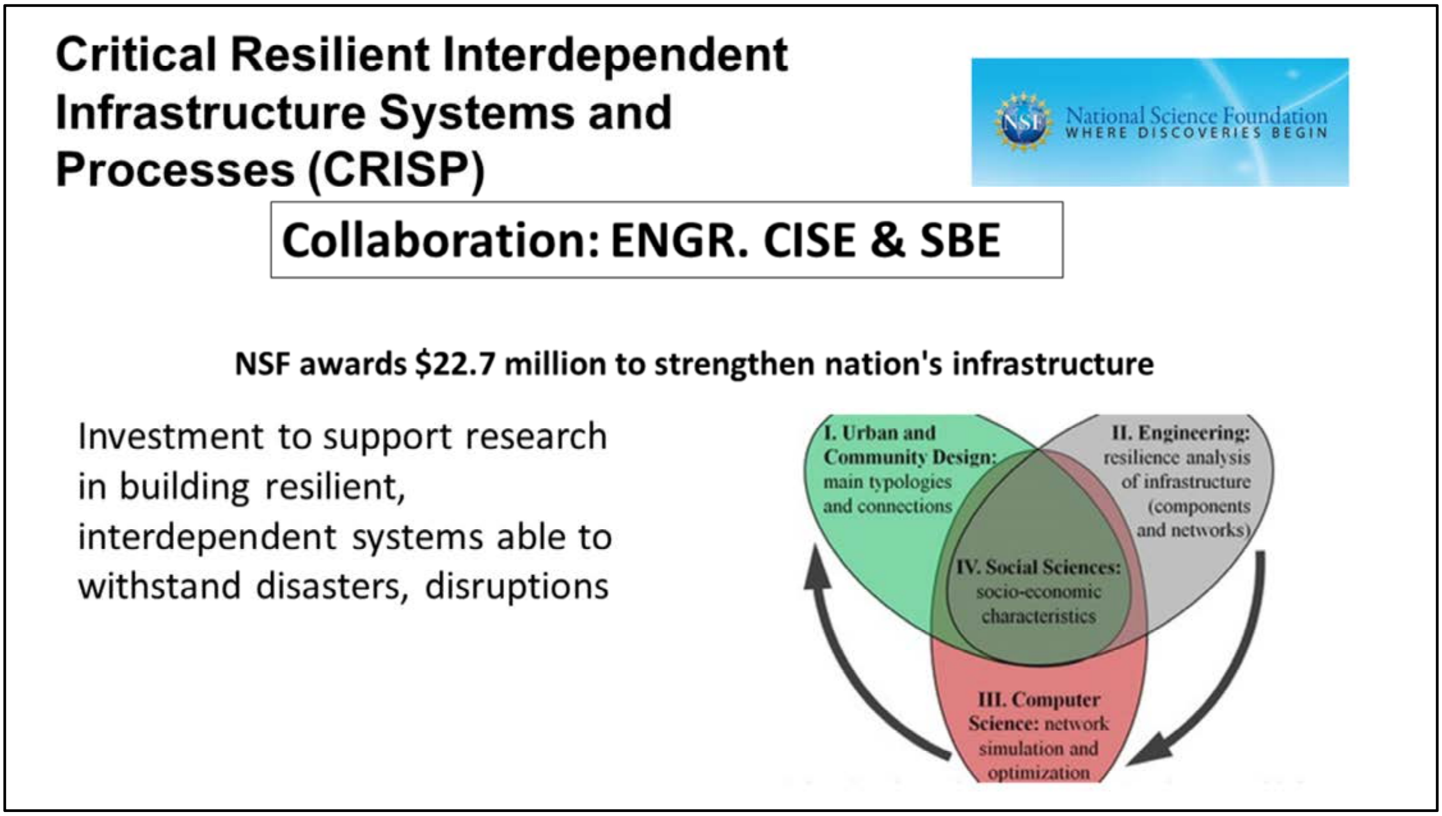
Directorate for Computer & Information Science & Engineering (CISE)



Research on:

- Advanced computing and communication systems
  - Sewage treatment plants, industries
- Transparent and open water communication
- Innovative and intelligent sensing devices

>> Nora Savage: And finally as I mentioned, the CISE Directorate is for advancing computing and communication across the Nation. One of the things that we could do is look at how both industries and the sewage treatment plants use water, clean water, provide water to society. How do we do transparent and open communication of what the water quality is? And if there's an issue with water quality, how do we communicate that to the public, in what venue? And how do we make sure that the public is protected when there is an issue with water quality? And finally, by developing innovative and novel sensing devices that can not only detect when there's an adverse or toxic compound in the water, but also can trigger either a notification, closing of a well, closing of a pipe source so that the water does not go into a community. Those are the things that we believe the CISE Directorate can successfully provide research for.

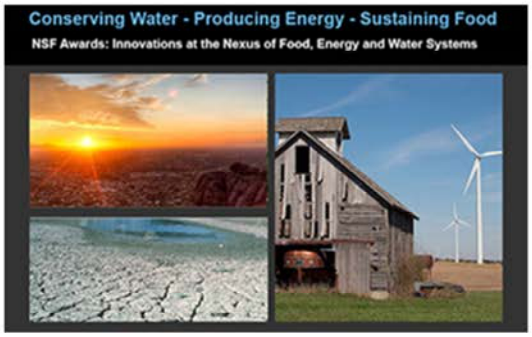


>> Nora Savage: One of the programs that I want to talk about has about $72 million invested in this area. It's Critical Resilient Interdependent Infrastructure Systems and Processes, called CRISP. It involves three directorates: CISE, SBE, and Engineering. Engineering is in the gray, SBE in the green, and CISE is down below in the red. And we want to hit that sweet spot in the center where understanding how those three things connect will help foster an interdisciplinary community that will look at social behavior, electronic devices, infrastructure, engineering solutions to make infrastructure resilient, to provide the services and goods that we design the infrastructure to do. We also want to enhance understanding of critical infrastructure systems, so that the goods and services they provide can continue despite any disruption. These disruptions can be technical disruptions from mechanical failure, they could be malicious disruptions from terrorist activity, or they can be natural disaster disruptions. So we have those three disruptions, and we want to make sure the systems we design are resilient and can provide services and goods. We also want to safely and securely expand the range of goods using this infrastructure in this sweet spot so we can make it resilient, and make it innovative and flexible so it meets the needs of current and future generations.

$72 million in innovations at nexus of food, energy and water systems

National Science Foundation
WHERE DISCOVERIES BEGIN

Collaboration: Across NSF, with USDA/NIFA



New interdisciplinary, fundamental research to address major challenge of new millennium

Advance our understanding of the food-energy-water system through quantitative and computational modeling, including support for relevant cyberinfrastructure
- Develop real-time, cyber-enabled interfaces that improve understanding of the behavior of food-energy-water systems and increase decision-making
- Enable research that will lead to system innovations and technological solutions to critical food-energy-water problems.
- Grow the scientific workforce capable of studying and managing food-energy-water systems through education and other professional development o

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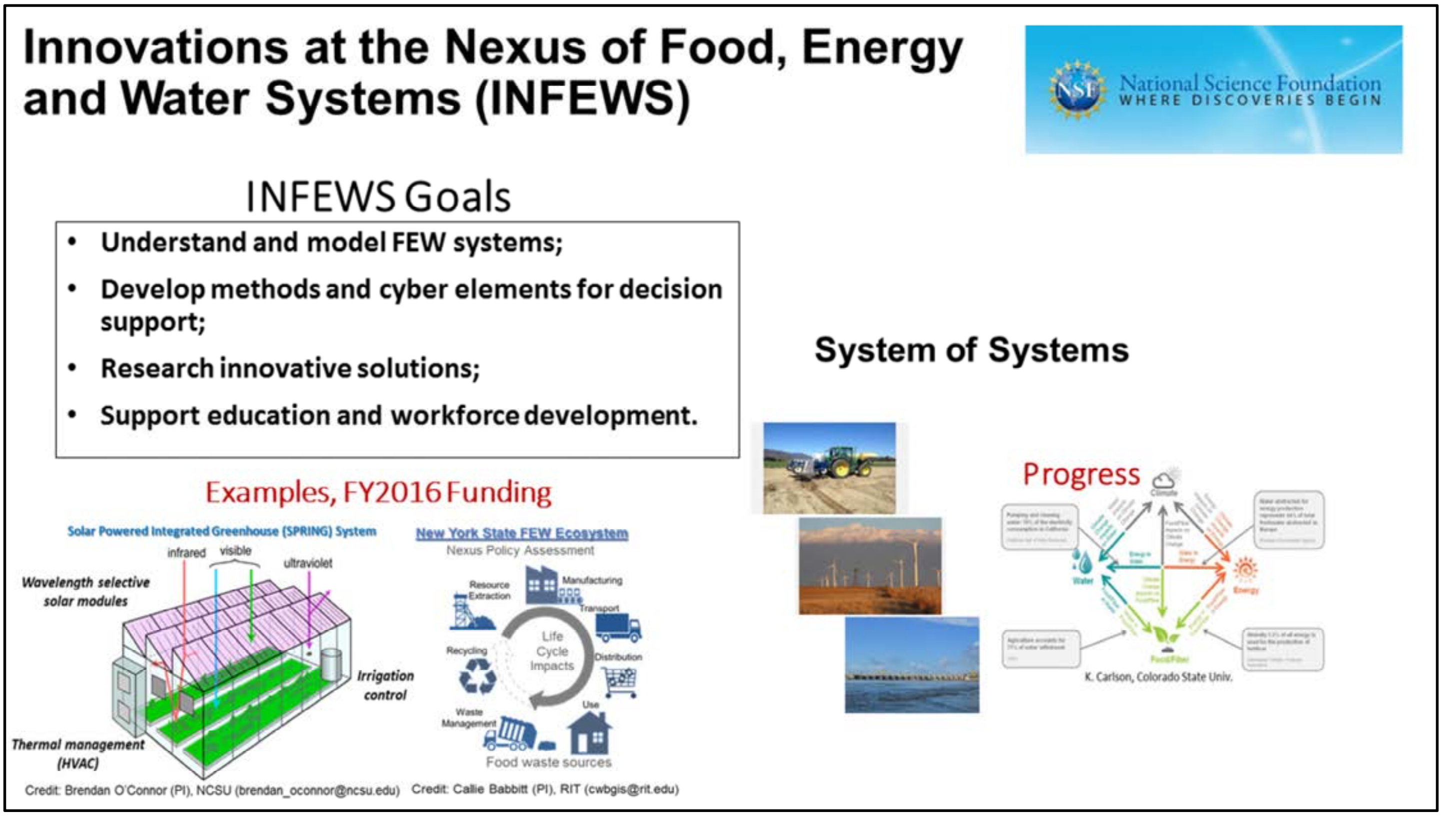
>> Nora Savage: The next slide is going to talk about INFEWS: Innovations at the Nexus of Food, Energy, and Water Systems. Its goal is to advance our understanding of how you can work at the nexus to develop some novel technologies and solutions to meet the challenges of those three critical areas. The goals are to develop cyber-enabled infrastructure and interfaces so that we can use decision making appropriately, and develop novel decision making tools to manage food, energy, and water better than we're doing now.



>> Nora Savage: We also want to develop systems innovations to have critical innovation in the nexus of this area so that we use these resources wisely and smartly and provide a sustainable use of these materials for the next generation. And we want to develop an appropriate workforce that's expert in this area, that's knowledgeable and that's really been thinking outside the box in how these three things can help us with our future challenges for food, energy, and water, which are all three critical issues for society. So looking here you'll see that there's a sample award that was a solar modular system at the bottom left that's looking at developing some more modular systems for thermal management. And then on the right, that’s showing you how these things are connected and how food, energy, and water play with climate. How that links and how it's all tied together. And how, by smartly thinking about these three things, we really can begin to engage the public and the researchers to develop novel strategies for the future. The overarching goal for INFEWS is to catalyze the community to do this. To think this way and to develop novel strategies for how we can develop the food, energy, water nexus.

Emerging Frontiers in Research and Innovation

National Science Foundation
WHERE DISCOVERIES BEGIN

NSF 16-138 for FY18 Call

Dear Colleague Letter: Seeking Community Input for Topic Ideas for Emerging Frontiers in Research and Innovation (EFRI)

invite the research community to submit suggestions for Topic Ideas to be considered for the FY 2018 Emerging Frontiers in Research and Innovation (EFRI) Program

- 500-Word Description
- Deadline for topic idea – **October 31, 2016**
- Outside scope of other NSF Programs
- multi-disciplinary
- Nexus of convergence

