



**Mike DeLuca, President, National Association of  
Marine Laboratories**

**Robert Cowen, Chairman, Public Policy  
Committee, National Association of Marine  
Laboratories**

# NATIONAL ASSOCIATION OF MARINE LABORATORIES

**Annual Public Policy Meeting**

**March 5 and 6, 2017**

**1201 New York Avenue NW, Suite 400**

**Washington, D.C. 20005**



Prepared by Joel Widder and Meg Thompson, Federal Science Partners



National Association of Marine Laboratories  
Winter Meeting  
1201 New York Avenue NW  
4th floor Ocean Leadership Conference Room  
Washington, D.C.  
March 5 and 6, 2017



**Sunday -- March 5, 2017**

**Location: Washington Plaza Hotel, 10 Thomas Circle NW, Washington, D.C. 20005**

**2:00PM Opening Remarks – Mike DeLuca and Robert Cowen**

- **New Member(s)**
- **Tribute to Graham Shimmield**

**2:15PM Briefing on the Federal Science Budget and Policy Environment – Joel Widder and Meg Thompson, Partners, Federal Science Partners and Consultants to NAML**

**2:45PM Discussion of NAML Public Policy Agenda and Related Activities – Robert Cowen**

- **NAML White Paper – Public Policy Agenda**
- **Testimony – Issues Beyond**
- **Congressional Briefing – Topic and Member Participation**
- **General Discussion**

**3:45PM NAML Business Meeting**

**Committee Reports**

<b>Public Policy</b>	<b>Robert Cowen</b>
<b>Treasurer</b>	<b>Billie Swalla</b>
<b>Membership</b>	<b>Brett Burk</b>
<b>Education</b>	<b>Jan Hodder or Mike DeLuca</b>
<b>Network Integration</b>	<b>Steve Weisberg</b>
<b>Science Communication</b>	<b>TBD</b>
<b>International</b>	<b>Ivar Babb (could be moved to 3PM)</b>
<b>Evaluation</b>	<b>Mike DeLuca</b>

**4:15PM Regional Meetings: WAML; SAML; and NEAMGLL**

**5:00PM Regional Meetings report out**

**5:30PM Reception – Washington Plaza Hotel**

**6:30PM Dinner (on your own)**

**Monday – March 6, 2017**

**Location: Consortium for Ocean Leadership, 1201 New York Avenue NW, Suite 400  
Conference Rooms A & B**

**8:00AM: Coffee and continental breakfast**

**8:30AM: Mike DeLuca, President NAML/Robert Cowen, Chair, Public Policy Committee**

**9:00AM: Speaker: Michael Conathan, Center for America Progress – Ocean Policy**

**10:00AM: Speaker: Kolo Rathburn, Majority Staff, Senate CJS Appropriations  
Subcommittee**

**10:45AM: Break**

**11:15AM: Speaker: W. Russell Callender, Assistant Administrator, National Ocean  
Service**

**12:15PM: Lunch Panel: Libby Jewett, Program Director, NOAA, Ocean Acidification  
David O’Brien, Deputy Director, NOAA, NMFS Aquaculture  
Jonathan Pennock, Program Director, NOAA Sea Grant**

**1:45PM: Break**

**2:15PM: Panel: Ocean, Coastal, and Great Lakes in the 115<sup>th</sup> Congress  
Fern Gibbons, Majority Staff, Senate Commerce, Science &  
Transportation Committee  
Sara Gonzalez-Rothi, Minority Staff, Senate Commerce, Science,  
& Transportation Committee**

**3:15PM: Panel: NSF: Marine Labs for Research, Infrastructure and Education  
Peter McCartney, NSF/BIO/DBI  
Chris Meyer NSF/BIO/DBI**

**4:15PM: Break**

**4:30PM: Speaker: Dr. Richard Murray, Division Director, NSF Ocean Sciences (and  
staff) -- Ocean Research Priorities Plan, OCE Challenges and  
Opportunities**

**5:30PM: Summing Up – Next Steps**

**6:00PM: Meeting Concludes**

**Biographical Sketches of Speakers and Suggested Questions**  
**NAML Public Policy Meeting**  
**Washington, D.C.**  
**March 5 and 6, 2017**

**Michael Conathan** -- Michael Conathan is the Director of Ocean Policy at American Progress. His work focuses on driving progressive solutions to the multitude of problems facing the world's oceans. Prior to joining American Progress, Mike spent five years staffing the Senate Committee on Commerce, Science, and Transportation's Subcommittee on Oceans, Atmosphere, Fisheries, and Coast Guard—initially serving a one-year appointment as a Dean John Knauss Marine Policy Fellow before joining the committee full-time as a professional staff member in 2007. In that capacity Mike worked primarily for Subcommittee Ranking Member Sen. Olympia Snowe (R-ME), as well as the Ranking Members of the full committee, Sen. Ted Stevens (R-AK) and Kay Bailey Hutchison (R-TX). He oversaw enactment of multiple key pieces of ocean legislation, including the Magnuson-Stevens Fishery Conservation and Management Reauthorization Act, the Integrated Coastal and Ocean Observing Act, the Federal Ocean Acidification Research and Monitoring Act, and the Shark Conservation Act. A native Cape Codder, Mike received a master's degree in marine affairs from the University of Rhode Island in 2005 and also holds a Bachelor of Arts in English literature from Georgetown University.

- Can you talk about the specific ocean policy issues you expect this Administration and the new Congress to confront and how they will impact the ocean and coastal research and education activities of concern to the membership of NAML?
- Can you give us some advice about the best way for NAML to effectively convey its views – particularly on the issues contained with our "[white paper](#)" to the new Administration?
- How can we go about increasing bipartisan support for the ocean, coastal and Great Lakes enterprise – the Oceans Caucus – and what can NAML members do to expand awareness of and support for ocean, coastal and Great Lakes research, education, and related matters?

**Russell Callender** -- Dr. Russell Callender is the Acting Assistant Administrator for NOAA's National Ocean Service. The National Ocean Service (NOS) is the nation's most comprehensive ocean and coastal agency. Its mission is to provide science-based solutions through collaborative partnerships to address evolving economic, environmental and social pressures on our oceans and coasts. The agency observes, measures, assesses, and manages the nation's coastal, ocean, and Great Lakes areas; provides critical navigation products and services; and conducts response and restoration activities to protect vital coastal resources. As Acting Assistant Administrator, Dr. Callender provides strategic vision for NOS. He leads the implementation of activities that support NOS's priorities of coastal resilience, coastal intelligence, and place-based conservation. He serves as the focal point for conveying the value of NOS products and services within NOAA and to the Department of Commerce, the Office of Management and Budget, and Congress. Dr. Callender actively establishes and grows partnerships with other federal agencies, non-governmental organizations, and industry.

- Can you discuss the nature of the interactions NOAA is having with transition officials and the Secretary's new team?
- Can you give us a sense as to when we might expect to see the White House nominate the next Administrator of NOAA?
- What do you expect to be the top three or four issues related to the health of our ocean enterprise the new Administration and the new Congress will address and in what ways will they impact the programs and activities of the National Ocean Service?
- Can you update NAML on the latest personnel changes to NOS? We understand Mary Erickson has left NCCOS for the National Weather Service. What does that mean for NCCOS?
- How can NAML best use its "[white paper](#)" to the new Administration and Congress?
- What role is NOS playing in the interagency ocean priorities exercise begun last fall?
- What would you like to see the Coastal Roundtable do over the next five to ten months that would be helpful to NOAA and the ocean/coastal enterprise?
- Given the emerging priorities of the new Administration, do you foresee any changes to the Coastal resilience grant program?
- What opportunities exist for NAML to engage in efforts to integrate ocean and coastal observing systems?

**Kolo Rathburn** -- Charles Kolo Rathburn is a Professional Staff Member -- Majority for Senate's Committee on Appropriations on the Commerce, Justice and Science subcommittee under the leadership of Senator Richard Shelby. His portfolio includes the Department of Commerce and related trade and science agencies including the National Oceanic and Atmospheric Administration (NOAA). Prior to serving on the Appropriations Committee, Mr. Rathburn was a Legislative Assistant to Senator Roger Wicker from 2011 to 2013. In 2010, Mr. Rathburn was a Sea Grant Legislative Fellow in Senator Wicker's office. Mr. Rathburn received an M.S. in Marine Biology from the College of Charleston in 2009.

- Can you give us a sense of the budget constraints the Congress will be confronting and how those pressures may impact the research and education programs important to NAML?
- Can you give us any advice as how NAML can effectively interact and educate new decision makers on both ends of Pennsylvania Avenue?
- Can you give us advice as what NAML can do to help Chairman Shelby and the CJS Subcommittee maintain strong support for research and education?
- What is the likelihood of Congress transferring NASA's earth science programs to another agency?
- How can we go about increasing bipartisan support for the ocean, coastal and Great Lakes enterprise and what can NAML members do to expand awareness of and support for ocean research and education?
- What is the likelihood that an infrastructure initiative will include research infrastructure such as rehabbing research facilities and or cyber infrastructure to support research and education? What role will your subcommittee play in any infrastructure initiative?

**Molly McCarthy** -- Molly McCarthy is a Professional Staff Member on the Senate Appropriations Committee's Subcommittee on Commerce, Justice, and Science. She covers appropriations and oversight for the Department of Commerce, the National Science Foundation, and independent trade agencies. Previously, she has worked for the Transportation and Housing Appropriations Subcommittee under Senator Patty Murray (D-WA) and for the House Committee on Science and Technology under Bart Gordon (D-TN). Molly also worked at OMB's Office of Information and Regulatory Affairs while completing her Master's in Public Policy at the University of Virginia.

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**Libby Jewett** -- Dr. Libby Jewett became the first Director of the NOAA Ocean Acidification Program in May 2011. A founding member of NOAA's Ocean Acidification Steering Committee, Dr. Jewett led NOAA-wide meetings of scientists and policymakers to conceive and develop NOAA's first comprehensive ocean acidification research plan. She continues to represent NOAA on the ocean acidification interagency working group (under Subcommittee on Ocean Science and Technology) where she helped develop an ocean acidification strategic research plan for the nation. Prior to becoming Director, she directed the only two national competitive hypoxia research funding programs as program manager for the Center for Sponsored Coastal Ocean Research in NOAA's National Ocean Service. In this role, she strived to make the funded science relevant to the management of coastal ecosystems, especially in the Chesapeake Bay and northern Gulf of Mexico. She also has many years of experience working in nongovernmental organizations. Jewett earned a Ph.D. in Biology with a focus on Marine Ecology at the University of Maryland, a Master of Public Policy at Harvard University's Kennedy School of Government, and a B.A. at Yale University.

- Can you give us a sense as to how ocean acidification is being received by the new Administration and what do you expect to happen to federal interest and support for ocean acidification under the new Administration?

- Can you talk about the ways in which the OA program has partnered with non-federal entities in carrying out research and other activities related to ocean acidification and do you expect those activities to continue or expand?
- Are there ways NAML can use its network of marine laboratories more effectively to support and participate in OA programs?
- What can NAML do to increase bipartisan support for ocean and coastal research and education issues – such as ocean acidification?