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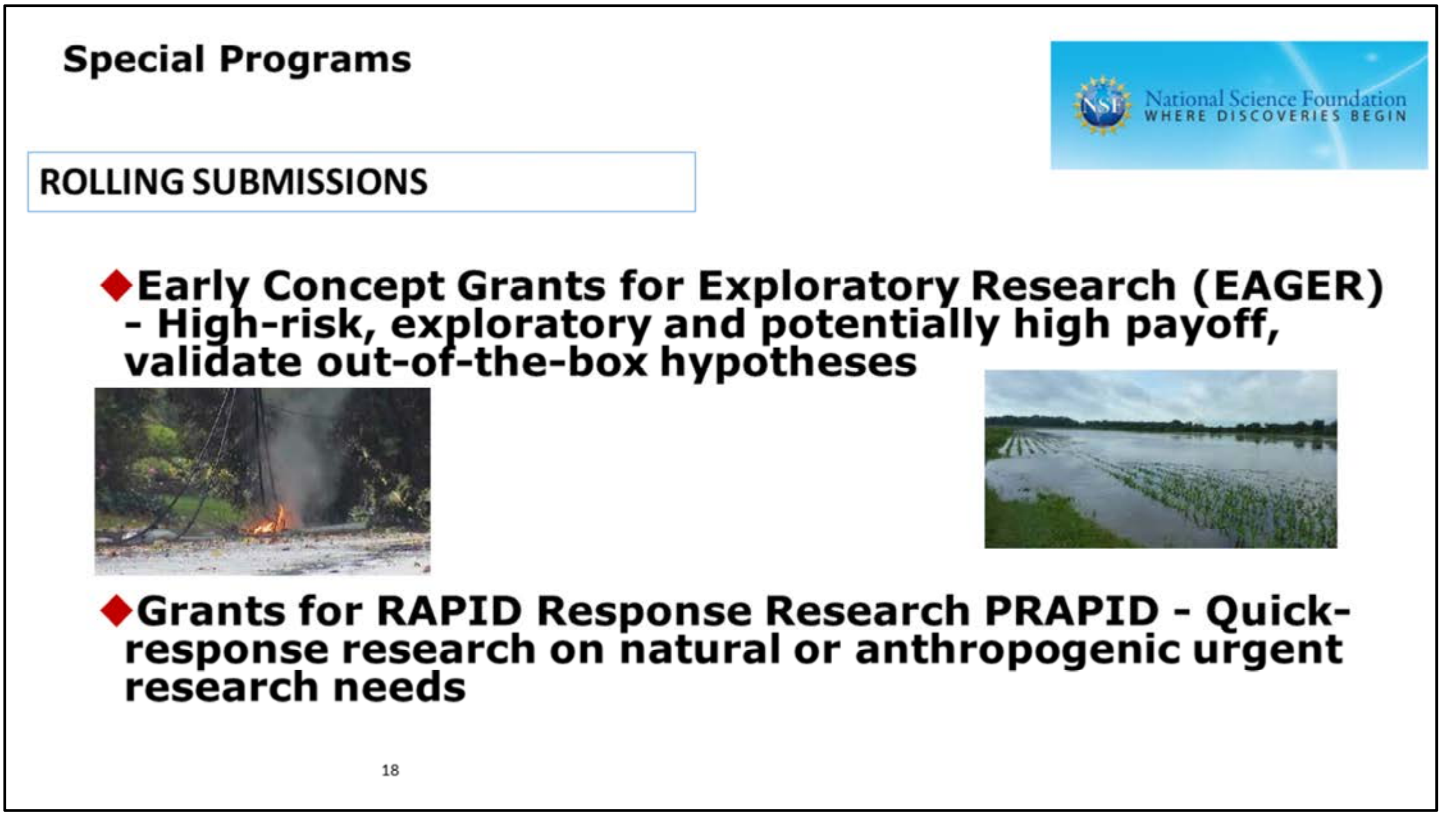
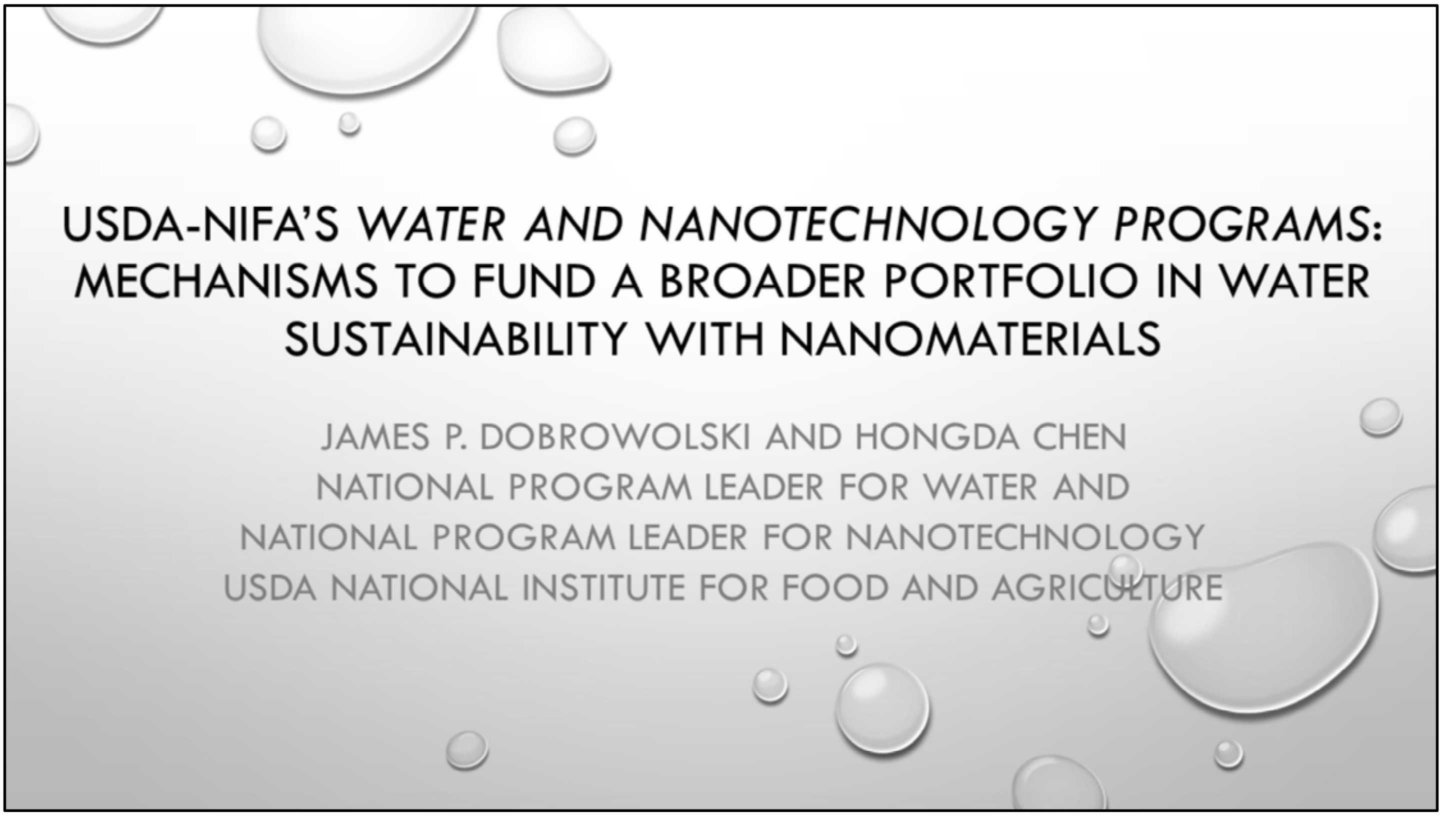
>> Nora Savage: Now I want to talk a little bit about the Emerging Frontiers in Research and Innovation program. This is really a fantastic program. I encourage everybody to look at this. If you look at the Dear Colleague Letter DCL 16-138, you can find that on NSF's website. We invite ideas from outside of the community to give us out-of-the-box ideas that NSF can't fund any other way. They have to be at the nexus or convergence of science and disciplines. We accept ideas from industry, academia, and within NSF. Please take a minute to go to the website and look at the DCL. The closing date for your topic idea is October 31st, and it's a 500-word description that you have to provide. It's a very innovative program.



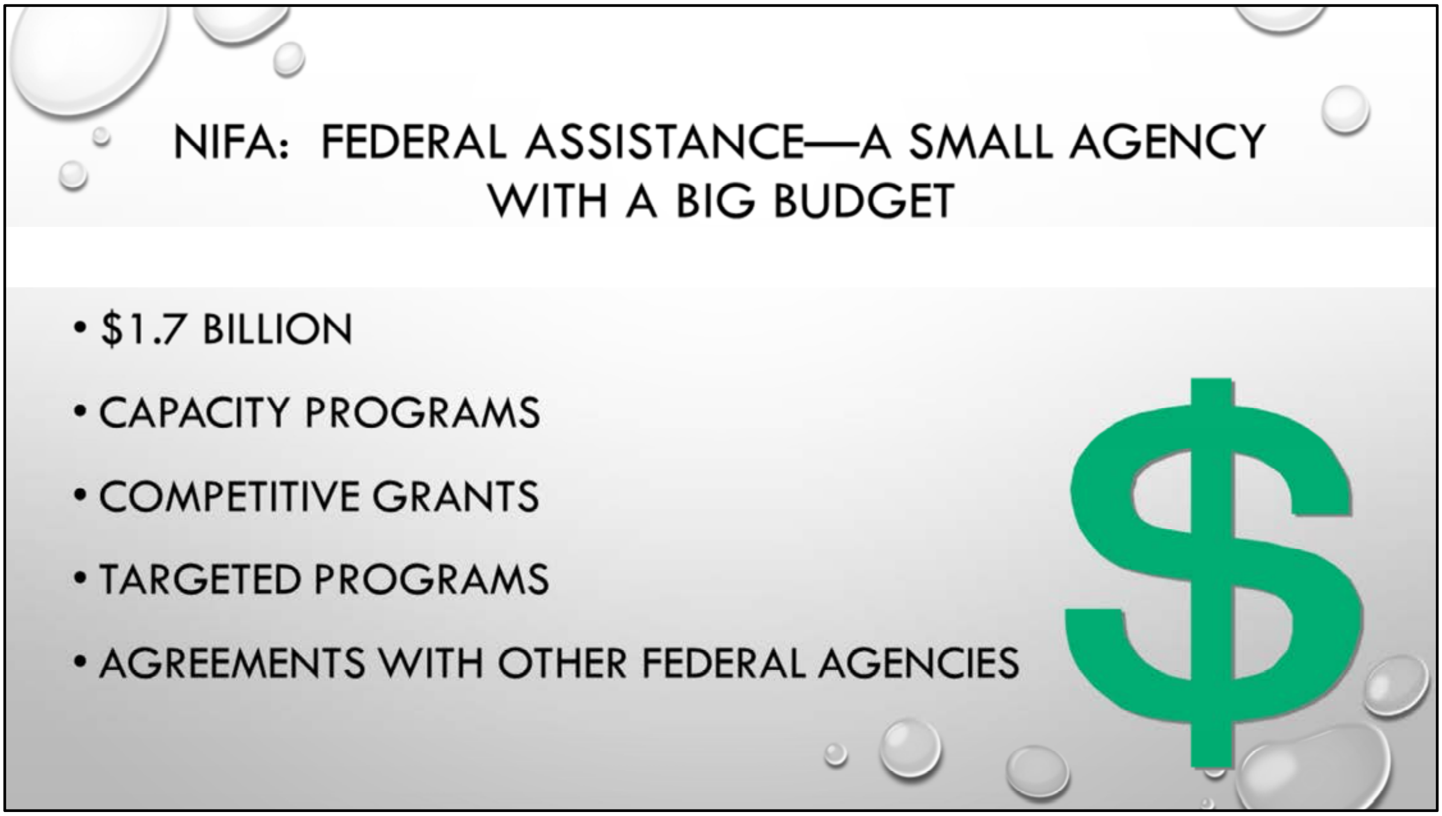
>> Nora Savage: Finally two other programs I would like to quickly talk about because I'm running over are the EAGER program and RAPID program. The EAGER program and RAPID program are small grants that NSF offers, and are program-specific, which allow us to be more flexible. EAGER, if you have an out-of-the-box novel idea, you could get a little bit of money. You could prove it, and it would be fantastic. And RAPID is to meet emerging challenging issues such as hurricanes, flooding, fire development, fire management, where we can develop novel ways of combating fire or helping people detect contaminants of water when there's excess flooding.

>> Nora Savage: So to wind up, that's it. NSF's motto, as you know, is *where discoveries begin*. And, actually, that's where you begin, by asking questions. You ask questions and then discoveries begin. If you have questions, you can ask those at the end, I believe that's how we're going to do this. And I turn it back over to Stacey.

>> Stacey Standridge: That was a great introduction to NSF’s activities that are related to water. As Nora mentioned, we will take questions at the end. But if you have questions while the speakers are giving their presentations, feel free to enter them in the “submit your questions here” box and we can queue them up for the Q & A session at the end. With that, I will hand it over to Jim Dobrowolski and Hongda Chen. The floor is yours.

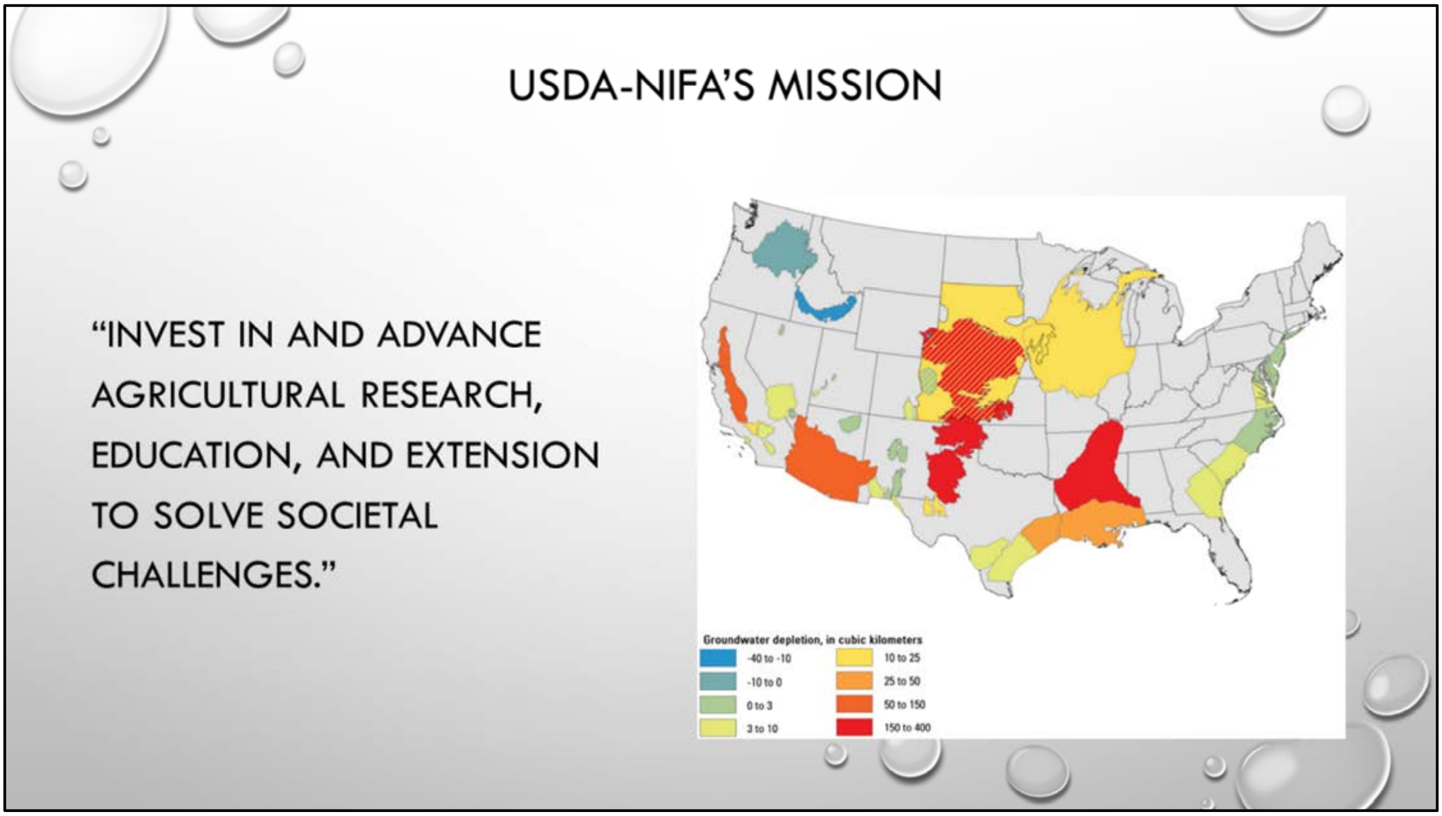


>> Jim Dobrowolski: Thank you, Stacey. This is Jim Dobrowolski, and I'm the National Program Leader for Water at the National Institute of Food and Agriculture, which is the extramural funding arm for USDA. Today I am going to talk about USDA NIFA's water and nanotechnology programs as mechanisms to fund a broader portfolio in water sustainability with nanomaterials.