**David O'Brien** -- David O'Brien has been the Deputy Director of the NOAA Fisheries Office of Aquaculture since 2012. David joined the office in 2006 where he served initially as Program Coordinator and later as International Coordinator. Mr. O'Brien started his career at NOAA in 2000 as a John A. Knauss Marine Policy Fellow and served for six years within the NOAA Fisheries Office of Protected Resources implementing listing and recovery provisions of the Endangered Species Act. A fishery biologist by training, Mr. O'Brien worked for two years as an aquaculture extension agent as a Peace Corps volunteer in Cameroon, West Africa prior to his graduate education. Mr. O'Brien has an M.S. in Marine Estuarine and Environmental Science from the University of Maryland, and a B.S. in Zoology from the University of Massachusetts.

- Can you tell us where you see aquaculture going as the new Administration settles in? The previous Administration had put increasing emphasis on growing this nation's ability to compete on the world stage. Do you expect that to continue and in what ways?
- Can you talk about how the NMFS aquaculture office engages with other NOAA offices – such as Sea Grant?
- Can you give us a preview of what issues your office and NOAA will be pursuing within the realm of aquaculture?
- In what ways can NAML and/or its members be helpful to NOAA on aquaculture?
- Do you foresee a role for NOAA to help address the emerging conflicts between conservation of threatened and endangered species and aquaculture?
- What opportunities may be developed to reduce conflicts between aquaculture operations and other uses of the coastal zone? Could this be an opportunity to incorporate aquaculture uses into spatial planning activities?

**Jonathan Pennock** -- Jonathan Pennock is the Director of the National Sea Grant College Program. Prior to joining NOAA, Jon was the director of the New Hampshire Sea Grant Program and the deputy director of the School of Marine Science and Ocean Engineering at the University of New Hampshire. Jon is a nationally-known coastal scientist with expertise in oceanography and estuarine sciences. His research has focused on understanding human impacts on coastal marine food webs. Jon has a PhD in oceanography and master's in marine studies from the University of Delaware and a bachelor's in biology from Earlham College.

- Can you talk about your efforts since arriving at the National Sea Grant office to expand Sea Grant's visibility and usefulness to other NOAA offices (e.g., OCM, NERRS, NCCOS, NMFS)?
- In what ways has the transition team interacted with NOAA and Sea Grant so far? Are there issues coming from the transition team that NAML can be helpful on?



- In what ways can NAML work with Sea Grant to raise the program's visibility and support within the Administration and on Capitol Hill?
- What is the biggest surprise to you since moving from UNH and running the NH sea grant program into NOAA and leading the National program? What are the top three issues facing Sea Grant, in your view?
- Past NAML President Nancy Rabalais has been a member of the Sea Grant Advisory Board. Are you looking for suggestions to fill future vacancies on the Sea Grant Advisory Board and what is the best way NAML can provide such suggestions?
- Do you foresee any expansion of the Sea Grant program?
- What steps can be taken to strengthen and grow some of the smaller Sea Grant programs?

**Fern Gibbons** – Fern Gibbons joined Chairman Thune's staff for the U.S. Senate Committee on Commerce, Science, and Transportation in 2014. She is Policy Director for Oceans, Atmosphere, Fisheries, and Coast Guard and Surface Transportation and Merchant Marine Infrastructure, Safety and Security. Prior to joining the Commerce Committee, Dr. Gibbons worked for the Nature Conservancy, where she advocated for science-based environmental policy in the federal government. Dr. Gibbons was a 2012 Sea Grant Legislative Fellow for the Commerce Committee. She received her Ph.D. from the MIT/Woods Hole Oceanographic Institution Joint Program in Oceanography. Her thesis focused on climate variability on long time scales. Her B.S. is from the University of Chicago where she studied the Geophysical Sciences and Biology.

- What specific legislative issues related to the oceans and coasts do you expect the Committee work on this year and how can NAML be helpful to the committee with respect to its legislative agenda? For example, NAML plans to sponsor one or more Congressional brown bag lunch briefings – are there topics we could pursue that would be helpful to the committee?
- What interaction has the committee had with the DOC and NOAA transition team and when do you expect the Administration to send up a nominee for NOAA Administrator?
- What role do you expect the committee to play with respect to any infrastructure package and do you see a place for the inclusion of research and cyber infrastructure in such a package?
- What practical advice would you have for NAML as the best way we can publicize and inform decision makers on the issues important to NAML (spelled out in our "[white paper](#)" to the new Administration and Congress?
- Does interest exist to advance any reauthorization measures such as the Coastal Zone Management Act and the IOOS reauthorization?
- Would you care to provide us with some advice on the best way to engage productively with your counterpart committee(s) in the House on ocean, coastal and Great Lakes issues?

**Sara Gonzalez-Rothi** -- Sara Gonzalez-Rothi currently serves as Counsel to the Senate Committee on Commerce, Science, and Transportation under Ranking Member Senator Bill Nelson. Her portfolio includes issues affecting the oceans and the atmosphere, including



oversight of line offices within the National Oceanic and Atmospheric Administration. Sara holds an undergraduate degree from the University of Florida, a law degree from the University of Miami, and is completing an LL.M. in environmental law at the George Washington University. Prior to joining the Committee, Gonzalez-Rothi worked as interim federal policy chair of the Mississippi River Delta Restoration Coalition and acting director of the National Wildlife Federation's Gulf of Mexico restoration program. From 2010-2012, Sara served as Legislative Counsel for Senator Bill Nelson, managing a wide range of environmental, energy, and agricultural legislation. In that role, she supported the Senator's immediate and long-term efforts to address the Deepwater Horizon oil disaster. Sara first joined the office of Senator Nelson in 2009 as an Everglades Policy Fellow from the University of Miami Leonard and Jane Abess Center for Ecosystem Science and Policy.

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**Peter McCartney** -- Peter McCartney has been a program director in the NSF Division of Biological Sciences since 2006, managing the Advances in Biological Informatics and Field Stations and Marine Labs programs. He has also participated in the management of numerous cross-cutting programs related to Cyberinfrastructure including Software Infrastructure for Sustained Innovation (SI2), Data Infrastructure Building Blocks (DIBBS), Cyber-enabled Discovery and Innovation (CDI) and DataNet. Prior to NSF he was Director of Informatics at the Global Institute for Sustainability at Arizona State University where he directed data management and software development projects in ecology, biodiversity, sustainability, and archaeology.

- How is NSF faring in the transition process? What have you heard from transition officials or NSF management officials regarding this Administration's attitude toward ocean, coastal, and Great Lakes research and education?

- What do you see as the future for the FSML program in terms of NSF and Administration support?
- What impact has the NAS report on FSML had on the program?
- What role can NAML play to help support the FSML program with decision makers on both ends of Pennsylvania Avenue?

**Chris Meyer** – Dr. Chris Meyer is a program director at NSF in the Division of Biological Infrastructure. Prior to joining NSF in August 2015, Dr. Meyer was chair and professor of chemistry and biochemistry at Cal State Fullerton. Dr. Meyer’s research has focused on carbon metabolism and the synthesis of biodegradable and renewable carbon sources such as starch. In 2008-09 Dr. Meyer served as a program director in NSF’s Division of Molecular and Cellular Biosciences. Among his many responsibilities is the serving as one of the NSF’s program directors for the new Inclusion across the Nation of Communities of Learners of Underrepresented Discoverers in Engineering and Science (NSF INCLUDES).

- How is NSF faring in the transition process? What have you heard from transition officials or NSF management officials regarding this Administration’s attitude toward ocean, coastal, and Great Lakes research and education?
- What do you see as the future for NSF cross disciplinary initiatives – such as INFUSE and INCLUDES given the new Administration?
- What role can NAML play to help support the NSF with decision makers on both ends of Pennsylvania Avenue?

**Richard Murray** -- Rick Murray is Director of the Division of Ocean Sciences at the National Science Foundation. He is on temporary leave from his position as Professor of Earth and Environment at Boston University (BU), where he has been located since 1992. He was the Director of the BU Marine Program from 2006-2009, and served as Chair of the Department of Earth Sciences from 2000-2005. While pursuing his undergraduate degree at Hamilton College (1985), he also participated in the Sea Education Association’s (SEA’s) program in Woods Hole. After receiving his Ph.D. from the University of California at Berkeley, he was a post-doctoral scholar at the Graduate School of Oceanography (University of Rhode Island). Murray’s research interests are in marine biogeochemistry, with an emphasis on sedimentary chemical records of climate change, volcanism, the seafloor biosphere, and modern oceanographic processes in the tropics. He has authored or co-authored ~90 peer-reviewed scientific research papers. Murray’s research funding has been provided by the National Science Foundation, the Ocean Drilling Program and Integrated Ocean Drilling Program (IODP), the U. S. Geological Survey, and other agencies. Murray is a Fellow of the Geological Society of America, a former Trustee of the Sea Education Association, and helped initiate and manage the Link Foundation’s Ph.D. Fellowship Program in “Ocean Engineering and Instrumentation”. As a seagoing oceanographer, he has participated on many research cruises in various capacities, including Co-Chief Scientist on the “Asian Monsoon” IODP expedition and Chief Scientist on the last full research cruise of the *R/V Knorr*.

- What do you see as the biggest challenges facing NSF generally and ocean sciences specifically with the new Administration and the Congress? What role do you see for NAML in that process that would be helpful and impactful?
- In general, how has the transition process been going within NSF and the new Administration?
- Can you talk about the incoming AD – Bill Easterling and how best can the ocean and coastal community work with him?
- Where do you see the interagency ocean priorities exercise going with the new Administration? Any sense yet on when new leadership at OSTP and NOAA is likely to be announced?
- Discuss the impact the Sea Change report has had on your division and the community thus far. What are the next big steps or hurdles OCE must confront?
- What role can NAML play in supporting your efforts and what advice would have on how best NAML can use its “[white paper](#)” to the new Administration and Congress?

**Joel Widder** -- Together with business partner, Ms. Meg Thompson, Mr. Widder provides government relations support to the National Association of Marine Laboratories. Mr. Widder has been providing government relations services to research universities and related organizations since he retired from federal service in 2002. Along with his partner, Ms. Meg Thompson, Mr. Widder has represented numerous clients including the University of Chicago, Columbia University, Florida State University, the State University of New York, the South Dakota School of Mines and Technology, the University Corporation for Atmospheric Research, the National Ecological Observatory Network, the National Association of Marine Laboratories, the Sea Grant Association, the Association of Children’s Museums, Vaisala, Inc., Quantum Spatial, Inc., and General Atomics. In the past he has also represented the California Institute of Technology, the University of Illinois, the University of Southern California, Georgia Tech, Rutgers University, Arizona State University, and Tulane University. As a result, Mr. Widder has extensive experience in the research and education issues important to major research universities as well as experience in working with major higher education and scientific/engineering associations.