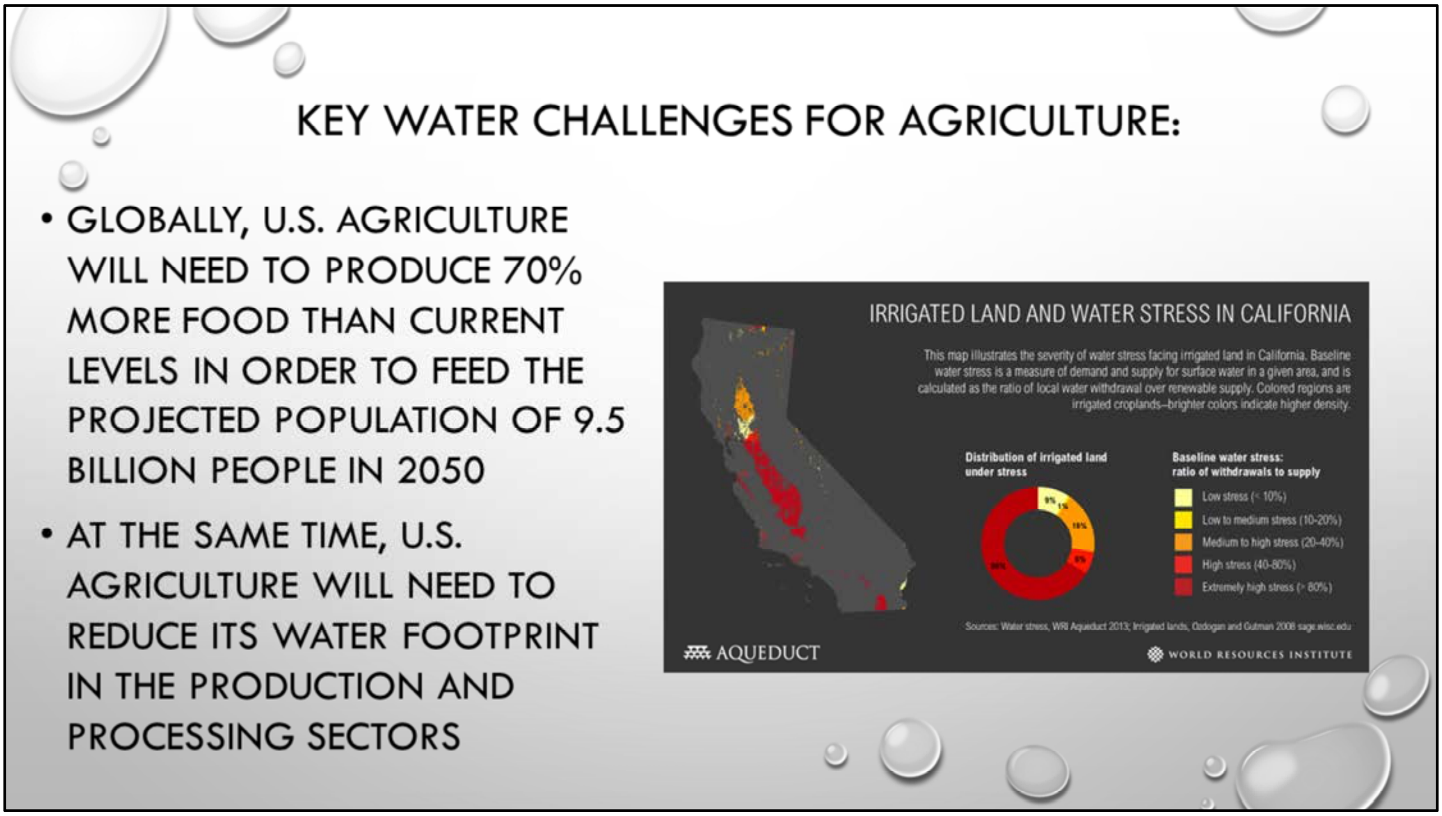
>> Jim Dobrowolski: The National Institute of Food and Agriculture is really a Federal assistance agency. We're a small agency with a big budget. Our budget varies between about $1.3 to $1.7 billion per year. And it's made up of funding lines and programs that support different aspects of our granting portfolio. One of those is capacity programs, and those capacity programs are really targeted towards our partners in the land-grant institutions that are made up of research, education, and outreach funding that goes to those institutions across the country every year. Funding lines like the Hatch Act funding, which is for research particularly; the McIntire-Stennis Act, focused on forestry; the Renewable Resources Extension Act, focused on natural resources in rangeland and forestry; and others, including Smith-Lever, where we support about a third of the outreach and extension activities of the land-grant institutions. So those capacity programs are important. They're really focused on long-term research and long-term outreach activities to try and solve some of these big generational problems that we have.

Other grant activities include competitive grants, and those you may have seen. We are, again, the extramural research arm of USDA. So we send out requests for applications, and those competitive grants are an important way for you to interact with us and to garner some Federal funding to be able to do the research, education, and outreach that's focused on water, in this particular case, and nanomaterials as they relate to water. We also have a couple other ways of delivering money through targeted programs. And also agreements with other Federal agencies. So we have these partnerships with other agencies and other organizations out there where we can focus on a particular problem or issue and move that forward.

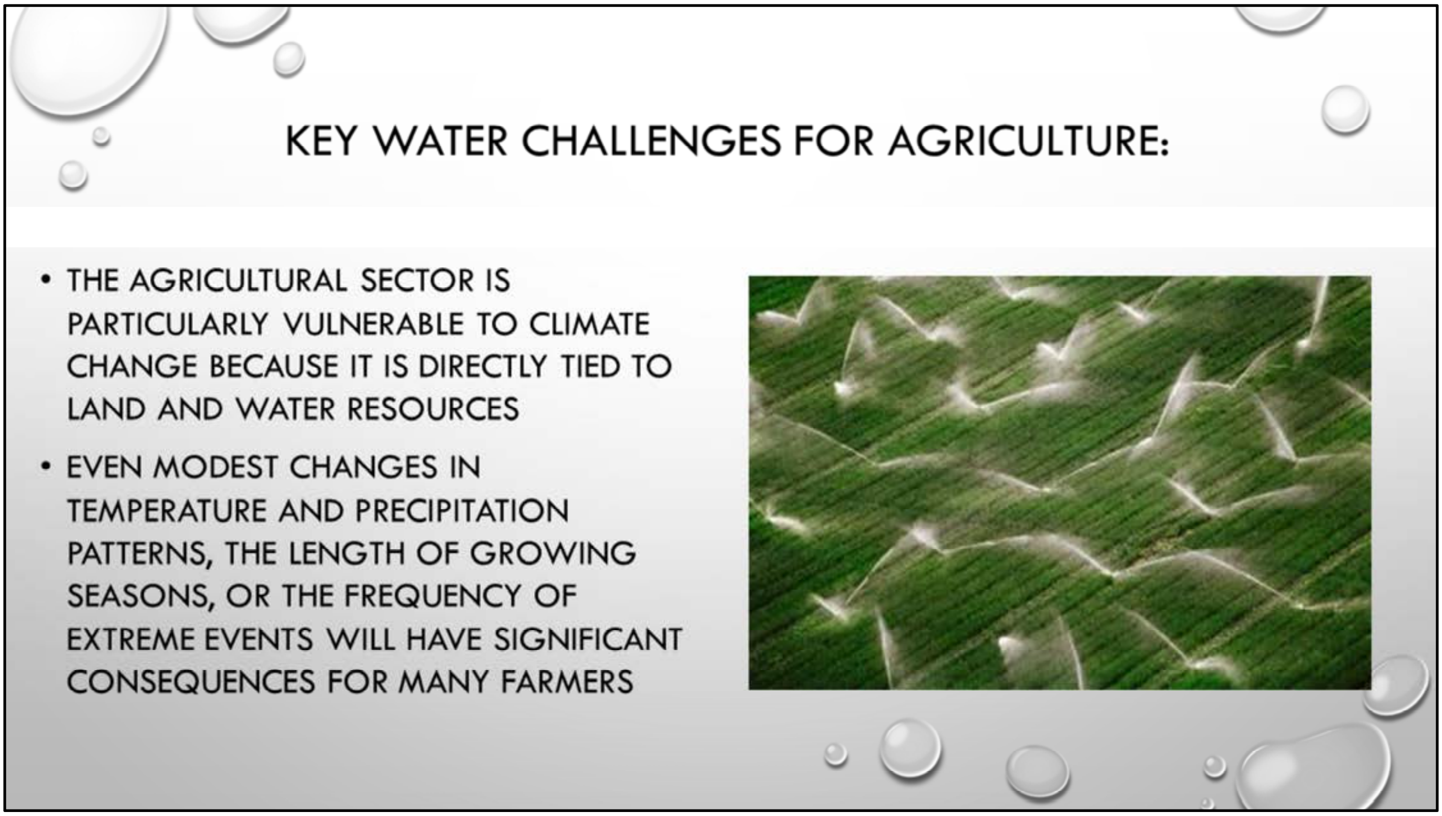


>> Jim Dobrowolski: Our mission is to invest in and advance agricultural research, education, and extension to solve societal challenges.

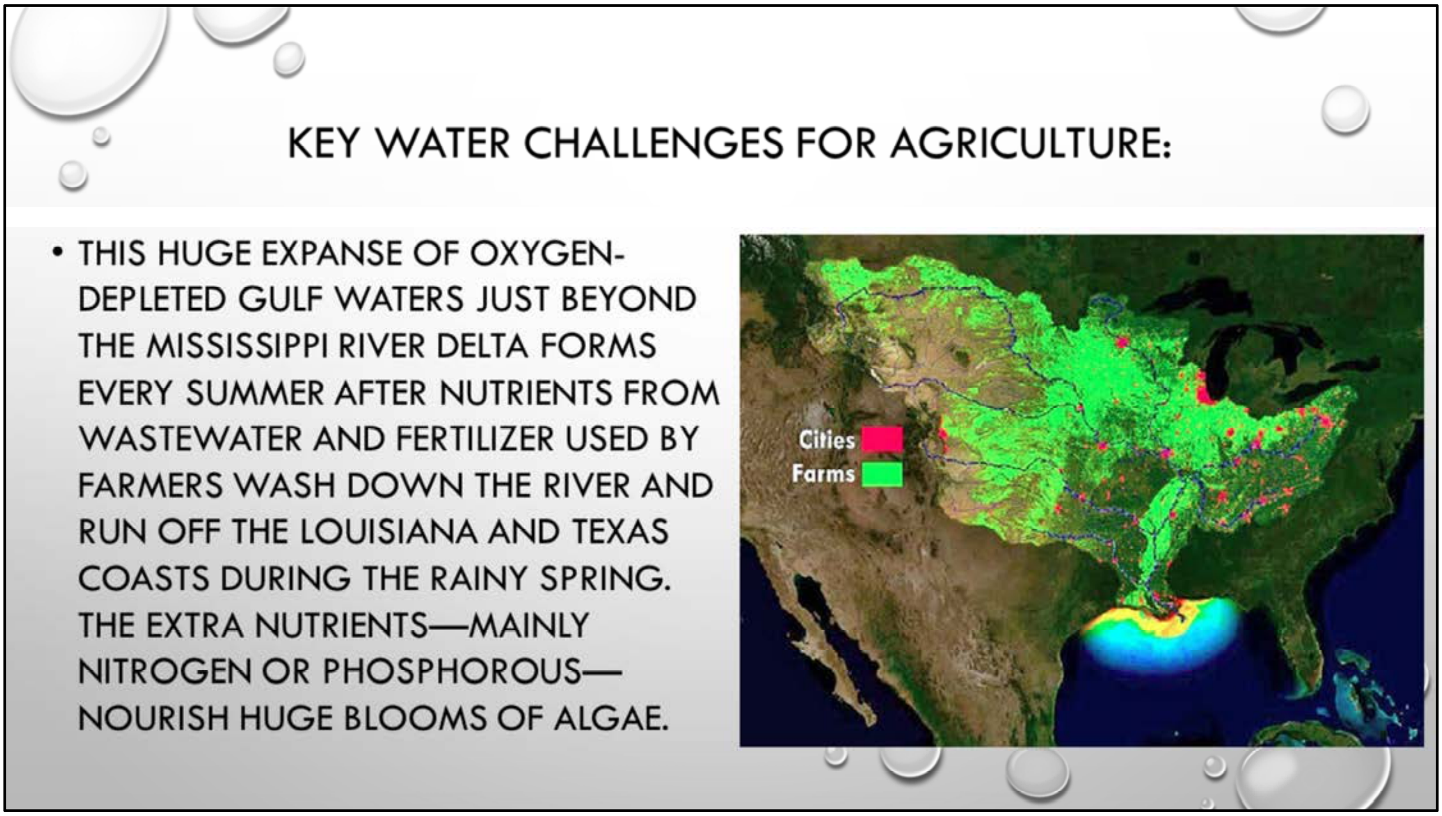
>> Jim Dobrowolski: And strategically NIFA plans to catalyze exemplary and relevant research, education, and extension programs and to advance America's global preeminence in food and agricultural sciences.



>> Jim Dobrowolski: So what are some of the key challenges for agriculture in the future related to water? Now, globally, U.S. agriculture will need to produce 70% more food than current levels in order to feed the projected population of 9.5 billion people in 2050. And at the same time U.S. agriculture will need to reduce its water footprint in the production and processing sectors. We have quite a challenge. We're going to have to increase production and at the same time reduce our water footprint.



>> Jim Dobrowolski: Other challenges include the fact that agriculture is particularly vulnerable to climate change because it's directly tied to the land and water resources. And even modest changes in temperature and precip patterns, the length of the growing season, for example, or the frequency of extreme events like frequent and more intense drought, will have significant consequences for many farmers.



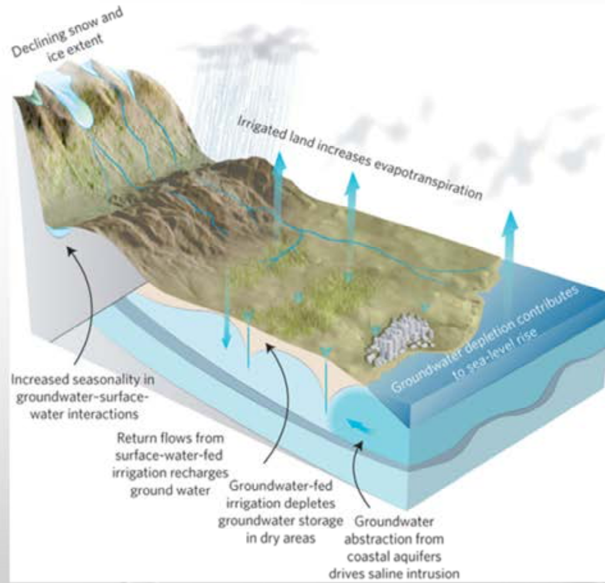
>> Jim Dobrowolski: Another one of our key water challenges, of course, is not just water quantity, but quality. And we have a generational issue, which is this huge expanse of oxygen-depleted gulf water just beyond the Mississippi River Delta. Every summer after nutrients from waste water and fertilizer used by farmers come down through the Mississippi River watershed, down into the delta and run off at the Louisiana and Texas coast during the rainy spring, those extra nutrients, primarily compounds of nitrogen and phosphorous, nourish huge blooms of algae. We’ve had this hypoxic zone in the gulf for quite some time, and it is a very difficult and challenging problem to solve. And if you'll notice you look at the global picture as far as these hypoxic zones, just about every coast around the world has hypoxia as an important water quality problem.