Before his work in the consulting field, Mr. Widder worked from 1982 to 2002 for the National Science Foundation (NSF) where he last served as the Deputy Director for the Office of Legislative and Public Affairs. Before leaving federal service, Mr. Widder also served for two years on the staff of the Senate Appropriations Committee where he had responsibility for issues related to research and education including space and environmental sciences. Mr. Widder was an original member of NOAA’s Environmental Information Services Working Group, which reports to the NOAA Science Advisory Board. He serves on the Executive Committee of the Board on Oceans, Atmosphere, and Climate within the Association of Public and Land-Grant Universities; and the American Meteorological Society’s (AMS) Weather & Climate Enterprise Commission Steering Committee. Mr. Widder received an undergraduate degree from the University of Maryland in 1975 and completed two years of graduate work at the SUNY College of Environmental Science and Forestry (1975–1977).

**Meg Thompson** -- Together with business partner, Mr. Joel Widder, Ms. Thompson provides government relations support to the National Association of Marine Laboratories. Ms. Thompson has over 20 years of Capitol Hill experience. Ms. Thompson has been professional staff on both the Senate and House Appropriations Committees for both Republican and Democratic majorities. Prior to joining the firm, Ms. Thompson served on the House Appropriations Subcommittee on Commerce, Justice, Science, and Related Agencies, where she had principle responsibility for all Department of Justice programs. In 2006, Ms. Thompson served on the House Subcommittee on Homeland Security where she had primary responsibility for the Federal Emergency Management Agency (FEMA) and Preparedness Directorate. From 2001-2005, Ms. Thompson served on the House Labor, Health and Human Services, Education, and Related Agencies Subcommittee. Before joining the House Appropriations Committee, Ms. Thompson spent three years as Director of Corporate Communications for the National Fish and Wildlife Foundation, and spent two years as a lobbyist for health and medical research clients. Prior to the private sector, Ms. Thompson served on the Senate Appropriations Committee, Subcommittee on Labor, Health and Human Services, and Education, and Related Agencies from 1992-1997.

Ms. Thompson, in partnership with Mr. Widder has represented numerous clients including the University of Chicago, Columbia University, Florida State University, the State University of New York, the South Dakota School of Mines and Technology, the University Corporation for Atmospheric Research, the National Ecological Observatory Network, the National Association of Marine Laboratories, the Sea Grant Association, the Association of Children's Museums, Vaisala, Inc., Quantum Spatial, Inc., and General Atomics. Ms. Thompson has also represented the Environmental Defense Fund, the National Fish and Wildlife Foundation, the University of New Mexico, and Purdue University.

## The Trump Administration – Views on Science and Technology

With no key science appointments made thus far by the new Administration, it is difficult to say much about the new Administration's views on science and technology. However, during the campaign, in [response to a questionnaire](#), then Candidate Trump provided the following responses to a number of key questions related to science, technology, energy, climate change, and public health:

*Innovation* -- Science and engineering have been responsible for over half of the growth of the U.S. economy since WWII. But some reports question America's continued leadership in these areas. What policies will best ensure that America remains at the forefront of innovation?

Trump Campaign Response -- Innovation has always been one of the great by-products of free market systems. Entrepreneurs have always found entries into markets by giving consumers more options for the products they desire. The government should do all it can to reduce barriers to entry into markets and should work at creating a business environment where fair trade is as important as free trade. Similarly, the federal government should encourage innovation in the areas of space exploration and investment in research and development across the broad landscape of academia. Though there are increasing demands to curtail spending and to balance the federal budget, we must make the commitment to invest in science, engineering, healthcare and other areas that will make the lives of Americans better, safer and more prosperous.

*Research* – Many scientific advances require long-term investment to fund research over a period of longer than the two, four, or six year terms that govern political cycles. In the current climate of budgetary constraints, what are your science and engineering research priorities and how will you balance short-term versus long-term funding?

Response – The premise of this question is exactly correct -- scientific advances do require long term investment. This is why we must have programs such as a viable space program and institutional research that serve as incubators to innovation and the advancement of science and engineering in a number of fields. We should also bring together stakeholders and examine what the priorities ought to be for the nation. Conservation of resources and finding ways to feed the world beg our strong commitment as do dedicated investment in making the world a healthier place. The nation is best served by a President and administration that have a vision for a greater, better America.

*Climate Change* – the Earth's climate is changing and political discussion has become divided over both the science and the best response. What are your views on climate change and how would your administration act on those views?

Response -- There is still much that needs to be investigated in the field of “climate change.” Perhaps the best use of our limited financial resources should be in dealing with making sure that every person in the world has clean water. Perhaps we should focus on eliminating lingering diseases around the world like malaria. Perhaps we should focus on efforts to increase food production to keep pace with an ever-growing world population. Perhaps we should be focused on developing energy sources and power production that alleviates the need for dependence on fossil fuels. We must decide on how best to proceed so that we can make lives better, safer and more prosperous.

During the campaign, President Trump often scoffed at concerns related to climate change. Appointments of personnel to head up key federal agencies involved in climate change – such as the U.S. Environmental Protection Agency – have included individuals with well-known skeptical views on climate change and actions the USG should take to respond to changing climatic conditions. As the new Administration continues to take shape, many in the science and technology community fear that climate change research will not be a welcome part of the federal research portfolio. A former Congressman -- Bob Walker, who serves as an influential space policy advisor to the President Elect’s transition team, has said he is in favor of eliminating climate change research from NASA’s operations and wants the agency to focus more on deep space research. Rep. Walker said that “earth-centric science” like climate change research is better placed within other agencies where it can be their prime mission. NASA’s budget has been threatened in recent years. Rep. Lamar Smith (R-TX) introduced a spending bill in 2015 that would have cut NASA’s Earth science program by more than \$300 million. However, there has been thus far a successful bipartisan effort to continue Earth science programs. Last year 15 former military leaders released a [letter](#) to congressional leaders to urge them to protect Earth and geoscience science programs. In a separate letter, over 100 academic institutions and research entities signed onto a [letter](#) in support of NSF and geo/earth sciences.

On November 30, *Science* published an [interview](#) with Rep. John Culberson, Chairman of the House appropriations subcommittee that funds NOAA, NASA, and NSF. In that interview Chairman Culberson was asked about cutting support for or moving earth sciences out of NASA. He said, “At this point that is very speculative. There’s strong support in Congress for keeping a close eye on planet Earth and understanding our complex planet. And the future level of funding and who’s responsible for earth science will be an ongoing debate with the new administration and the incoming Congress. I’m quite confident there will continue to be strong support for the earth sciences as well as planetary sciences and the human space flight program throughout Congress and in the new administration.” When pressed on whether the earth sciences would remain in NASA or be moved elsewhere the Chairman responded, “It will continue to be a topic of ongoing discussion. But nobody in the earth sciences community should be concerned in the least. All of us in Congress are strong supporters of keeping a close eye on planet Earth.”

*Energy* – Strategic management of the U.S. energy portfolio can have powerful economic, environmental, and foreign policy impacts. How do you see the energy landscape evolving over the next 4 to 8 years, and as President, what will your energy strategy be?

Response – It should be the goal of the American people and their government to achieve energy independence as soon as possible. Energy independence means exploring and developing every possible energy source including wind solar, nuclear and bio-fuels. A thriving market system will allow consumers to determine the best sources of energy for future consumption. Further, with the United States, Canada and Mexico as the key energy producers in the world, we will live in a safer, more productive and more prosperous world.

*Public Health* -- Public health efforts like smoking cessation, drunk driving laws, vaccination, and water fluoridation have improved health and productivity and save millions of lives. How would you improve federal research and our public health system to better protect Americans from emerging diseases and other public health threats, such as antibiotic resistant superbugs?

Response -- The implication of the question is that one must provide more resources to research and public health enterprises to make sure we stay ahead of potential health risks. In a time of limited resources, one must ensure that the nation is getting the greatest bang for the buck. We cannot simply throw money at these institutions and assume that the nation will be well served. What we ought to focus on is assessing where we need to be as a nation and then applying resources to those areas where we need the most work. Our efforts to support research and public health initiatives will have to be balanced with other demands for scarce resources. Working with Congress—the people’s representatives—my administration will work to establish national priorities and then we will work to make sure that adequate resources are assigned to achieve our goals.

*Water* – The long-term security of fresh water supplies is threatened by a dizzying array of aging infrastructure, aquifer depletion, pollution, and climate variability. Some American communities have lost access to water, affecting their viability and destroying home values. If you are elected, what steps will you take to ensure access to clean water for all Americans?

Response -- This may be the most important issue we face as a nation for the next generation. Therefore, we must make the investment in our fresh water infrastructure to ensure access to affordable fresh water solutions for everyone. We must explore all options to include making desalinization more affordable and working to build the distribution infrastructure to bring this scarce resource to where it is needed for our citizens and those who produce the food of the world. This must be a top priority for my administration.



*Space* – There is a political debate over America’s national approach to space exploration and use. What should America’s national goals be for space exploration and earth observation from space, and what steps would your administration take to achieve them?

Response -- Space exploration has given so much to America, including tremendous pride in our scientific and engineering prowess. A strong space program will encourage our children to seek STEM educational outcomes and will bring millions of jobs and trillions of dollars in investment to this country. The cascading effects of a vibrant space program are legion and can have a positive, constructive impact on the pride and direction of this country. Observation from space and exploring beyond our own space neighborhood should be priorities. We should also seek global partners, because space is not the sole property of America. All humankind benefits from reaching into the stars.

*Ocean Health* -- There is growing concern over the decline of fisheries and the overall health of the ocean: scientists estimate that 90% of stocks are fished at or beyond sustainable limits, habitats like coral reefs are threatened by ocean acidification, and large areas of ocean and coastlines are polluted. What efforts would your administration make to improve the health of our ocean and coastlines and increase the long-term sustainability of ocean fisheries?

Response -- My administration will work with Congress to establish priorities for our government and how we will allocate our limited fiscal resources. This approach will assure that the people’s voices will be heard on this topic and others.



# Office of Science and Technology Policy Executive Office of the President

**Dr. John P. Holdren, Assistant to the President for Science and  
Technology and Director**

**Megan Smith, Assistant to the President and United States Chief  
Technology Officer**

Cabinet Exit Memo | January 5, 2017

# Introduction

The White House Office of Science and Technology Policy ([OSTP](#))<sup>1</sup> has a broad mandate to: provide the President and the President's senior staff with accurate, relevant, and timely advice on the scientific and technological aspects of all issues before them; ensure the policies and programs developed across the Executive Branch are informed by sound science; and ensure that Federal investments in science and technology (S&T) are making the greatest possible contribution to economic prosperity, public health, environmental quality, and national security.

Technology has become increasingly important to policy, to the delivery of government services, and to the Nation as a whole. President Obama fulfilled a campaign pledge to appoint within OSTP the first-ever U.S. Chief Technology Officer (CTO), with the rank of Assistant to the President. The mission of the [Office of the U.S. CTO within OSTP](#) is to advise the President and the President's senior staff on how to harness the power of data, technology, and innovation on behalf of the American people—in so doing, the Office of the U.S. CTO continuously catalyzes and supports the Federal Government to better serve the American people.

In this memorandum, we: (1) highlight the profound impact President Obama's leadership has had in "reaffirming and strengthening America's role as the world's engine of scientific discovery and technological innovation,"<sup>2</sup> as he set out to do at the start of his Administration; (2) offer an overview of frontiers that the American S&T enterprise will advance in the coming decades; and (3) call for actions needed in the years ahead to include all Americans in driving continued innovation and progress across those frontiers.