3 MAJOR LONG-TERM CHALLENGES TO SUSTAINABLE GROUNDWATER:

LONG-TERM AVAILABILITY OF GROUND-WATER SUPPLY (AND SURFACE-WATER SUPPLY),

PROTECTION OF GROUND-WATER QUALITY, AND ENVIRONMENTAL EFFECTS OF GROUND-WATER DEVELOPMENT

WE AWARDED 53 GROUNDWATER IDENTIFIED PROJECTS FOR TOTAL OF $41,406,000 IN THE LAST TWO YEARS

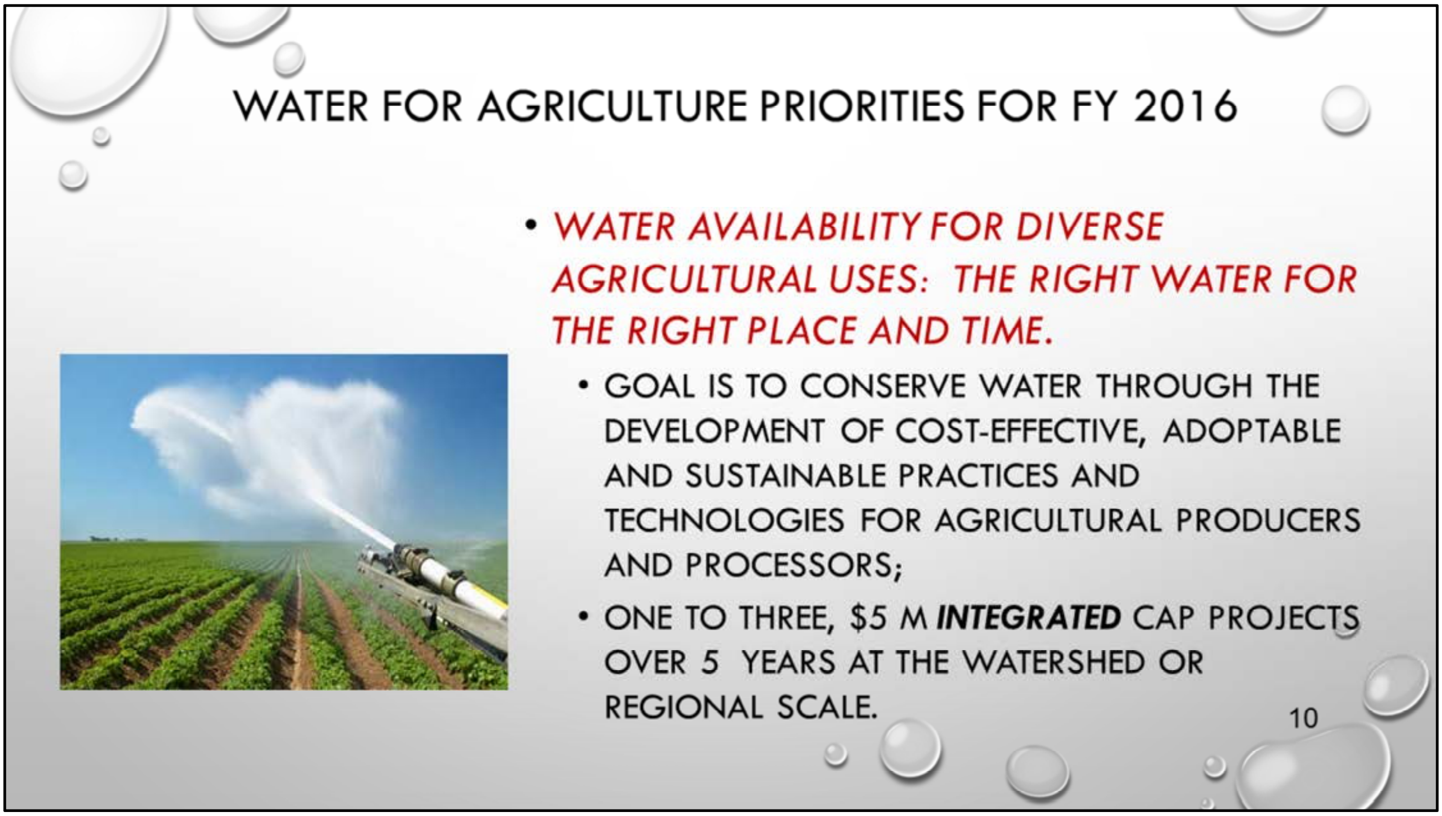


>> Jim Dobrowolski: So we also have an important part of the water system that we haven't funded as much in the past, and that's the ground water. So we have three major long-term challenges to sustainable ground water that we're focusing on:

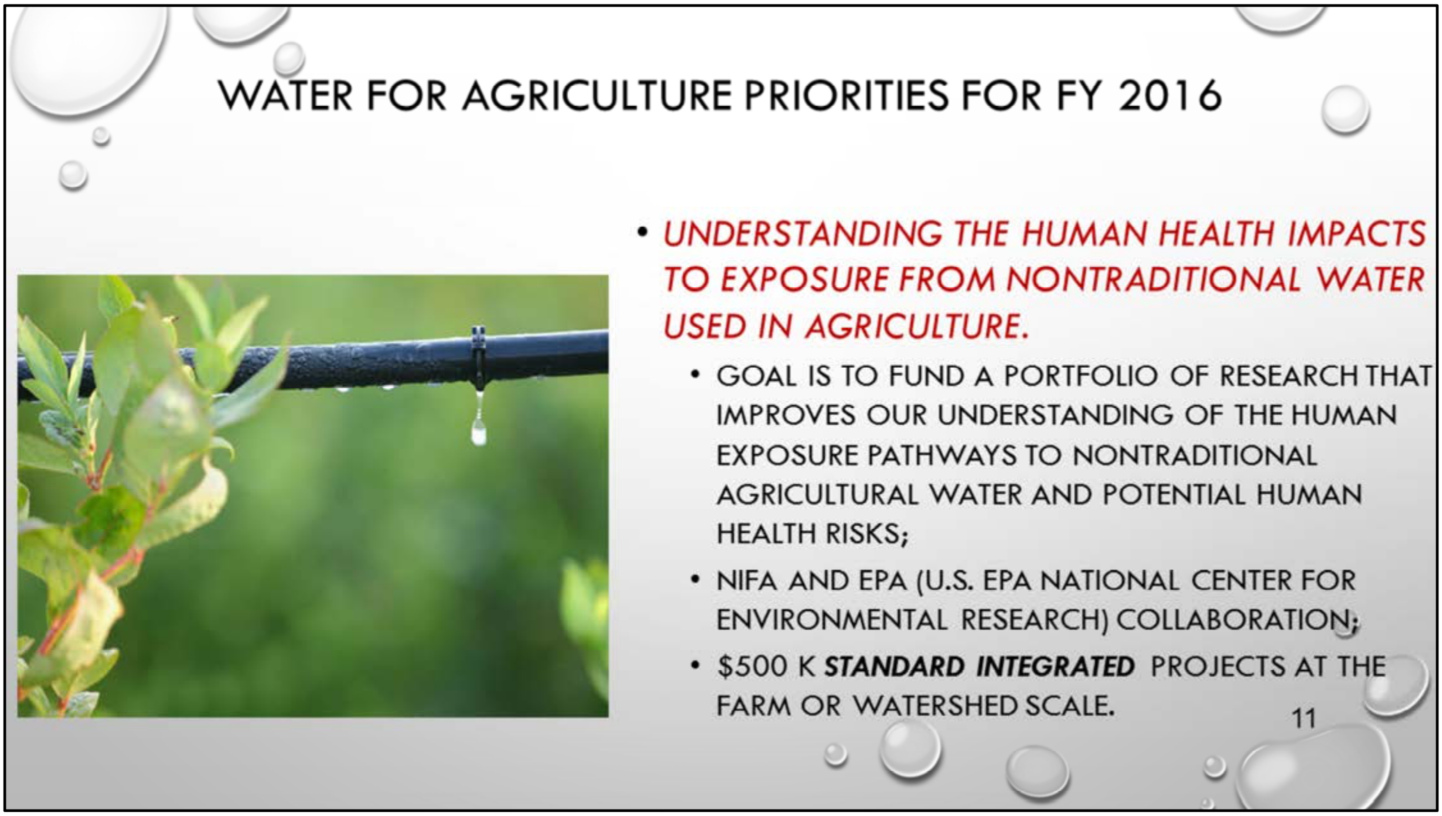
- Long-term availability of ground water supply and surface water supply, and actually linking ground water with surface water so we're managing them both the same and together.
- We're also trying to predict ground water quality and environmental effects of ground water development. So we are seeing a lot more use of ground water as the intensity and the frequency of these droughts come into play.
- And we are looking at the challenges of trying to balance out the need for improved water quantity with the fact that, in some cases when we are using more ground water, we're also degrading the quality. For example, pulling in salt wedges near the coast.

So in the last two years we've actually funded 53 ground water-identified projects for a total of $41 million so that we can try and focus on this part of the hydrologic cycle.

>> Jim Dobrowolski: So how do we address these challenges through the USDA National Institute of Food and Agriculture? We have some funding lines that you need to pay attention to. One of them is the Agriculture and Food Research Initiative, or AFRI. It's our flagship funding line. It is typically funded at about $350 million out of that $1.3 to $1.7 billion. And within AFRI we have a Water for Agriculture Challenge Area. This year, fiscal year 2016, we had $21.7 million to spend, and we were looking at developing new technologies focused on intentional artificial recharge of ground water, focusing on the ability to create, assess, and apply good data to balance supply and demand of both ground water and surface water. And looking at new techniques to improve the adoption and support of decision and policy making. In other words, how to move ground water recharge towards a consideration as a beneficial use, for example. Or other ways that we can promote adoption of conservation technologies. We have a lot of technologies out there, but we really need to determine why people aren't adopting them. And so part of what we're doing in this Water for Agriculture area is looking at behavior change, looking at adoption, and trying to figure out how to get these water technologies that we developed from the biophysical part of our activities into the social and psychological world.

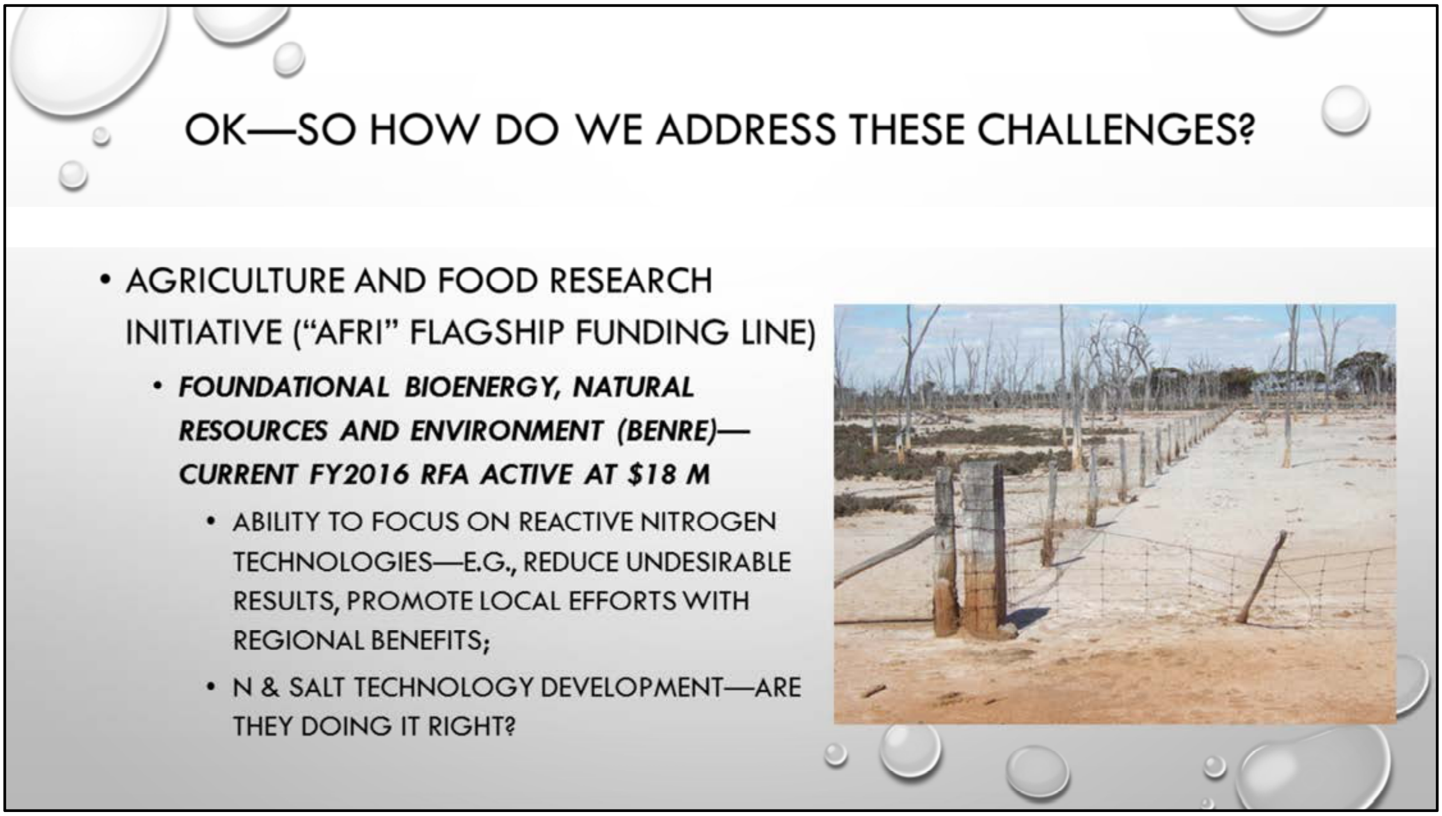


>> Jim Dobrowolski: So there are a couple priorities I want to mention really quickly. For this Water for Agriculture funding line that's part of AFRI, one of them is the water availability for diverse agricultural uses, the right water for the right place and time. The goal was to conserve water through the development of cost-effective, adoptable, and sustainable practices, and we're just about ready to actually panel this request for applications. And we are going to fund one to three large-scale projects that are called Coordinated Agricultural Projects. Coordinated Agricultural Projects are a way of delivering a fairly large amount of money over a long period of time, for five years in this case, at the watershed- or regional-scale so that folks can actually try and move towards solutions. So we're trying to give enough money for a long enough time that people can at least help kick start things towards solutions.