OSTP continues to be optimistic about America's ongoing leadership in science and technology because of two exceptional characteristics of Americans. Americans continue to lead the world in our curiosity and desire to understand the world around us, which helps us innovate and improve the world around us. And, Americans are exceptionally diverse and can bring a wide range of experiences and backgrounds to solving the hardest problems. Our country's diversity continues to be the greatest source of its strength.

President Obama has repeatedly shown his commitment to inclusion, noting that, "research has shown that diverse groups are more effective at problem solving than homogeneous groups. Policies that promote diversity and inclusion will enhance our ability to draw from the broadest possible pool of talent, solve our toughest challenges, maximize employee engagement and innovation, and lead by example by setting a high standard for providing access to opportunity to all segments of our society."<sup>3</sup> Taking on the S&T frontiers that we describe in this memorandum requires including all Americans in leading innovation across industry, academia, and government.

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<sup>1</sup> The Office of Science and Technology Policy was established in 1976 by Public Law 94-282.

<sup>2</sup> From remarks by President Obama on November 23, 2009 at the launch of his "Educate to Innovate" campaign for excellence in science, technology, engineering, and math education.

<sup>3</sup> Presidential Memorandum on *Promoting Diversity and Inclusion in the National Security Workforce* (October 5, 2016)

# Record of Progress on Science, Technology, and Innovation

On January 20, 2009, President Obama [issued a simple and powerful pledge](#): to restore science to its rightful place. Coming into office, the President was committed to reinvigorating the American scientific enterprise through a strong commitment to basic and applied research, innovation, and education; to ensuring integrity in science policy; and most importantly, to making decisions on the basis of evidence, rather than ideology. In a speech at the National Academy of Sciences in April 2009, the President [called for expanded investments in research and development](#) (R&D) and a renewed focus on science, technology, engineering, and math (STEM) education. He noted that science, technology, and innovation are essential to sustaining economic growth, enabling Americans to lead longer and healthier lives, limiting the harm from climate change, and providing U.S. armed forces and homeland defenders with the tools they need to succeed in every contingency.

In the nearly 8 years since, the full scope of the President's science, technology, and innovation agenda has been [sweeping](#), and is already setting the stage for new industries and continued innovation in the years ahead. For example, President Obama and his Administration:

- (1) **Increased science, technology, and innovation talent in the Executive Branch** by creating and empowering new technology leadership positions at the White House and in Federal agencies; reinvigorating the President's Council of Advisors on Science and Technology (PCAST); and recruiting, retaining, and empowering people with information, digital, collaboration, communication, data, and related technical backgrounds to improve government services and inject modern technology expertise into public policymaking.
- (2) **Strengthened scientific integrity** by issuing and implementing a policy to ensure the public is able to "trust the science and scientific process informing public-policy decisions," by recruiting and retaining the highest-caliber scientists, by ensuring policy decisions are based on sound science, and by putting in place strong whistleblower protections.
- (3) **Enacted a historic increase in research and development**—with \$18.3 billion in R&D funding, the American Recovery and Reinvestment Act of February 2009 was part of the largest annual increase in R&D funding in America's history—and maintained R&D funding as a priority despite tight fiscal constraints.
- (4) **Prioritized and encouraged broad participation in STEM education and the technology sector**, with the Nation now on track to meet the President's goal to train 100,000 additional excellent STEM teachers by 2021, with 100,000 engineers graduating yearly from American colleges and universities for the first time ever, with organizations around the country responding to the President's call to provide all U.S. students with access to rigorous computer-science education, and with over 1,500 employers hiring from new short-course training programs such as coding boot camps.
- (5) **Supported American manufacturing innovation** through a national network of Manufacturing USA Institutes supported by over \$600 million in Federal investment and matched by more than \$1.3 billion in non-Federal investment, with more institutes on the way, and increased opportunities for Americans to make, design, create, and invent using new hardware and software tools and skills.

- (6) **Expanded entrepreneurship across the Nation**, with venture-capital firms committing to advance entrepreneurship opportunities for women and underrepresented minorities, with nearly 80 companies committing to take action to broaden participation and make the technology workforce at each of their companies representative of the American people as soon as possible, with investors pledging to create more inclusiveness in their funding practices, with nearly 200,000 datasets now available to the public on Data.gov, and with more than 4 million full-text scientific journal articles now free and accessible to researchers, entrepreneurs, and the public.
- (7) **Launched major new science initiatives to advance health care** through precision medicine, understanding the brain, accelerating progress in treating and preventing cancer, and combating antibiotic resistance.
- (8) **Took unprecedented action to address climate change** through the successful December 2015 Paris Agreement; a comprehensive Climate Action Plan to cut carbon pollution, enhance resilience, and lead internationally; and the development of tools, services, and partnerships to make science and information about on climate change actionable for decision-makers across the Nation.
- (9) **Expanded broadband access**, adding or improving more than 114,000 miles of broadband infrastructure and making high-speed connections available to more than 25,000 community institutions and fast 4G/LTE mobile broadband available to more than 98 percent of Americans.
- (10) **Fostered a burgeoning private space sector and increased capabilities for our journey to Mars**, with the extension of the lifetime of the International Space Station's (ISS) until at least 2024 through the Administration's leadership, with American companies and NASA collaborating to deliver cargo to ISS, and with those companies on track to start ferrying astronauts to ISS within the next 2 years.

## 20 Science and Technology Frontiers

In October 2016, at the White House Frontiers Conference, President Obama encouraged Americans to imagine our Nation and the world in 50 years and beyond, and to explore America's potential to reach the frontiers that will make the world healthier, more prosperous, more equitable, and more secure.

In answer to the President's challenge, below we highlight 20 S&T frontiers where future investment and cross-sector collaboration will drive American innovation in the decades ahead, including:

- **Personal frontiers** in health care innovation and precision medicine;
- **Local frontiers** in building smart, inclusive communities that serve all residents;
- **National frontiers** in harnessing the potential of artificial intelligence, data science, machine learning, automation, robotics, and advanced computing to engage and benefit all Americans;
- **Global frontiers** in accelerating the clean-energy revolution and developing advanced climate information, tools, services, and collaborations; and
- **Interplanetary frontiers** in space exploration, including our journey to Mars.

### Personal Frontiers

Science, technology, and innovation supported and encouraged by the Federal Government have made major contributions to helping Americans live longer, healthier lives. We have vaccines to protect us from devastating diseases such as cervical cancer, flu, and meningitis. We have developed an artificial retina and have achieved promising initial results on brain control of robotic prosthetic arms. Just as the

seeds for these breakthroughs were planted decades ago, President Obama’s visionary investments in biomedical research, medicine, health, and the life sciences have set the stage for the cures, treatments, and innovations of the future. Frontiers in biomedicine include:

- (1) **Developing precision medicine.** The next great revolution in medicine will emerge from an ability to use genomic, lifestyle, behavioral, environmental, imaging, and clinical data to understand health and disease, and to use those insights to develop tailored prevention approaches and medical treatments. To revolutionize how we improve health and treat disease, President Obama launched the [Precision Medicine Initiative](#) with these goals: (a) build a large research program that includes participants who volunteer their biomedical samples and health data, leveraging the diversity of the United States; (b) increase access to data so that researchers can better conduct science to enable groundbreaking new discoveries; (c) create a nimble framework for ensuring the accuracy of genomic-sequencing tests to support public safety; and (d) optimize the deployment of these technologies and research discoveries to medical practitioners.
- (2) **Investing in neuroscience and neurotechnology.** Advances in neuroscience and neurotechnology offer promise for developing a comprehensive understanding of the brain in action and uncovering the mysteries that hold the key to future scientific breakthroughs in areas such as Alzheimer’s and Parkinson’s diseases, depression, and traumatic brain injury. Since April 2013, President Obama’s [BRAIN Initiative](#)®—Brain Research through Advancing Innovative Neurotechnologies—has catalyzed more than \$1.5 billion in public and private funds for novel neurotechnologies aimed at revolutionizing understanding of the human brain. BRAIN Initiative researchers and public-private collaborating organizations are pursuing an ambitious 10-year [research agenda](#).
- (3) **Combating antibiotic resistance.** The Centers for Disease Control and Prevention (CDC) estimate that drug-resistant bacteria cause 2 million illnesses and about 23,000 deaths each year in the United States alone. The Obama Administration issued a [national strategy](#) and a [national action plan](#)—both responsive to the recommendations of a PCAST report—for domestic and international efforts to prevent, detect, and control illness and death related to infections caused by antibiotic-resistant bacteria. OSTP and the Presidential Advisory Council on Combating Antibiotic Resistant Bacteria have noted the opportunity for the next Administration to pilot innovative economic models to encourage investment in antibiotic-drug development, to strengthen antibiotic-resistance surveillance in agricultural settings, and to develop a “one health” approach to combating antibiotic-resistant bacteria, encompassing human, animal, and environmental components.
- (4) **Advancing biotechnology and global health security.** Advances in biotechnology have dramatically improved capabilities such as DNA sequencing, gene editing, gene synthesis, and high-throughput manipulation of biomolecules. These advances have reduced the cost and time required to develop biotechnology products and perform novel research. The Obama Administration released the [National Bioeconomy Blueprint](#), led an effort to [modernize the regulatory system for biotechnology products](#), and led [biosafety and biosecurity](#) improvements. The next Administration and the scientific community should consider continuing to track the ethical, legal, economic, security, safety, and social implications of biotechnology developments and participate in international discussions around appropriate oversight of biotechnology research and products. In addition, the United States has committed to assist at least 31 countries to achieve common, measurable targets of the [Global Health Security Agenda](#) for prevention, detection, and response to infectious disease outbreaks. Opportunities abound for the next Administration to advance S&T against infectious disease threats—especially for mosquito-vector control and through social and behavioral science and biotechnology—and to predict infectious-disease outbreaks through rapid data-sharing and “one health” approaches.



## Local Frontiers

Many complex social challenges—from developing transportation systems that fuel equitable growth, to improving community-police relationships, to connecting small towns, tribal communities, and rural areas—will require cities and communities of all sizes to be hubs for innovation. The rapid pace of social innovation and technological change, including the rise of data science, machine learning, artificial intelligence, the sharing economy, social networks, ubiquitous sensor networks, and autonomous vehicles holds significant promise for addressing important challenges communities face throughout the country. Local S&T frontiers include:

- (5) **Building smart communities and the Internet of Things.** “Smart Cities” are communities leveraging the “Internet of Things” (IoT) and information-technology tools, including data analytics and urban sensors, to improve the lives of all of their citizens. Federal research investments—with a continued focus needed on cybersecurity—and multisector technology partnerships can help local communities tackle key challenges such as reducing traffic congestion, fighting crime, fostering economic growth, managing the effects of a changing climate, and improving the delivery of city services. The [White House Smart Cities Initiative](#) has invested nearly \$350 million from multiple Federal agencies in research and technology deployment in communities, with over 70 participating communities. The [Opportunity Project](#) has catalyzed the creation of over 40 new digital tools that use Federal and local data to increase access to opportunity in communities around the country by solving challenges such as helping families find affordable housing near jobs and transportation, matching unemployed Americans with jobs that meet their skills, and enabling local leaders to use data to better target investments.
- (6) **Using innovation and data to improve policing and the criminal justice system.** As part of President Obama’s commitment to ensuring that the power of data and technology are used to address the biggest challenges this country faces, the Police Data and Data Driven Justice Initiatives cultivate local advances in the [use of data and technology in policing and the criminal-justice system](#). The Police Data Initiative supports local police department efforts in leveraging data to increase transparency and accountability and build trust with their communities. The Data-Driven Justice Initiative assists city, county, and State governments in using data-driven strategies to divert low-level offenders with mental illness out of the criminal justice system and to change approaches to pre-trial incarceration so that low-risk offenders no longer stay in jail simply because they cannot afford bond. These complementary initiatives each now support more than 100 jurisdictions—communities, counties, and states—and collectively reach over 95 million Americans.
- (7) **Harnessing the ingenuity of citizen solvers and citizen scientists.** The Obama Administration has harnessed American ingenuity, driven local innovation, and engaged citizen solvers in communities across the Nation by increasing the use of open-innovation approaches including crowdsourcing, citizen science, and incentive prizes. Following guidance and legislation in 2010, over 700 incentive prize competitions have been featured on [Challenge.gov](#) from over 100 Federal agencies, with [steady growth every year](#). Federal agencies and non-governmental organizations have used citizen science, crowdsourcing, and other innovative approaches to mobilize millions of people—including youth—to accomplish scientific work and improve their communities, from improving predictive models for coastal change and vulnerability to extreme storms, to tagging millions of archival records for the National Archives. Since 2014, OSTP has taken an active role in encouraging the increased use of these approaches to address scientific questions, issuing [guidance](#) to agency heads in 2015, and working with General Services Administration to launch [CitizenScience.gov](#) in early 2016. The next Administration should consider continuing to increase Federal Government efficiency and effectiveness through these open-innovation approaches.



- (8) **Connecting Americans through broadband deployment and spectrum for wireless Internet access.** Recognizing the importance of broadband connectivity for American innovation, collaboration, economic growth, and well-being, the Administration—through initiatives including [ConnectED](#), [ConnectHOME](#), [ConnectAll](#), the [Global Connect Initiative](#), and increased USDA funding of broadband access for tribal communities—has expanded affordable high-speed broadband access, improved adoption, increased speeds, lowered costs, and narrowed the digital divide in the United States. The Administration has advanced international connectivity to bridge the global digital divide and promoted U.S. Internet governance priorities. And, the Administration has taken steps to ensure that there is sufficient spectrum, governed by sound policies to support fast, affordable, and reliable wireless Internet access and other longstanding and emerging technologies, including being on track to meet the President’s goal of making available an additional 500MHz of spectrum for exclusive private and shared commercial use by 2020. Going forward, the next Administration should consider continued attention to these goals and to increasing the network-engineering expertise in the Federal Government to accelerate national and international deployment of Internet access and to maximize the benefits of our connected world.

### National Frontiers

Emerging technologies carry both potential and risk, present policy challenges, and have economic, safety, security, and regulatory implications for the Nation, including for increasing access to opportunity for all Americans. National technology frontiers include:

- (9) **Understanding the potential of AI, machine learning, and big data.** The Administration published a public report on AI, [Preparing for the Future of Artificial Intelligence](#), accompanied by a [National Artificial Intelligence Research and Development Strategic Plan](#). These documents detail how the Federal Government can take future steps to: use AI to advance social good and improve the operation of government; adapt regulations in a way that encourages innovation while protecting the public; ensure that applications of AI, including those that are not regulated, are fair, safe, and governable; develop the most skilled and diverse AI workforce, including addressing the current limited diversity in the technical-leadership ranks; and address the use of AI in weapons. This work built on earlier Obama Administration work on big data, including three Administration “Big Data” reports covering [privacy](#), [values](#), and [fairness in algorithmic systems, ethics, and civil rights](#), and also [PCAST](#) and National Information Technology R&D Program ([NITRD](#)) reports on big data.
- (10) **Developing robotics and intelligent systems.** Robotics and intelligent systems are technologies that seek to advance physical computational agents that complement, augment, enhance, or emulate human physical capabilities or human intelligence, and have the capacity to improve lives and advance the Nation’s economy. OSTP has focused on: R&D investments, including through the [National Robotics Initiative](#); capacity-building in the Federal Government; and providing technical input to the development of smart regulations governing the public and commercial use of such technologies. The Administration has also worked to improve regulatory frameworks for some applications, including the Federal Aviation Administration’s [integration of unmanned aircraft systems \(UAS\) into the National Airspace System](#) and the Department of Transportation’s work on developing a [Federal Automated Vehicles policy](#). Future work is needed to formulate a Federal strategy for UAS privacy authority and responsibilities.
- (11) **Investing in strategic computing.** The National Strategic Computing Initiative ([NSCI](#)) was created in July 2015, at President Obama’s request, to ensure continued U.S. leadership in high-performance computing (HPC) and to maximize the benefits of HPC for the economy, scientific discovery, and national security. The initiative calls for the creation of a coordinated research, development, and

deployment strategy that draws on the strengths of Federal departments and agencies to accelerate progress on a range of critical applications—from predicting severe weather, to modeling the safety of the nation’s nuclear weapons stockpile, to developing new drugs that are tailored to the needs of individual patients. Federal agencies have identified five strategic objectives: (a) accelerate the successful deployment and application of capable exascale computing; (b) ensure that new technologies support advances in data analytics as well as simulation and modeling; (c) explore and accelerate new paths for future computing architectures beyond the limits of today’s silicon-based semiconductors; (d) promote a vibrant HPC ecosystem, including the workforce needed to design and use HPC; and (e) establish enduring cross-sector collaboration.

- (12) **Supporting advanced manufacturing and a Nation of Makers.** To spur innovation in manufacturing, the Administration has created a growing network of advanced-manufacturing R&D hubs, known as [Manufacturing USA](#). In addition, the Administration has increased support for advanced-manufacturing R&D by 40 percent since FY 2011, and has encouraged multi-agency collaboration in areas such as continuous manufacturing of pharmaceuticals, engineering biology for biomanufacturing, and biomanufacturing for regenerative medicine. Delivering on this vision will require: (a) spurring innovation through next-generation technologies; (b) making the United States more cost-competitive for production; (c) strengthening skills, communities, and supply chains to attract investment; and (d) leveling the playing field for international trade, opening access to foreign markets, and promoting investment in the United States. In addition, people’s ability to design, create, and invent is being amplified by hardware and software tools such as computer-aided design software, laser cutters, accessible design tools, and 3D printers. The President’s [Nation of Makers Initiative](#) is engaging innovators, private-sector leaders, and educators to increase the number of Americans that have the opportunity to participate in making, with a particular emphasis on K-12 education, workforce development, and manufacturing entrepreneurship.

## Global Frontiers

Under President Obama, the United States has led global progress in addressing the challenge of climate change—including through the historic Paris Climate Agreement—and has advanced climate science, technology, and innovation to inform decisions and enable breakthroughs. Global frontiers include:

- (13) **Advancing climate science, information, tools, and services.** Understanding and addressing the current and future impacts of global climate change requires sustained investments in climate science and services. It is essential that governments, businesses, researchers, and individual citizens have access to science-based information, tools, and services that can inform decision making. The Obama Administration launched the [Climate Data Initiative](#), [Climate Resilience Toolkit](#), and [Partnership for Resilience and Preparedness](#) to improve access to the Federal Government’s climate data and tools. Thanks to this effort, more than 600 datasets and 200 tools have been made available. The Administration also released the [Third National Climate Assessment](#), the most comprehensive assessment of climate impacts to date, through a user-friendly online interface, and created a sustained assessment process. In addition, the U.S. Government joined with private-sector partners to launch the [Resilience Dialogues](#) and [Climate Services for Resilient Development](#), to connect climate information to on-the-ground decision making. Enhanced observations—particularly in areas such as the polar regions and much of the world’s oceans that are inadequately monitored today—will be required to advance a more comprehensive understanding of global change.
- (14) **Growing a clean-energy economy.** The Obama Administration has made the largest investments in cleaner and more efficient energy systems in the Nation’s history, starting with over \$90 billion in the American Recovery and Reinvestment Act in 2009. As a result, the United States has seen

dramatic increases in the proportions of energy and electricity coming from low- and no-carbon energy sources. Under President Obama’s leadership, the United States has steadily expanded the reach and magnitude of its bilateral and multilateral cooperation with other countries in clean and efficient energy. The “Mission Innovation” initiative, launched by President Obama and other world leaders at the December 2015 climate conference in Paris, brings together 22 countries and the European Union that have pledged to double their governments’ investments in clean-energy R&D over a period of 5 years. To complement this effort, the “Breakthrough Energy Coalition” of leading investors has pledged to support the commercialization of the discoveries that result from increased R&D funding. These initiatives will require continued attention and encouragement—including doubling U.S. clean energy R&D by 2021—from the U.S. Government.

- (15) **Addressing climate change and national security.** The Obama Administration—through the February 2015 [U.S. National Security Strategy](#) and a September 2016 [report from the National Intelligence Council](#)—has recognized that global climate change is posing growing challenges to U.S. national security. Sea-level rise threatens operations and infrastructure at important naval bases, including this country’s largest (in Norfolk, VA); extreme heat impairs the efficiency of troops and certain military equipment; military forces may be increasingly diverted to humanitarian missions following climate-related extreme events; chronic stresses from climate-change-accentuated phenomena such as droughts and crop failures can lead to civil unrest; and, eventually, flows of refugees from regions rendered less hospitable or even uninhabitable by climate change may produce political instability in areas critical to U.S. interests. President Obama directed Federal agencies in a [September 2016 Presidential Memorandum](#) to ensure that climate change is fully considered in national security doctrine, policies, and plans.
- (16) **Increasing ocean resilience.** The health and productivity of the world’s oceans are imperiled by a number of threats, including climate-change related warming and acidification, overfishing and destructive fishing practices, dead zones, and marine debris and pollution. The Obama Administration has pioneered ocean stewardship through the development of the first ever U.S. [National Ocean Policy](#), as well as through the creation and expansion of Marine Protected Areas and National Monuments, which provide refuges of reduced stress for species. This science-based management and smart conservation will help to enhance ocean resilience to climate change.

### Interplanetary Frontiers

At the beginning of his Administration, President Obama set out a [new vision](#) for space exploration. In 2010, the Administration [restructured](#) the U.S. civil space program to look forward to bold new goals; to collaborate with, rather than compete with, American entrepreneurs; and to broaden participation and take advantage of new technologies being created at NASA and in America’s laboratories. These policies have fostered a burgeoning commercial-space sector that is creating new jobs and attracting venture capital. Looking ahead, frontiers in space exploration and space science include:

- (17) **Supporting our Journey to Mars and a robust U.S. commercial-space market.** In April 2010, President Obama challenged the country to send American astronauts on a Journey to Mars in the 2030s. Continued development of advanced space technologies—including better life-support systems and efficient solar-powered electric propulsion systems—will be crucial to achieving [President Obama’s vision for space exploration](#). NASA already has started collaborating with industry to [build the space modules or “habitats”](#) in which U.S. astronauts will live and travel to Mars and other deep-space destinations. And in the coming years, the work NASA will do—in collaboration with private and international partners—to develop these deep-space habitats will help reduce the barriers to private companies that envision building their own space stations in

Earth orbit or beyond. NASA will soon provide companies the opportunity to add their own modules and other capabilities to the International Space Station. As NASA shifts the focus of its human exploration program to deep space, America's businesses will take a larger role in supporting space activities in Earth orbit.