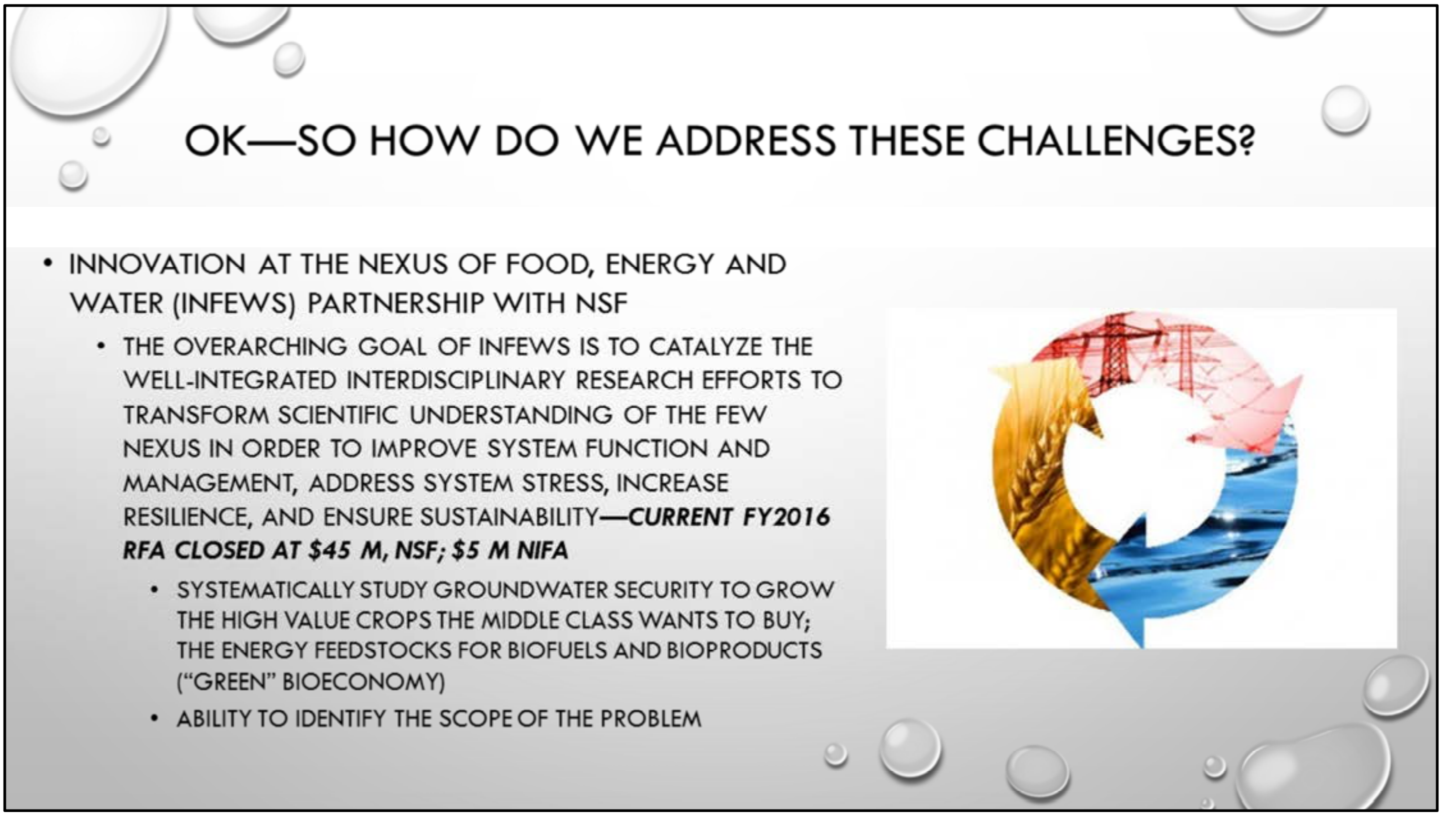


>> Jim Dobrowolski: Another one of these priorities that is of interest to water folks and nanoparticle folks is understanding the human health impacts to exposure from non-traditional water used in agriculture. So this is a collaboration with the Environmental Protection Agency, and it's really to fund a portfolio of research that improves our understanding of the human exposure pathways to non-traditional ag water and potential human health risks associated with using that non-traditional, in some cases it could be recycled water, it could be fracking water, it could be agricultural irrigation run-off water. Where we are looking at some of these potential risks of using those, focused on crops eaten fresh.

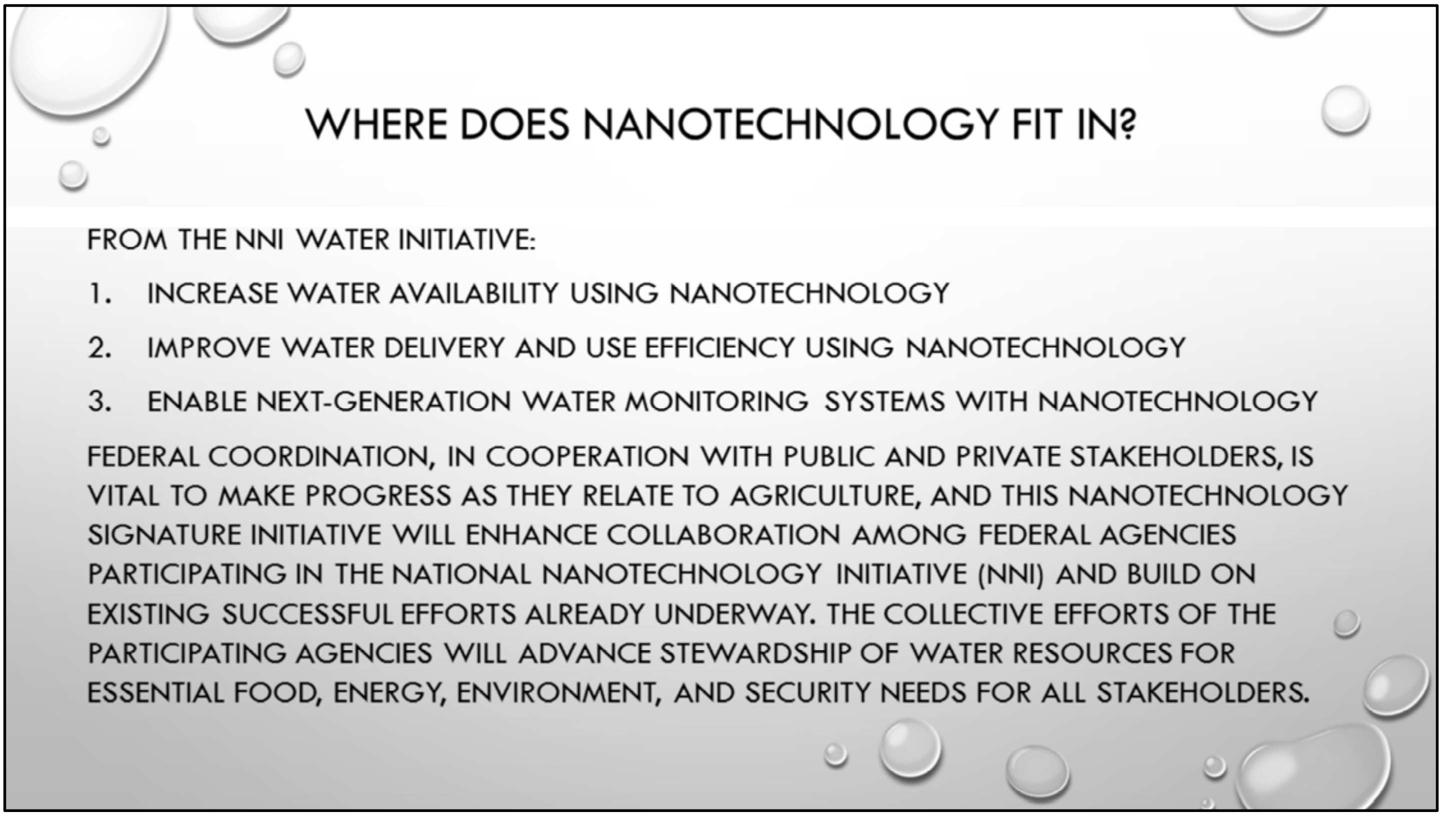
So, again, this is a NIFA and EPA collaboration. And this is a standard project. This is a smaller project than the Coordinated Agricultural Projects, and they are focused on a smaller activity and fewer project directors. So we're looking at about $500,000 for those at the farm- or watershed-scale.



>> Jim Dobrowolski: And lastly we are in the AFRI realm, we have another funding line that's called the Foundational Bioenergy, Natural Resources, and Environment (BENRE) funding line that is active right now at $18 million. And we're really focusing on reactive nitrogen technologies, reducing undesirable results, and promoting local efforts. And looking at N and salt technology development. One of the things we are dealing with is we have a lot of reactive nitrogen out in the world. We're trying to solve that problem. And also looking at the use of recycled water and the effects of repeated use on salinating soil. So these are some of the challenges that we're dealing with.



>> Jim Dobrowolski: We already heard from Nora about the Innovation at the Nexus of Food, Energy, and Water. The National Institute of Food and Agriculture is a partner with the National Science Foundation, where we are, again, looking at trying to deal with this Nexus of Food, Energy, and Water. And, of course, food and water in the National Institute of Food and Agriculture are critical. That's why we’ve teamed up with NSF. And we're systematically studying ground water security to grow high-value crops and also energy feedstocks for biofuels and bioproducts. But you can start to see as we talk about how we’re addressing these challenges, how water and nanotechnology and nanoparticles can feed into not only treatment of that water to use as irrigation water, but also dealing with contamination issues and also transport issues of the water and delivering it to agriculture.



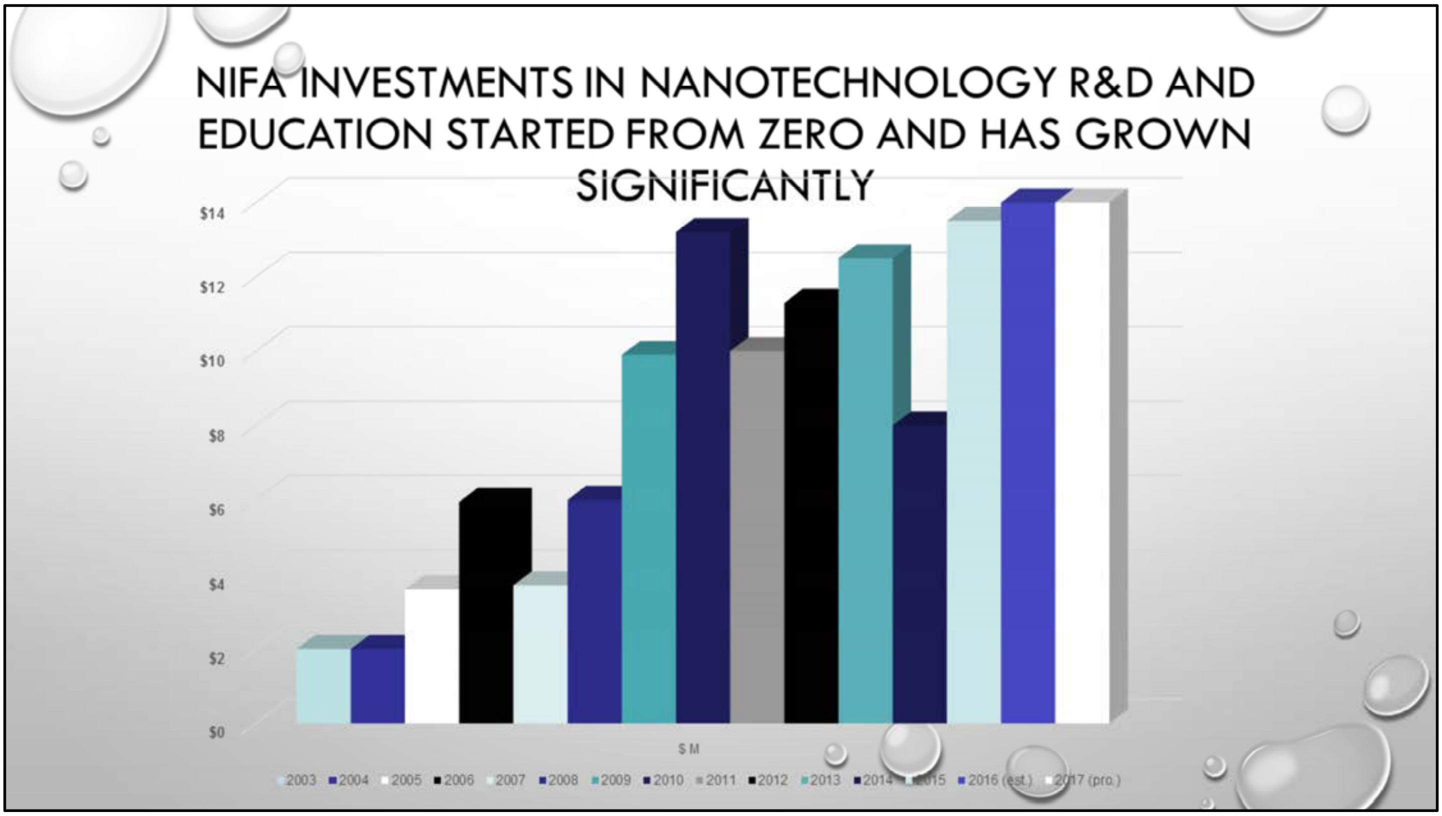
>> Jim Dobrowolski: So where does nanotechnology fit into these concepts? Where we're trying to address these challenges through research, education, and outreach? Well, we're leaning heavily on the water nanotechnology signature initiative, where we have these three action areas:

- Increasing water availability using nanotechnology. That's of interest to USDA.
- Improving water delivery and use efficiency using nanotech. That's of interest to USDA.
- And enabling the next-generation water-monitoring systems with nanotech. That's of interest as well.

So we're working with other Federal agencies across government and in cooperation with public and private stakeholders to really try to enhance this concept of using nanotechnology and building on these successful efforts already underway to improve our ability to deliver the right quantity and quality. And when we talk about quantity and quality together at USDA/NIFA, we talk about it as availability, trying to deliver the available water necessary to produce food, fiber, flowers, and fuel.

>> Jim Dobrowolski: NIFA is interested in in-line, real-time smart sensors for identifying pathogens, chemicals, and contaminants in ag production systems, including water, plants, and soil. We’re interested in recycling nontraditional water for ag uses, and in the use of precision agricultural technologies to improve water use efficiency and reduce water demand. Our intramural research partner, the USDA Agricultural Research Service, has labs across the country and research sites and long-term agricultural research areas. They're studying the use of nanoparticles to remediate chlorinated solvents and heavy metals in soils, and also salinity. NIFA is also investigating the various health effects and risks of engineered nanoparticles as contaminants introduced into water and soil sources.