- (18) **Driving advancements in space science.** OSTP works with NASA, the National Science Foundation (NSF), and the Department of Energy (DOE) to ensure that Federally funded space-science activities comprise a robust portfolio of space-based missions, ground-based facilities, and research funding for astronomy, planetary science, and heliophysics. The Kepler Space Observatory, which was launched in March 2009, has discovered more than 2,330 extrasolar planets and more than 2,400 additional planet candidates to-date. Curiosity, the Mars Science Laboratory, has been exploring Gale Crater on Mars since it landed in 2011, discovering evidence of an ancient streambed, organic carbon in powdered rock samples, and methane in the Martian atmosphere. Construction of the Atacama Large Millimeter Array (ALMA)—funded by the United States through NSF with other international partners—was completed in 2011 with full science observations beginning in 2013. In July 2015, the New Horizons spacecraft flew by Pluto obtaining the first up-close images of the dwarf planet, and a year later, Juno arrived at Jupiter to begin collecting scientific data to understand the planet's structure and formation. Looking ahead, progress on the James Webb Space Telescope—designed to be the premier space-based observatory of the next decade, serving thousands of astronomers worldwide—is on track and on budget to meet a 2018 launch date. NSF and DOE, in collaboration with other partners, are supporting the development of the ground-based Large Synoptic Survey Telescope, which expects to see first light in 2019.
- (19) **Enhancing prediction of and preparedness for space hazards.** OSTP and Federal agencies are identifying actions to extend and enhance prediction and preparedness for potentially hazardous near-Earth objects (NEOs) and define an approach for establishing reference NEO Earth-impact missions that can help the United States and its international partners detect, track, and respond to the threat of collision by a NEO. OSTP also worked with NASA to develop NASA's Asteroid Grand Challenge, an effort focused on finding all asteroid threats to human populations and knowing what to do about them. NASA's Asteroid Redirect Mission will, among other benefits, be used to demonstrate a promising asteroid-deflection technique called a gravity tractor. Also, in an effort to better plan for space weather hazards, OSTP led the development of the October 2015 [National Space Weather Strategy and National Action Plan](#), and subsequently, President Obama signed an [Executive Order](#) in October 2016 to minimize the harm that space-weather events can cause across our Nation, save lives, and enhance national security. The called-for actions include identifying mitigation technologies, creating nationwide response and recovery plans and procedures, and improving prediction of space-weather events and their effects.
- (20) **Harnessing the small satellite revolution.** A critical area for space-technology development is advancing the capability of small satellites ("smallsats") and constellations of smallsats to support important commercial, civilian, and national-security applications. Potential applications include capturing continuously updated imagery of the entire planet and providing high-speed Internet connectivity to remote rural communities. Traditional large satellites typically cost hundreds of millions of dollars per satellite and often take years to build and launch. Smallsats sometimes can be delivered at a fraction of the cost and time of legacy satellite systems. Scientists and engineers can quickly test smallsat systems on orbit, allowing them to shorten the innovation cycle to devise new, better systems. The next Administration should consider working with OSTP, NASA, the Department of Defense, the Department of Commerce, and other Federal agencies to foster innovation in the [development and use of smallsats](#).

# 10 Actions Needed to Foster Continued Innovation across the Frontiers

Below we offer 10 actions that are needed if the United States is to succeed in broadening participation in and delivering on the potential of science, technology, and innovation to drive prosperity for all Americans and to address challenges across science and technology frontiers in the coming decades.

## **ACTION 1: Invest in Fundamental Research**

Federal Government funding for R&D is essential to address societal needs in areas in which the private sector does not have sufficient economic incentive to make the required investments. Key among these is basic research—the fundamental, curiosity-driven inquiry that is a hallmark of the American research enterprise and a powerful driver of new technology and innovation in the medium and long terms. Of all the challenges involved in protecting and expanding Federal R&D budgets in the face of overall fiscal constraints, the challenge of supporting basic research (and the infrastructure that enables it) deserves particular attention in the years to come. The Federal Government must bear proportionally the largest burden for basic research because high risk and high uncertainty about timing and magnitude of returns limit the private sector’s incentive to contribute. Simply supporting research is not sufficient, however; Federal agencies should ensure that research results are made available to other scientists, the public, and innovators who can translate them into the businesses and products that will improve our lives.

## **ACTION 2: Recruit, Retain, and Empower Top S&T Talent in the Federal Government**

A core component of President Obama’s innovation agenda has been an effort to attract individuals who can help build a more effective, efficient, and innovative government. This included recruiting high-caliber leaders for traditional S&T leadership positions in the Executive Office of the President and across Federal departments and agencies, and creating a new set of modern science, technology, and innovation positions—e.g., the U.S. Chief Technology Officer (CTO), U.S. Chief Information Officer (CIO), and Chief Data Scientist, as well as the White House Office of Digital Strategy, the Director of White House IT, and department and agency CTOs, CIOs, and Chief Data Officers. These technical leaders are bringing new best practices working in deep collaboration with others in government to leverage all tools of government to address our hardest challenges. This work includes the President’s efforts to expand technical-talent integration for tech transformation that significantly improves the service delivery of IT services through the U.S. Digital Service, GSA’s Tech Transformation Service, and the Presidential Innovation Fellows program, which the Office of the U.S. CTO played a key role in creating. Strategies to make public service more attractive include time-limited “tours of duty”; short “sprint team” engagements to bring new perspective on entrenched problems; a focus on making hiring processes as efficient as possible; and proactive outreach to the technology and scientific communities.

It also means empowering that top technical talent to change the way the Federal Government delivers services and makes policy. For example, within the EOP, the Tech Policy Task Force (TPTF) draws membership from tech components and other policy councils to ensure tech expertise can advise other policy councils and drive its own policy. TPTF has been used to initiate and create tech-related policy, such as the [Federal Source Code Policy](#) and the White House’s [Artificial Intelligence Initiative and Report](#); to advise on or co-lead agency efforts, such as international connectivity with the State Department; and to answer questions raised by other policy councils, such as considerations regarding encryption policy and cybersecurity. To maintain this progress in the future, the next Administration should consider including groups such as TPTF in the processes of core policymaking bodies, such as the



National Security Council, and continuing to increase the scientific, technical, and innovation understanding at senior levels of agency policymaking.

### **ACTION 3: Identify and Pursue Grand Challenges**

President Obama has called for companies, research universities, foundations, and philanthropists to join him in identifying and pursuing grand challenges as a key component of his innovation strategy. Grand challenges are ambitious yet achievable goals that harness S&T and that have the potential to capture the public’s imagination. OSTP has encouraged Federal agencies to pursue grand challenges, including the BRAIN Initiative, NASA’s Asteroid Grand Challenge, an Administration effort to eliminate the waiting list for organ transplantation, and a nanotechnology-inspired Grand Challenge in brain-inspired computing. Other agencies that have been particularly active include the Department of Energy (with grand challenges on solar energy and electric vehicles), U.S. Agency for International Development (USAID, with numerous grand challenges related to global development, such as Saving Lives at Birth), and DARPA (with grand challenges related to cybersecurity, robotics, and self-driving cars). President Obama’s [call to action on Grand Challenges](#) has also encouraged universities to embrace ambitious goals and to make commitments to expand opportunities for undergraduate engineers and create other opportunities for students to learn about and pursue grand challenges.

### **ACTION 4: Increase Access to High-Quality STEM Education and Drive Innovation for Education**

Increasing access to and participation in STEM fields is critical to developing the human capital needed to fuel American innovation; tackling economic inequality and the gender pay gap by allowing more Americans to succeed in high-wage STEM fields; and supporting informed citizenship. The Obama Administration made an unprecedented commitment to improving access to and quality of STEM education for all students and to meeting the need for one million additional STEM graduates in the workforce by 2022 by: (1) setting ambitious goals and rallying public and private action through an “all-hands-on-deck” approach that has led to more than \$1 billion in philanthropic support for the President’s Educate to Innovate campaign; (2) elevating the profile of STEM education through efforts including the launch of the annual White House Science Fair; and (3) improving the impact of Federal STEM education programs by executing on the first-ever Federal STEM Education [5-Year Strategic Plan](#). The Administration’s [STEM for All](#) goals are supported by President Obama’s proposed FY 2017 budget and call for increased efforts to improve STEM teaching; support active learning; expand access to rigorous STEM courses; address bias where it exists; and expand opportunities for underrepresented students in STEM. In response to a pressing need to fill high-paying tech jobs,<sup>4</sup> President Obama launched the Computer Science for All initiative to give all U.S. students access to computer-science education, which requires increased Federal funding and, building on actions taken by 14 states, additional collaboration to prepare teachers and expand access to high-quality instructional materials.

Science, technology, and innovation can be leveraged to improve educational outcomes through new models of grant-making; open licensing of educational resources developed through Federal funding; investments in infrastructure and educational-technology R&D to support next-generation learning; redesign the high school experience to make it more engaging; and multi-sector collaborations to increase the adoption of learning technologies. While significant advances have been made to expand access to technology for education and close the digital divide, there are opportunities for continued improvement in cognitive science, AI, learning analytics, and learning games.

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<sup>4</sup> In 2015, there were more than 600,000 high-paying tech jobs across the United States that were unfilled, and by 2018, 51 percent of all STEM jobs are projected to be in computer-science-related fields.

## **ACTION 5: Improve Diversity, Equity, and Inclusion and Mitigate the Impacts of Bias**

America's role as a global leader in science and innovation is fortified by tapping into one of America's foundational strengths—the unparalleled diversity of the American people and the diversity of ideas that they generate. Obama Administration reports, such as on [big data](#) and on [artificial intelligence](#), have noted that government policies can help America harness the potential of emerging technologies by designing, deploying, and regulating those technologies in ways that preserve American values, avoid and mitigate bias and discriminatory outcomes, and promote fairness and opportunity. In addition, research shows that diversity on teams leads to better outcomes. Systemic barriers, such as implicit and explicit bias, present challenges to efforts to draw upon a diverse community in building a STEM workforce for the 21st century. In November 2016, OSTP and the Office of Personnel Management (OPM) released a report, [Reducing the Impact of Bias in the STEM Workforce: Strengthening Excellence and Innovation](#), which recommended that: (1) each Federal agency exercise leadership at all levels to reduce the impact of bias where it exists in their internal operations; (2) each Federal agency incorporate bias-mitigation strategies into its proposal-review process and offer technical assistance to grantee institutions to implement bias-mitigation strategies; and (3) OSTP, OPM, and the Department of Justice, as appropriate, exercise leadership to reduce the impact of bias where it exists in the Federal STEM workforce and Federally-funded institutions of higher education.

Also in November 2016, OSTP released an [Action Grid](#) as a resource for those striving to create diverse, equitable, and inclusive S&T teams and workforces. This set of potential actions—including leadership engagement, retention and advancement, hiring, and ecosystem support—can provide ideas and a jumping-off point for organizations around the country to increase workforce diversity. In addition, research demonstrates that popular entertainment media can influence the public's perceptions of STEM fields and careers. By highlighting the [importance of depiction of STEM](#), as has been led through OSTP's Image of STEM effort, the Federal Government can support inclusion of diverse and compelling STEM images, stories, and positive messages—including [improvement of historic accuracy](#)—in mainstream entertainment media to encourage greater diversity in the future STEM workforce.

## **ACTION 6: Support Innovative Entrepreneurs**

America's entrepreneurial economy is the envy of the world. Young companies account for almost 30 percent of new jobs, and as we have fought back from the worst economic crisis of our lifetimes, startups have helped our private sector create 15.5 million jobs since early 2010—the longest streak of private-sector job creation on record. To ensure that every American entrepreneur has a straight shot at success, we need all hands on deck. Since the launch of the White House [Startup America](#) initiative in 2011, President Obama has issued a consistent public call to action to companies, nonprofits, universities, investors, and others to accelerate high-growth entrepreneurship and broaden participation. Breaking down barriers for all entrepreneurs is not the task of just one Administration. Studies suggest that the share of venture-funded startups with women founders has nearly doubled in 5 years—but it is still only 18 percent. Continuing to reverse America's 40-year decline in startup activity will require building on President Obama's record of addressing income inequality, promoting competitive markets, reducing unduly restrictive occupational licensing, and scaling up rapid skills training. The next Administration should consider additional steps to ensure early-stage entrepreneurs from all backgrounds have access to startup capital, and to expand access to entrepreneurial networks and resources across all communities, so we field the entire American team of potential entrepreneurs.



## **ACTION 7: Maximize Economic and Social Return from Federal Government Data and the Results of Federally Funded R&D**

The Obama Administration has leveraged open data and data science to inform and support Federal agencies and programs, including engaging data-innovation stakeholders to support agency missions. [President Obama ordered](#) the default state of Federal Government information resources to be open and machine readable, followed by an [Open Data Policy](#) issued by OMB. In February 2015, the President established the role of the Chief Data Scientist under the U.S. CTO within OSTP to: maximize social and economic return from Federal Government data; create Federal data policies that enable shared services, data engagement, and forward-leaning data practices; and recruit and retain the best minds in data science for public service. Federal agencies should be empowered with the people, processes, and practices necessary to build their data capacity. As of October 2016, nearly 40 Federal agencies have added Chief Data Officers (CDOs) and Chief Data Scientists to ensure data-driven decisions are made in support of mission priorities. OSTP established a Data Cabinet to serve as the principal community of practice for Federal data professionals to share case studies and best practices for scaling data-talent capacity through recruitment, training, and hiring and to ensure data is responsibly gathered, processed, leveraged, and made discoverable, accessible, and reusable in a timely fashion.

The Federal Government invests approximately \$140 billion per year in R&D, which results in hundreds of thousands of peer-reviewed scholarly publications and growing volumes of digital research data every year. In February 2013, the Director of OSTP issued a [memorandum](#) directing all Federal departments and agencies with R&D expenditures of more than \$100 million per year to develop plans for increasing access to the scholarly publications and digital data resulting from Federally funded research. More than 20 Federal agencies responsible for more than 99 percent of Federal R&D have completed and are implementing their public-access plans. Going forward, agencies should identify additional steps to make scientific knowledge freely and readily available to accelerate innovation and drive advances in health, energy, environmental protection, agriculture, national security, and other areas of national and international importance. Agencies are also working to improve the management and accessibility of scientific collections that support research and agency missions. These efforts complement the Obama Administration's Lab-to-Market initiative, which aims to accelerate and improve the transfer of new technologies from the laboratory to the commercial marketplace.

## **ACTION 8: Increase Federal Agency Capacity for Innovation**

As outlined President Obama's [Strategy for American Innovation](#), agency S&T innovation capacity is a strategic priority because with the right combination of talent, innovative thinking, and technological tools, government can deliver better results. Federal agencies have pioneered new approaches—and applied approaches piloted by other sectors—that can deliver better results at lower cost for the American people. Widespread adoption of these approaches can significantly improve government effectiveness. OSTP and Federal agencies are developing an Innovation Toolkit to facilitate the broader adoption and awareness of a core set of innovative approaches, including: (1) “pay for performance” incentive prizes; (2) citizen science and crowdsourcing; (3) applying behavioral science insights to improve Federal programs and policies; (4) Grand Challenges; (5) flexible approaches to procurement that allow the government to interact with startups and commercial firms; (6) human-centered design; (7) “market shaping” approaches such as milestone payments and Advance Market Commitments; (8) flexible hiring authorities such as those that allow for “tours of duty” by experts; and (9) “scout and scale” approaches that find and share existing solutions.

To increase Federal capacity for innovation, the Administration has supported the development of Innovation Labs at Federal agencies that provide resources and support for employees and members of the public to develop, test, and scale new approaches to meeting agency goals, resulting in significant improvements to the effectiveness and efficiency of the Federal Government. Agency innovation capacity also is facilitated by upgrading digital collaboration tools, allowing for real-time shared documents, instant messaging, video conferencing, access to social media and wiki-based sites for team projects, data and content management, and open innovation, which empower communities of practice to work at rapid pace. Incorporating people with diverse skill sets into those communities of practice has led to innovative practices being shared and adopted faster.

#### **ACTION 9: Promote Open Government through Transparency, Participation, and Collaboration**

Teams across the Federal Government have been making progress to promote transparency, empower citizens, and transform how the Federal Government engages with the American people. These initiatives have led to cost savings, fueled American businesses, improved civic services, informed policy, catalyzed research and scientific discoveries, driven transparency and accountability, expanded and broadened collaboration, and increased public participation in the democratic dialogue. In addition, the United States co-founded and remains a leader in the Open Government Partnership (OGP), composed of 70 countries working with hundreds of civil-society organizations and civic-tech leaders collaborating internationally and pushing each other to increase public integrity, enhance public access to information, improve management of public resources, reduce costs, and give the public a more active voice in government processes. Each member of the OGP creates bi-annual Open Government National Action Plans (NAPs). More than 20 agencies also are leading continued implementation of the 48 commitments in the third U.S. NAP, including efforts to modernize Freedom of Information Act processes, improve transparency of privacy programs, streamline declassification, and increase public participation in policymaking. Work remains to implement agency-level 2016 Open Government Plans.

#### **ACTION 10: Continue International S&T Cooperation and Engagement**

OSTP works to strengthen international science, technology, and innovation cooperation among the United States and international partners through bilateral and multilateral engagements, and to support the President's foreign-policy agenda through international science, technology, and innovation activities. OSTP, in coordination with the State Department, represents the United States in bilateral and multilateral meetings with foreign nations, and works closely with government science agencies, independent research and scientific institutions, and non-governmental organizations to promote international S&T initiatives and strengthen global science cooperation. The OSTP Director co-chairs for the United States all six of the ongoing bilateral, ministerial-level Joint Commissions on Science and Technology Cooperation that exist under S&T cooperation agreements with Brazil, China, India, Japan, Korea, and Russia. In his 2009 Cairo speech, President Obama announced S&T related initiatives for Muslim-majority countries, including his intention to appoint science envoys, U.S. scientists who travel abroad as science ambassadors and inform the White House, U.S. Department of State, and the U.S. scientific community about the insights and opportunities for scientific engagement they find abroad. To date, there have been 5 cohorts of 3-5 Envoys each who have traveled to over 25 countries. The State Department has committed to supporting the Envoy program through 2017.

## Conclusion

We have been honored to serve President Obama—our Science, Technology, and Innovation President. He has relentlessly focused on building American talent and capacity in S&T; making the long-term investments that will continue to power American innovation; and setting ambitious goals that inspire and harness the ingenuity and creativity of diverse whole of the American people. We thank the science and technology communities inside and outside government for their continued innovation and collaboration. We are especially appreciative of their shared passion for broadening participation, especially among our youth, to field the whole American team in pursuing the frontiers that will increase prosperity, opportunity, justice, health, and security for all. Driving further progress across the aforementioned frontiers will require focus by the next Administration and the next Congress on: sustained investment in research, development, and innovation; the importance of diverse, cross-sector, and multi-disciplinary collaboration for solving difficult challenges; education innovation to develop skills for Americans at all levels; job creation and workforce-skills development across these sectors; and equity, to ensure all Americans help create these innovations and have access to and benefit from advances in these frontiers.



## MEMORANDUM FOR 45<sup>TH</sup> PRESIDENT OF THE UNITED STATES

**Date:** July 2016

**From:** The National Association of Marine Laboratories

**Re:** Ocean, Coastal & Great Lakes Research and Education Fuels the Nation's ~~Ocean and Coastal~~ Economy

The National Association of Marine Laboratories (NAML), first established in 1985 with nearly a dozen separate marine laboratories, has grown into a network of over 100 institutions operated by universities, non-profit organizations, and local, state, and federal governments that focus on the oceans, coasts and Great Lakes. According to the National Academy of Sciences' report *Sea Change: 2015-2025 Decadal Survey of Ocean Sciences* (p.92), **marine laboratories are one of the most cost effective and highly relevant** components of the ocean, coastal, and Great Lakes research and education enterprise.

NAML labs are national assets formed by the unique merger of natural, intellectual, social, and infrastructural capital that leads to important scientific endeavors required to understand our rapidly changing natural world. They are repositories of long-term observations and datasets. These facilities are distributed throughout our nation's coastlines and provide diverse and unique settings for research, access to vital research infrastructure, and opportunities for education and outreach, while employing thousands of scientists, engineers, students, and educators. Scientists at NAML laboratories provide critical, actionable findings that inform policy and improve decision-making on important issues such as food safety, water quality, coastal resiliency, and natural resource management. Students and citizens that visit NAML labs engage in experiential learning that enhances science literacy and improves knowledge of our ocean and coastal environments.