>> Jim Dobrowolski: We have invested in research and development for societal challenges. Our challenges have included food security, climate variability and change, water for food systems, sustainable bioenergy and the bioeconomy, nutrition and childhood obesity prevention, and food safety. We've funded over 500 nanotechnology projects, and there's a URL that you can go to, http://cris.nifa.usda.gov. You can look at a lot of these projects and take a loot at what we have spent in nanotechnology and the subject areas.



>> Jim Dobrowolski: Our investment in nanotechnology R&D and education started from zero and has grown significantly. Since 2003 we started at a little over $2 million. And now in 2017, we're pushing the $14 million level. That's just for nanotechnology. And we also have a significant increase in the water-related programs, which also can fund nanotechnology activities in research, education, and outreach. And those have started at about $6 million. This year we had $21.7 million, and next year we're anticipating about $48 to $50 million. So things are going up as far as our ability to fund these activities that are so critical related to water and nanotechnology.

RECENTLY FUNDED PROJECTS SUPPORTING GROUNDWATER SUSTAINABILITY

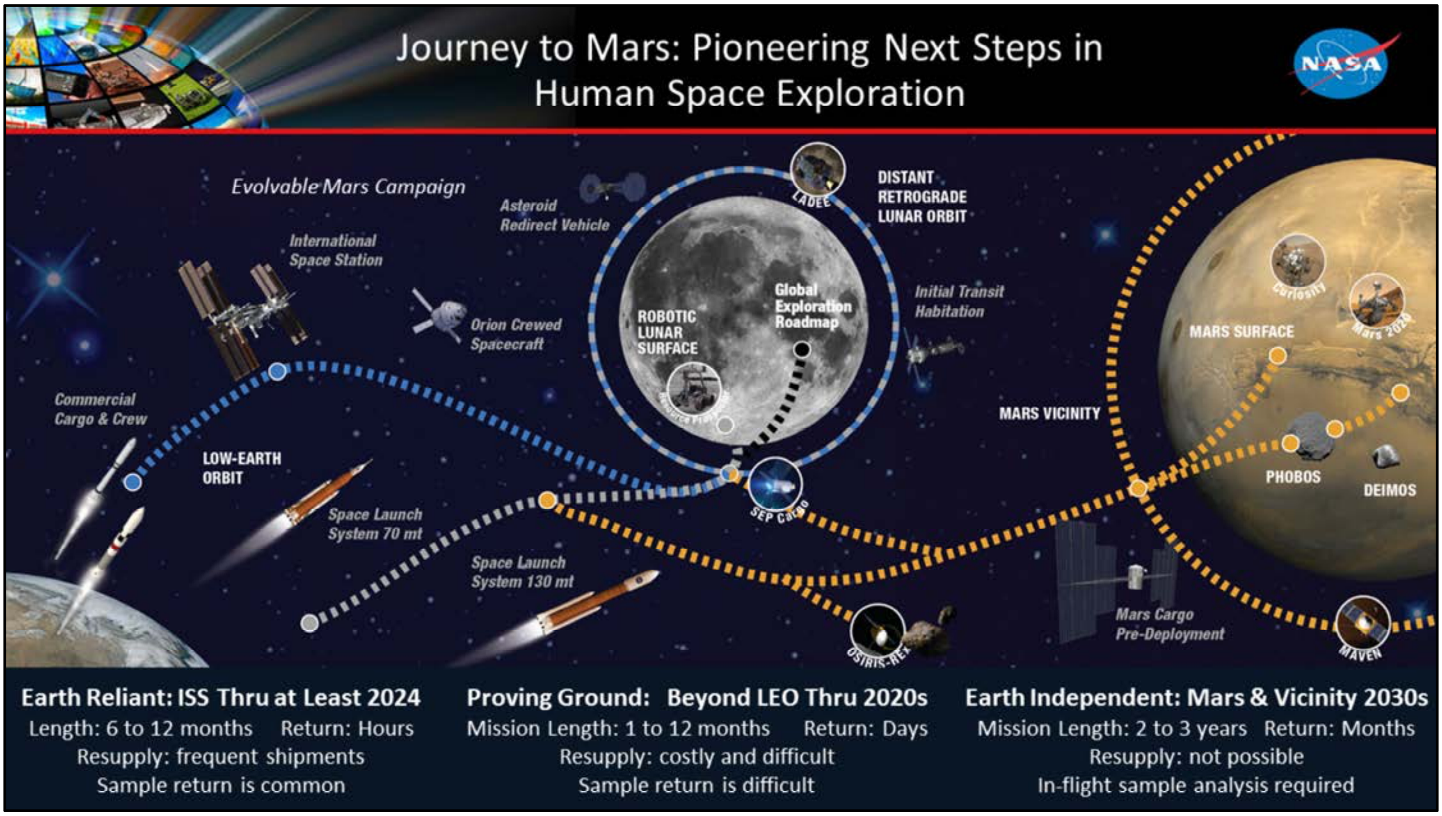
- SUSTAINABLE ON-FARM SOLUTIONS SUCH AS NANO-SUPPORTED WATER TREATMENT ARE NEEDED TO ENABLE AGRICULTURAL PRODUCERS TO CONSERVE GROUNDWATER THROUGH:
  - THE SAFE USE OF EMERGING NONTRADITIONAL WATER SOURCES
  - IN MARYLAND, A TEMPERATE STATE WITH AN AMPLE GROUNDWATER SUPPLY, 35 SITES ARE CURRENTLY REGISTERED USERS OF RECYCLED WATER FOR SPRAY IRRIGATION OF CROPS (OR LANDSCAPES)

>> Jim Dobrowolski: One of the recently funded projects that I wanted to highlight was a ground water sustainability project. And it's one where we're looking at on-farm solutions with nano-supported water treatment as the key to conserve ground water. The safe usage of emerging nontraditional water sources focused on crops eaten fresh. In Maryland, a temperate state with an ample groundwater supply, there are still 35 sites that are currently registered users of recycled water for the spray irrigation of crops.

>> Jim Dobrowolski: You need to see yourself in our Request For Applications, RFAs. That's our request for your proposals. And we're really going to focus on improving our funding of water sustainability issues across the U.S. You need to take advantage of review panel membership. It's a good way to come into our agency and really establish some knowledge about how to write a successful proposal. You're an important stakeholder group, nanotechnology folks and the water folks out there. And we'd like to thank you for your attention, and we're Jim Dobrowolski and Hongda Chen at the USDA National Institute of Food and Agriculture. Thanks.

>> Stacey Standridge: Thanks, Jim. That's a great overview of NIFA's interests in water and nanotechnology, as well as the programs that you have to support these activities. And finally we'll move on to our last speaker of the afternoon, Dan Barta. And the floor is now yours.

>> Daniel Barta: Thank you, Stacey. It's a pleasure to be here today and to talk to you about NASA's water recycling in space. I'm going to talk about water at a whole lot of different levels than the previous speakers. I'm a technical person. I tend to get into the technical. Many of you who are actually developers out there may be looking for applications for your nanotechnologies, you might find some things in my talk. Or at least you might find some links to go where you might find more information.



>> Daniel Barta: Our vision for space is to go to Mars. That's our ultimate destination. And to do that we need to develop systems that allow us to get there, capabilities that we don't have right now. Currently, NASA has a major investment in activity on the International Space Station. We have crews up there for six to 12 months. And it's pretty easy to get up to the space station. It's a matter of hours to days to really get up there and down. We can bring cargo up there if we need it. Recycling really does help us save mass to orbit and cost. But it's not as necessary because we can bring stuff with us. But if we go to Mars or go away from the Earth's low-Earth orbit we have to take everything we need with us. And the farther we go, especially Mars, which is about a six-month trip, if you run out of something if you want to ask for it, well, if we're ready and the planets are aligned, it may be a couple years before we could send another ship, and takes six more months to get there. So you want to really be self-sufficient. You want to be sustainable. And then to the extent that you can, you need to really reuse all the resources you have. So we're really focused on recycling of water in flight. And we're proving those systems on the International Space Station today, right now.

Nominal Water Requirements by Mission

Quantities

- Water usage in spacecraft is very low compared to conventional Earth-based applications.
- Water requirements for missions beyond ISS are not yet fully established
- Usage may be periodic, resulting in higher rates of usage on days of use, with no usage on days in between.
- Nominally, water use results in comparable amounts of wastewater.

Potable Water Quality

- Potable water is currently used for all spacecraft uses.
- For some applications the biocide is removed before usage.
- Maximum levels of selected inorganic and organic species for acute and prolonged exposures are listed in "Spacecraft Water Exposure Guidelines for Selected Waterborne Contaminants", JSC-63414

Parameter	Units*	ISS	Mars Transit Vehicle	Early Planetary Base	Mature Planetary Base
Drinking Water	kg/CM- d	2.00	2.00	2.00	2.00
Food Rehydration	kg/CM- d	0.50	0.50	0.50	0.50
Total Consumption	**kg/CM- d**	**2.50**	**2.50**	**2.50**	**2.50**
Urinal Flush	kg/CM- d	0.30	0.30	0.50	0.50
Personal Hygiene	kg/CM- d	0.40	0.40	0.40	0.40
Medical water	kg/CM- d	0.50[†]	0.50[†]	0.50[†]	0.50[†]
Shower	kg/CM- d	n/a	n/a	1.08	1.08
Laundry	kg/CM- d	n/a	n/a	n/a	1.8
Dish Wash	kg/CM- d	n/a	n/a	n/a	3.54
Total Hygiene	**kg/CM- d**	**0.70**	**0.70**	**1.98**	**7.32**

* Kilograms per crewmember per day [†] Plus base amount of 5 kg per mission
Data from Baseline Values and Assumptions Document NASA/TP-2015–218570

Parameter	Units	Requirement
Total Organic Carbon	mg/L	< 0.5
Microbial	CFU/ml	< 1
Silver Biocide	ppb	400

Data for Kg/CM-d was derived from "Life Support Baseline Values and Assumptions Document" NASA/TP-2015–218570

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>> Daniel Barta: When one looks at the amounts of water that we really need on a daily basis, they're actually pretty low. In order to save weight and mass, we really only provide astronauts drinking water and some water that goes into the food. But for hygiene right now on the International Space Station basically we use wet wipes. You might take some rags and wet them up and basically rub yourself down to clean yourself up. But we recycle the water in those wipes by hanging them up. And then that water gets in humidity and gets condensed. Those missions to the space station are relatively short, so you can get used to some inconveniences, I suppose. But we don't have hand wash. We don't have a shower. We don't have laundry there. We don't have dishes that we have to wash. So we don't have a lot of wastewater generated. Some of the astronauts have created their small little showers they've used, just to wet themselves up. Then dry themselves down with a towel and hang up the towels to dry.

But we do believe, for long-duration missions, we're going to need to increase the amount of different uses for water. Hopefully we'll have a shower. Especially if we're on Mars, and we have dust come into the vehicle or we get a little dirty from the local resources that are there, then we'll probably need a little better job. And then it may be that with the length of a mission that rather than just bringing clothing, investing in the hardware to wash clothes to recycle clothes is important. So we may introduce a laundry. But what we have to do when we look at future systems, the hardware we bring must be lower in weight, along with its supporting systems, the energy, the heat rejection. Then it must be much lower in weight than the water, for instance, that it helps to recycle and produce. And it must be very reliable as well.

I'd like to bring to your attention some references that I have at the bottom of the document. The "Life Support Baseline Values and Assumptions Document" gives some projections for the kinds of water and other resources that we'll need in future missions. We right now don't have a true mission or schedule to go to Mars. So we don't have actual requirements set for that. But we have some nominal or expected values and they're in that document. Also, in terms of water quality, I reference a document, JSC-63414, which you can search for on the Internet, which discusses the type of water quality that we need. We have very rigid standards for water quality: essentially organic carbon less than a half a milligram per liter, only one colony forming unit -- microbial. Those are the targets that we have.

Nominal Wastewater Generation Rates by Mission

Quantities

- On ISS, crewmembers use wet wipes or wet towels for hygiene, then hang the towels to dry – wastewater re-enters the water recovery systems as humidity condensate. No hand wash, shower, laundry or dish wash exist on the ISS
- For stabilization of urine, a pretreatment is added composed of hexavalent chromium and either sulfuric or phosphoric acid.

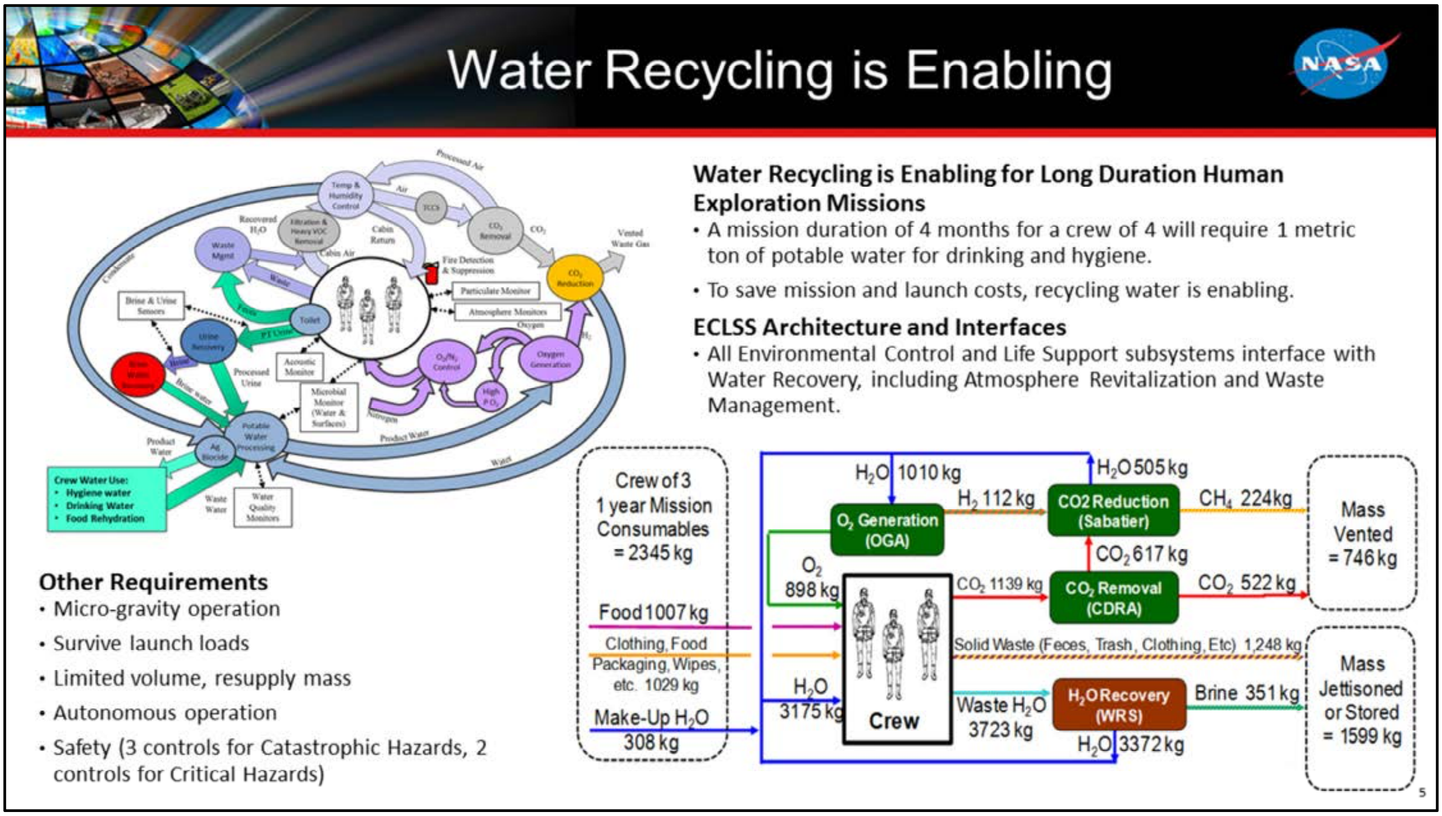
Wastewater Composition

- Expected composition of wastewater streams is available in the reference cited below

Parameter	Units	ISS	Transit Vehicle	Early Planetary Base	Mature Planetary Base
Urine	kg/CM- d	1.20	1.50	1.50	1.50
Urine Flush	kg/CM- d	0.30	0.30	0.50	0.50
Total Urine Load	**kg/CM- d**	**1.50**	**1.80**	**2.00**	**2.00**
Oral Hygiene	kg/CM- d	n/a	n/a	0.37	0.37
Hand Wash	kg/CM- d	n/a	n/a	4.08	4.08
Shower	kg/CM- d	n/a	n/a	2.72	2.72
Laundry	kg/CM- d	n/a	n/a	n/a	11.87
Dish Wash	kg/CM- d	n/a	n/a	n/a	5.87
Food Preparation	kg/CM- d	n/a	n/a	n/a	TBD
Total Hygiene Load	**kg/CM- d**	**0.00**	**0.00**	**7.17**	**24.45+**
Humidity Condensate	kg/CM- d	2.27	2.27	2.27+	2.90+
Total Wastewater Load	**kg/CM- d**	**3.77**	**4.07**	**11.44+**	**29.35+**

Data derived from "Life Support Baseline Values and Assumptions Document" NASA/TP-2015–218570

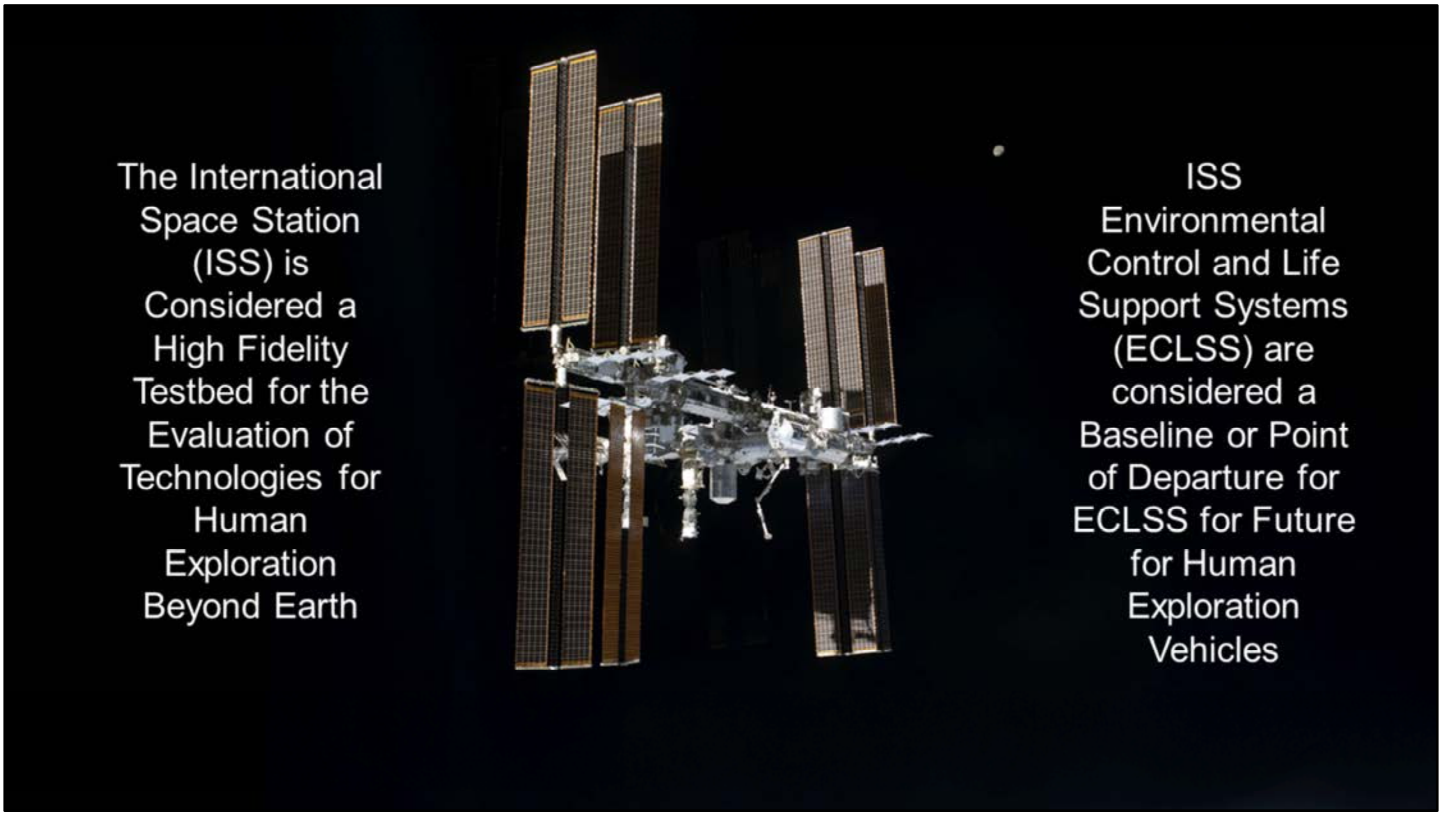
>> Daniel Barta: And then the amount of wastewater that we generate really depends upon the amount of water that we use, and so it's kind of one and one. What's interesting with respect to the wastewater is that it needs really to be stabilized. Because we have it in a closed cabin, we need to add a sanitation agent, a pre-treatment. And we use fairly heavy duty materials: hexavalent chromium, which we got from the Russians as a pre-treatment chemical, and either sulfur or phosphoric acid, which helps to prevent microbial growth and also to prevent precipitation. These are the concerns we have.



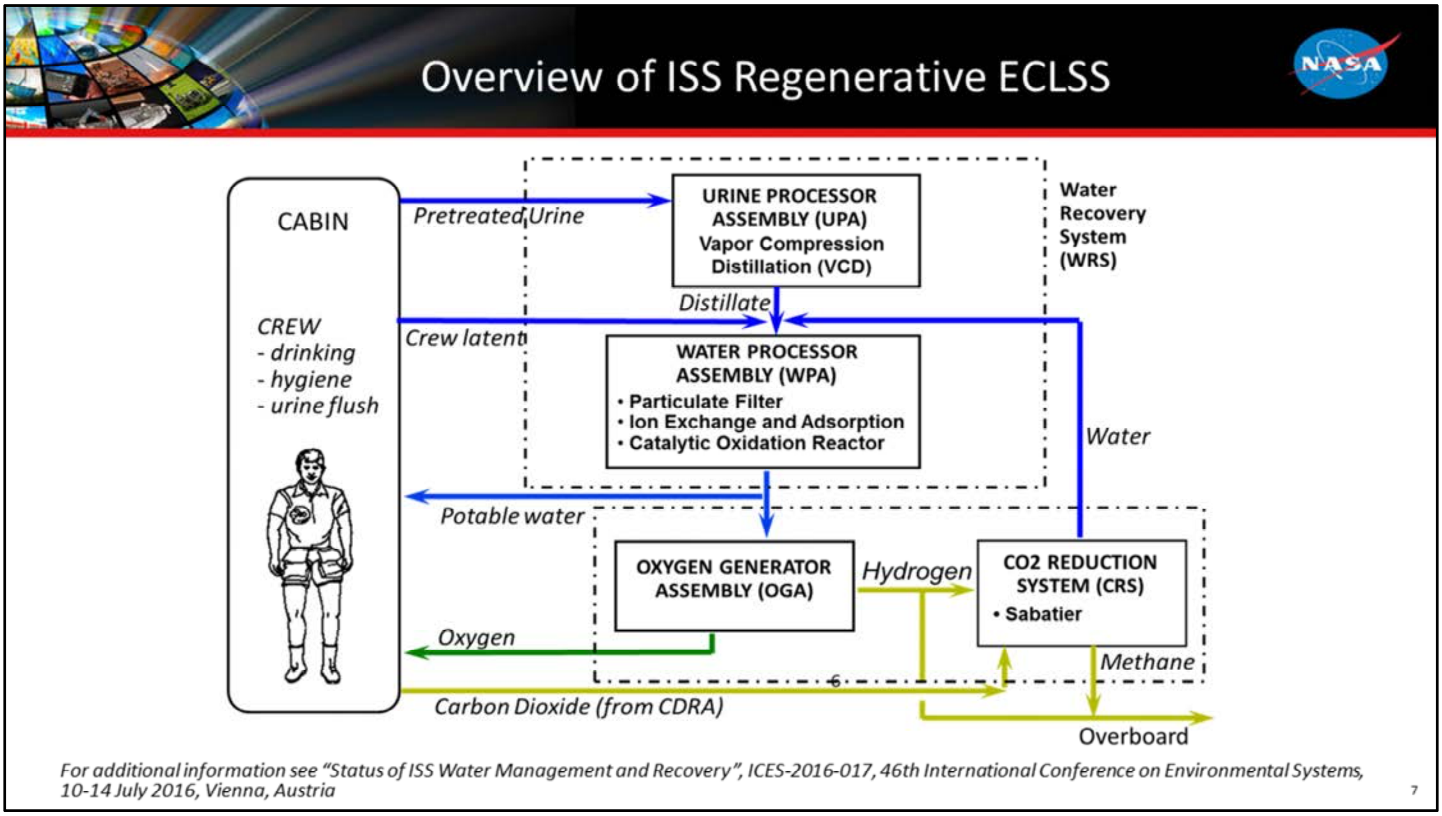
>> Daniel Barta: But I mentioned water recycle is enabling. If you take just small amounts of water that we may use, but we add it to the number of crew members we have, the number of days of a mission -- a mission to Mars may be three years -- we're talking about literally tons of water. And that would save a lot of mass in the mission if we recycle it. Other constraints we have with regard to systems for processing water:

- They need to be able to operate in microgravity. You don't want to have bubbles generated if you can. Phase separation of gases and liquids and solids is very difficult to do.
- Systems need to survive launch load. You need to be able to shake them and tolerate those kinds of conditions.
- And they need to be small and miniature. We don't have a lot of space volume in the spacecraft.
- And as well as having margins for safety and reliability.

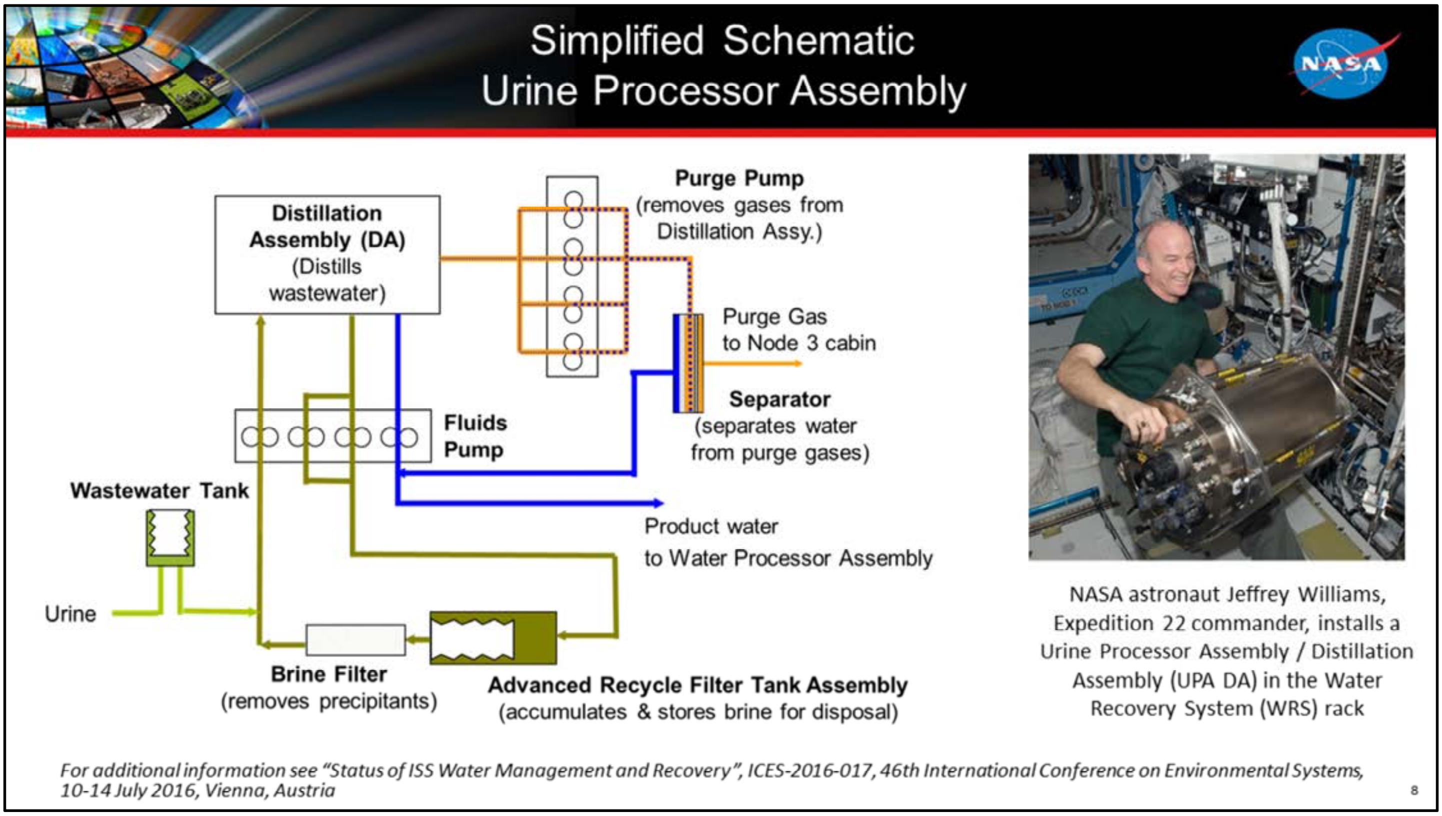
One other thing to add: the water systems we use have interfaces or are integrated pretty much with most of the other systems in spacecraft. The way we produce oxygen right now on the space station is we break water through electrolysis into hydrogen and oxygen. So water partly is our source of oxygen. And we can recycle water through human metabolism -- people produce water in their metabolisms. So we condense that. And so we have really an integrated system that integrates the atmosphere revitalization, water recovery, and even waste management. Right now we don't recover water from solid waste like human feces, but that's something we might want to do in the future.



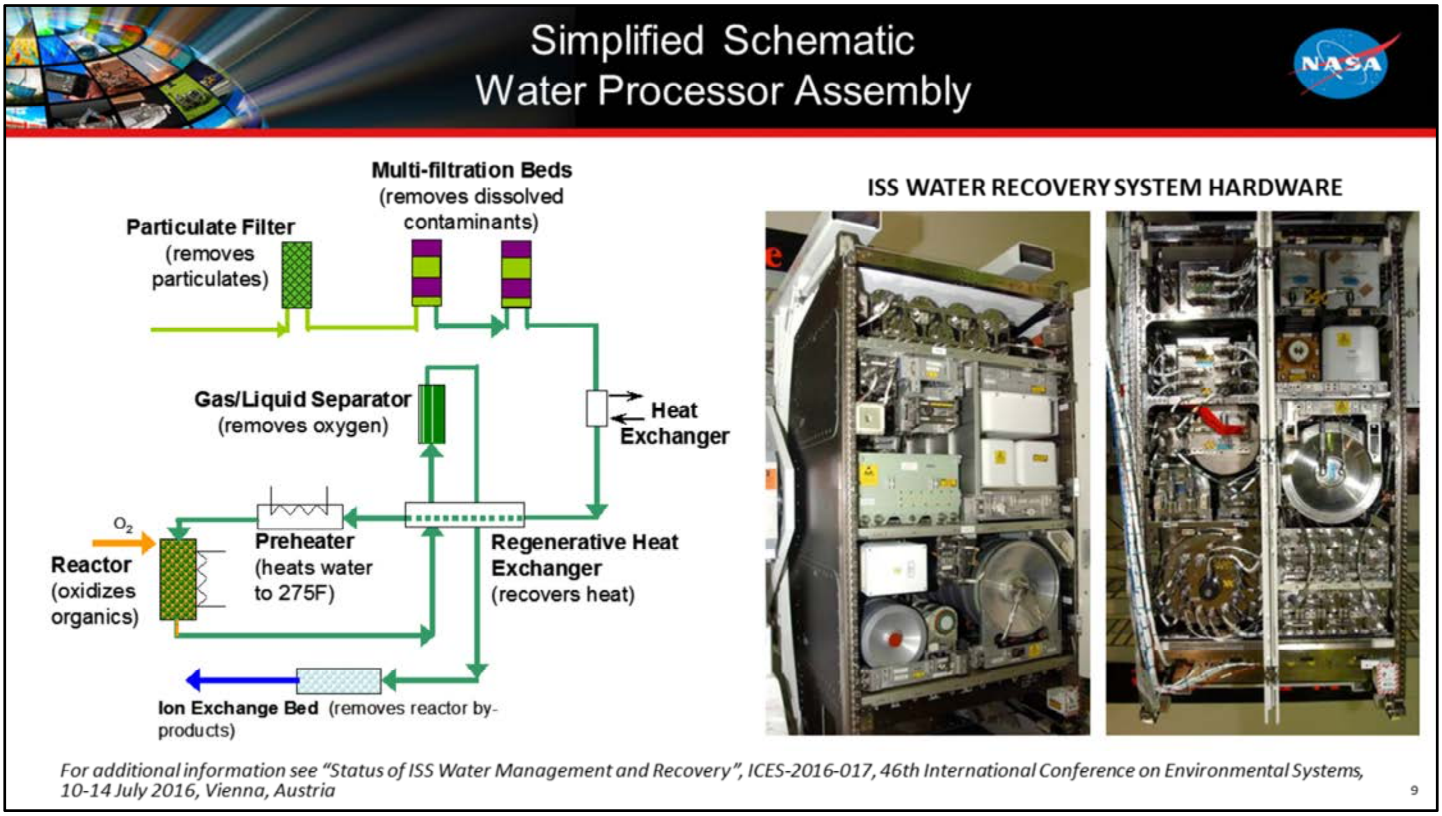
>> Daniel Barta: As I mentioned, the International Space Station is what we currently have. It really is considered a high-fidelity test bed for evaluation of technologies for long-duration missions such as Mars. And likely the systems we have aboard right now are the point of departure or baseline. But we would like to have the best systems. If we can improve upon those systems, we would like to do that.



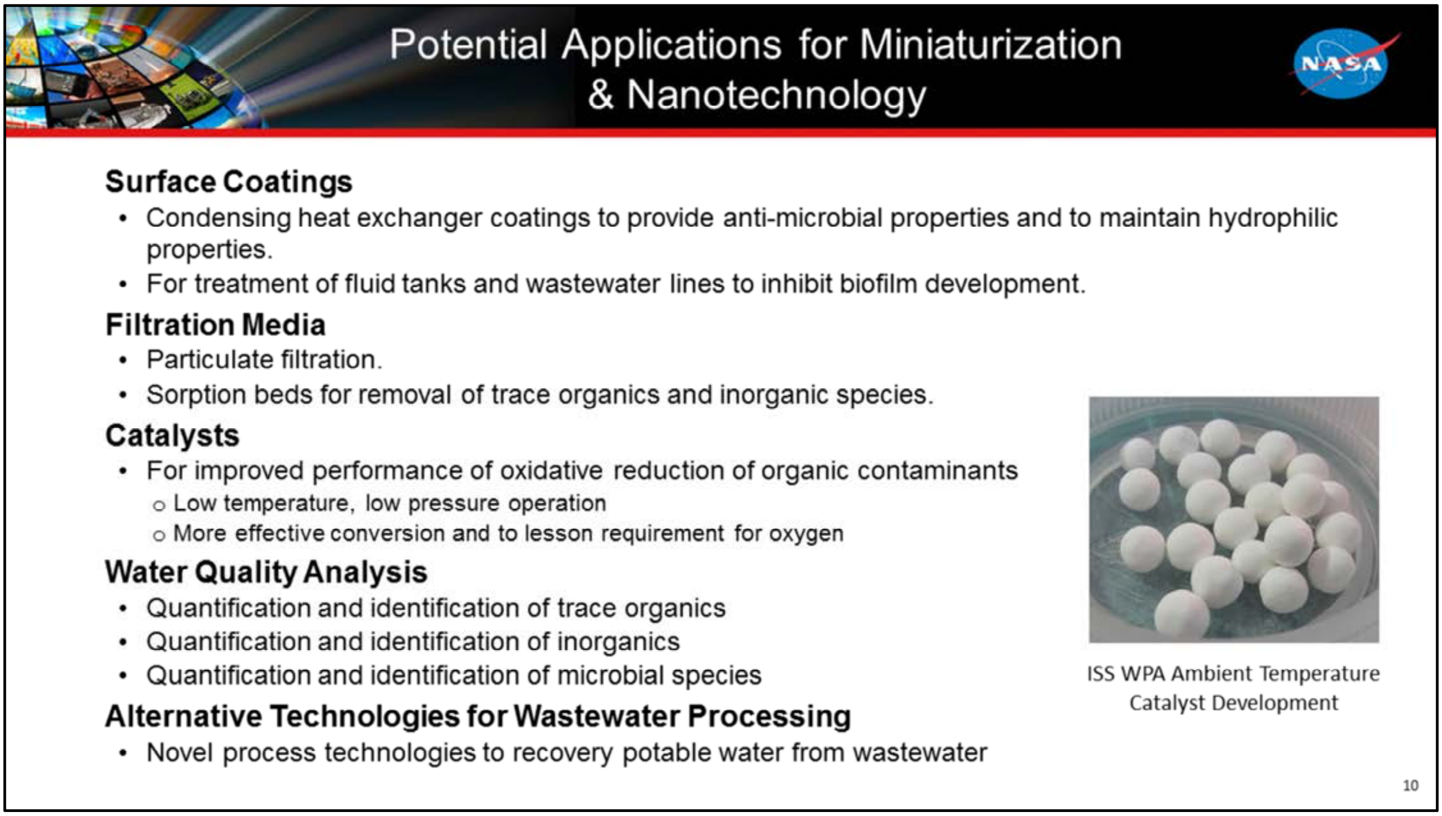
>> Daniel Barta: I mentioned a little bit about the integration of the water systems with other systems on board. We process our urine in a urine processer assembly, which is basically a distillation system. Basically, all of the salts and the organics stay behind and are concentrated. And then we process the distillate, with the humidity condensate that comes from the spacecraft humidity control, through a water processer. And that water is used to generate oxygen or for potable water for crew use. Any additional information you would like on this, you can read the citation I have at the bottom of the presentation.



>> Daniel Barta: I mentioned the urine processer. It is a distillation system. One of the reasons we add pre-treat is to keep solids from forming, which can be a problem with this. This is a centrifugal type of system. And basically solids will be a problem. We had some calcium buildup in the system. Human urine is actually higher in concentration of calcium because of some slow bone de-mineralization that can occur in space if you're not actively exercising and using muscles. And that little bit higher amount of calcium, because we hadn't had the pre-treat right, we actually got some precipitation of calcium sulfates in our system and caused that system to go down actually. We have improved upon the process now, and we don't have that issue.



>> Daniel Barta: Also, the water systems, once they're distilled, they go through a particulate filter, multi-filtration beds that remove organics, residual organics, and salts. And then we go through a catalytic oxidation system, which reacts any organics and removes inorganics in the system. And you can see on the right, there's the systems that currently are up in space to recycle water. Those are two large racks that we have. Effectively, you wouldn't want a rack that was that size only to recycle a couple gallons of water. It wouldn't make sense. But over the duration of a long-duration mission, you're now recycling thousands and thousands of gallons.



>> Daniel Barta: Potential applications for nanotechnology, and miniaturization -- how to make things smaller. We need to do a lot in the small amount of space and volume. And these are ideas that I came up with based on our knowledge. And those in the community may also have some others to add, things their solutions may benefit.

- Surface coating for condensing heat exchangers to provide anti-microbial properties, maintain the hydrophilic property of the heat exchanger, treatment of fluid tanks, fluid lines to prevent and inhibit biofilm development.
- Maybe some different filtration media for sorption of trace organics or inorganic species.
- Catalysts. There's a lot of work in nanotechnology for different catalysts. Right now the catalyst I showed in one of the processers operates at very a high temperature and pressure. If we can get the performance of the catalyst to where we can reduce the pressure and then the temperature, it would be of a great benefit.
- And we need complete water quality analysis on board our spacecraft for trace contaminants, inorganics, microbial species. When we go away from Earth, we will not be able to send samples down. We'll need to do in-house monitoring. We need to essentially equip a spacecraft with a full complement of an analytical laboratory. And the only way to do that is to do it at a very small level.
- And then any other sort of alternative. If you have a great way to process water using nanotechnology, we often look at other ideas.

>> Daniel Barta: And we have had a number of investments recently in water through our SBIR program. I actually serve as a topic manager for habitation system, which includes waste water processing. And if you want to find out about any of these we have funded, you can search the NASA SBIR website. And then lastly, we did have an industry day about a month ago. And there were two things we actually released that we likely will have, not for sure, but have in our coming solicitation in November related to in-line silver monitoring technologies that we're looking for to measure silver between zero and a hundred parts per billion. We use silver and not chlorine as a disinfection agent in potable water. And then we're looking at some sample processing modules that would interface with a polymerase chain reaction microbial analysis system, between a sample collection and then that system for basic sample processing.

>> Daniel Barta: Essentially, with recycling, which we currently do, yesterday's coffee, yesterday's wastewater, turns into today's coffee. Thank you very much.

>> Stacey Standridge: Thanks, Dan. I think that's the first time I've ever heard someone use the phrase “if the planets align” literally.

>> Daniel Barta: That's why we can only launch about every two years.

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Q&A

For more information, please visit
www.nano.gov/waterNSI

>> Stacey Standridge: We're now at the point of our webinar where we invite you to ask questions of our panelists. You can submit questions via the webinar interface, and I know that we have one queued up already.

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What does the future hold for funding research on water-related nanoparticles at NIFA?

>> Stacey Standridge: This is for Jim and Hongda. What does the future hold for funding research on water-related nanoparticles at NIFA?

>> Jim Dobrowolski: Thanks, Stacey. I've got a couple answers for that. The first one is really the fact that we've had this Water for Agriculture funding line, that part of AFRI, now for three years. And because of the demands to try and improve the water footprint of agriculture into the future, at the same time trying to accelerate the productivity level and certainly the processing speed and what have you, we are shifting the program a little bit to focus on food production systems. So in the future, we're going to be looking very particularly at trying to improve our ability to produce food as fast and as efficiently as possible with respect to water. And so the ability to impart nanoparticles and other nanotechnology to assist us in delivering water to the site for irrigation is going to be critical. Where it's also going to be critical that we have the ability to trade off water so that we are using more and more nontraditional water sources and less and less of the water that we currently control. We control about 80% of the water in the United States, and most of that water is potable. But we're going to have to start leaning on the nontraditional water sources to be able to reach the goals that we need to do for water efficiency.

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Are there nanotechnology-enabled treatments for taking the lead out of drinking water?

>> Stacey Standridge: Great. Thank you. And I think we have just a few minutes left. I wondered, Nora, if you'd be willing to, in like a minute or so, if you could, answer the question that we got: are there nanotechnology-enabled treatments for taking the lead out of drinking water?

>> Nora Savage: There are technologies for taking lead out; are they nano? I think there are some nano-enabled technologies, including some that have been developed at Rice, where they have developed a nanoparticle that collects lead, arsenic, and other metals. And then what they can do is actually use a magnet to pull it out. It's easy. You don't have to dispose of the solution because now they can just pull it out and separate it totally. Other than that, I know there are other lead detection technologies because we knew there was lead in Michigan. It wasn't the detection that was the issue. It was addressing it. So that's the one I know of specifically. I do believe some of the other nanoscale zero valent iron, NZVI, I think that's more of a chlorinated compound remediation technique. But actually DB Bhattacharyya at University of Kentucky has developed some membrane technologies for treating lead.

>> Stacey Standridge: Great. Thank you. So I think we've reached the end of our hour. And I would like to thank all our panelists for taking the time to participate today and putting together the great presentations. I'd also like to thank the audience for joining us. We will post the transcription and the slides at www.nano.gov/publicwebinars, along with information on the upcoming water signature initiative webinars. Again, my thanks to our panelists, and that concludes our webinar for today.