**The ocean, coastal and Great Lakes communities are significant drivers of the nation's economy – in coastal and inland communities. Ocean, coastal, and Great Lakes research and education, much of which is conducted within the network of NAML laboratories, is a vital part of the nation's research and education enterprise, and is a critical component of the economic and environmental health of the nation. The nation is faced with a widening gap between the actual level of federal funding for research and education and the required investment to sustain the U.S. as the world's leader in innovation.**

**Therefore, NAML strongly recommends:**

- **The nation increase its investment in research and education to develop the knowledge, people, and technologies that power the ocean and coastal economies, create jobs, improve health, strengthen our national security, and support the U.S. as a global leader;**
- **This effort should include ocean observations, data integration, and related cyber and physical infrastructure; monitoring, research, and response to changing environmental conditions (such as sea level rise, ocean temperature increases, and ocean acidification); and**
- **Renew the commitment to improve the quality of STEM education and re-energize efforts to attract, recruit, support, and retain women, minorities and others not currently well represented in the science and technology workforce.**



## The Value of the Nation's Coastal and Ocean Economy

For centuries, the sea has sustained lives and livelihoods, divulged ancient and unforeseen treasures, and stirred our dreams of remarkable new discoveries. But never in history have we had the immense opportunities now beckoning from the sea. On the horizon is a new blue economy, an exciting oceanic frontier that offers great promise for making our nation safer, healthier, and more prosperous. The new blue economy is a knowledge-based economy, looking to the sea not for extraction of material goods but for data and information to address societal challenges and inspire their solutions. This economy is entrepreneurial and environmentally responsible, collaborative and competitive.<sup>1</sup>

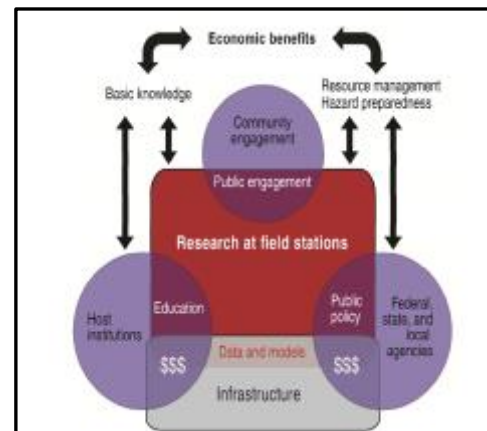
A recent report from the Center for the Blue Economy reported that the ocean economy<sup>2</sup> generated a larger share of U.S. economic activity than farming, food products, oil and gas extraction, and forest products. Employment supported by the ocean economy is almost as large as the employment of all of these industries combined. The Great Lakes alone generate nearly \$5 trillion in economic activity or about 30% of combined U.S. and Canadian economic output. Finally, the U.S. marine transportation system is an essential driver of the U.S. economy and its impact is felt well beyond the coast and reaches into the heartland of the nation. America's seaports are crucial generators of economic development and well-paying jobs, both regionally and nationally, that is felt throughout all supply chains that use the ports.

The ocean and our coasts are invaluable for humanitarian, environmental, and health reasons. The oceans are a primary source of food for over one billion people, a globally significant regulator of the earth's climate, the basic source of water for the hydrologic cycle, a cleaning agent that absorbs carbon dioxide and generates oxygen, and home to thousands of flora and fauna, many with pharmaceutical value. The ocean has been a source of new drugs to treat certain cancers. Blue-green algae, commonly found in Caribbean mangroves, are used to treat small-cell lung cancer and certain sponges produce chemical substances that can be used to treat cancer and manage pain. A wide gulf often separates science from the people who need research results to protect and support them. However, the new blue economy puts science and predictive capabilities to work in a way that can fill critical, fast-rising needs across sectors.<sup>3</sup>

The network of the Nation's marine laboratories is cost effective, highly relevant, and the vehicle that brings science to those who depend on research results to protect lives and support livelihoods.

### Examples of ocean, coastal and Great Lakes research impacting coastal economies

**Oysters:** The Pacific Northwest is home to the largest hatchery based oyster industry in the US. Research conducted at Oregon State University found that losses of \$110 million dollars to the hatchery industries of Oregon and Washington State were due to ocean acidification, which impedes shell formation in the early stages of oyster development. Based on OSU's research findings, the hatcheries in the Pacific Northwest have adapted by "buffering" their hatchery and nursery waters, the equivalent to using "Tums" to buffer an acidic stomach. Although buffering can be done in a controlled hatchery to a limited extent, it is not practical to buffer the entire ocean. Further research is focused on finding more acid-tolerant oyster strains for providing brood stock to the hatcheries.



Source: *Enhancing the Value and Sustainability of Field Stations and Marine Laboratories in the 21<sup>st</sup> Century*, National Academy of Sciences. 2014



**Great Lakes Restoration:** Muskegon Lake is part of the Great Lakes coastal wetlands ecosystem, which is a critical source of food and habitat for fish and wildlife within the Great Lakes. Approximately 65% of the shoreline had been hardened with seawalls and concrete or rock riprap. Additionally, broken concrete, foundry slag, sheet metal, slab wood, saw dust and other materials in shallow water areas posed hazards to recreation and degrade habitat. The Muskegon Lake Habitat Restoration Project was initiated, to restore hardened shoreline areas, create or restore emergent and open-water wetlands, and remove unnatural fill on the south shore of Muskegon Lake. Scientists at the Annis Water Resources Institute at Grand Valley State University used both biological and socioeconomic research to improve the design and impact measurement of the restoration activity. The economic impact of the restoration returned \$66 million to the region for the \$10 million expended.

**Lobsters** -- In the Gulf of Maine, since 1980 the temperatures have been rising on average at the rate of one degree Celsius every 40 years. But in the last decade the temperatures are increasing at a rate of one degree about every four years. As the temperatures rise, so do the incidences of shell disease in lobsters. Scientists at the University of Maine, describe the latter as a “nasty looking disease” with dramatic effects on the lobster’s exoskeleton. It is a bacterial infection that dissolves the shell, pitting it and rendering the lobster unpalatable for sale. In its most severe forms, the disease can cause blindness, prevent the lobster from molting - when it sheds its exoskeleton - and interfere with its hormonal system. In the latter case, an egg-bearing female lobster might suddenly cast off its skeleton, taking the eggs with it. The disease is now present in some 30 per cent of the harvestable size lobster caught in southern New England. With knowledge of the temperature link to this disease, scientists are working to devise mitigation strategies to address this issue.

### **Maintaining a Vibrant Ocean, Coastal, and Great Lakes Research and Education Enterprise is Important for the Economic and Environmental Health of the Nation**

Research conducted by people educated and trained, in part, at the nation’s network of marine laboratories has uncovered the linkage between changes in ocean temperature and its impact on the lobster industry; the role science can play to maximize the return on shoreline restoration; and the impact of ocean acidification on the oyster industry. Training and research centered in the nation’s network of marine laboratories should:

- develop vital, lifesaving adaptive and mitigation strategies to enhance coastal resiliency with forthcoming environmental challenges facing the Nation;
- develop a deeper fundamental understanding of earth system science so that we can more accurately predict and respond to severe weather and climate changes on local, regional, national, and global scales;
- develop techniques and technologies that will increase the competitiveness of the U.S. aquaculture industry, and contribute to sound fishery management practices, thereby enhancing food security by increasing society’s access to safe, affordable, sustainable, and healthy seafood; and
- lead to the discovery of new marine biological agents that may prove valuable in the treatment of diseases and other ailments.

To develop the knowledge and technologies needed to meet these and other challenges in the ocean, coastal, and Great Lakes environment, it will take the continued education and training of people in science, technology, engineering, and mathematics (STEM). This argues for a renewed commitment to improve the quality of STEM education provided at the pre-K levels and continuing on through the undergraduate and graduate levels of education and for a meaningful and sustained effort to attract, recruit, support, and retain women, minorities, and others not currently well represented in our scientific and technical workforce.

*The National Association of Marine Laboratories (NAML) is a nonprofit organization representing the ocean, coastal and Great Lakes interests of member laboratories that employ thousands of scientists, engineers and professionals nationwide. NAML labs conduct high quality research and education in the natural and social sciences and translate that science to improve decision-making on important issues facing local, state, regional, national and international entities.*





## **The U.S. Research and Education Enterprise is Essential for the Long Term Health of the Nation**

NAML lab directors are concerned about the long-term health of the nation's research and education enterprise and its ability to contribute to the nation's ocean and coastal economy. Increased funding for research, development, and education is critical to the economic enterprise. However, the U.S. is failing to keep pace with our competitors' investments in R&D. For example, China's research investments are rapidly growing by an average of 8% per year, in pursuit of the goal of investment equal to 3% of GDP. By contrast, U.S. investments have not been growing at an influential pace. At this rate, China will surpass the U.S. in R&D intensity in about eight years.

Re-gaining our Nation's competitive edge will require federally funded research and education to become a higher priority than has been the case in over two decades. The Nation needs an enriched workforce of trained, science savvy, entrepreneurs. Basic research is often where the breakthroughs occur that change existing theories and revolutionize technologies. During the 18 years from 1975 to 1992, the federal investment in basic research grew at an average annual inflation-adjusted rate of over 4%, despite serious challenges including the 1973 oil embargo, the Great Inflation of 1979-1982, and the final years of the Cold War. Leaders in both parties, in the White House and Congress, were able then to agree that investments in research should be a high priority for federal support.

Additionally, scientific and technological advances allow us to better understand our world. Building our knowledge allows us to respond more appropriately to new challenges, adapt to changing conditions, and take advantage of emerging opportunities for the benefit of our Nation. Strong science, technology, and engineering capabilities and informed people and communities are the foundation for improving our understanding of the marine environment—from the coasts to the deep sea—and informing our decisions about how best to manage the activities that affect the valuable and multiple resources the marine environment provides. Sustained scientific research and innovative technologies give us the high-quality information we need to maintain or restore ocean resources, guide development and investment opportunities, safeguard lives and property from marine hazards, enhance national security, prepare for and respond to the impacts of climate change and ocean acidification, improve public health, and protect ocean resources. Advancing our scientific, technological, and engineering capabilities also increases the Nation's competitiveness and helps spur the innovation that drives our economy and improves our quality of life. Ultimately, success in improving the ways we use and manage ocean resources depends on building broad public understanding and recognition of the importance of the ocean, coasts, and Great Lakes to our daily lives and the long-term welfare of our Nation.

For the United States to continue to be a global leader in understanding and acting on the connections between our well-being and the health of the natural environment, we need to continue exploring and expanding our knowledge of the ocean, our coasts, and the Great Lakes. Management and policy decisions must be based in the context sound science provides, through the integration of natural and social science data, information, and knowledge. The next Administration must support actions that will contribute to high quality science and ensure that information based on that science is made available to guide decisions and actions. Insight gained from scientific research, advances in observations, and innovative technologies will further enable evaluation of trade-offs between alternative management scenarios, enhance our ability to balance competing demands on ecosystems, and strengthen our Nation's economic and scientific competitiveness. At the same time, increasing understanding of the ocean, coasts, and Great Lakes among our people and communities will empower better-informed public stewardship of ocean resources.

NAML lab directors believe the challenges confronting this Nation and the world with respect to sea level rise and its impact on national security, domestic unrest in developing countries, expanding diseases, flooding, severe weather, and coastal community economic resiliency will all rely on the natural and social sciences, engineering, and technological developments to provide the information and people needed to deal with these challenges. Continuing changes to the ocean and coastal environment, such as ocean and coastal acidification and rising ocean temperatures, will have impacts on marine life (both plant and animal life) that we do not

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fully understand, but yet will surely complicate issues related to food security, commercial fishing, and seafood production and marketing. This country must accelerate the discovery of new scientific knowledge and the education and training of its technical workforce to meet these and many other challenges facing us in the 21<sup>st</sup> century.

Investments in research and education are essential for maintaining technological innovations and advancements that will help our society and a global population survive in rapidly changing times. NAML urges stronger investment into the research and education enterprise of the United States, to reverse the trend of the last 24 years that has left the United States trailing our international competitors. Every research dollar invested returns economic prosperity many times over. If the U.S. is to meet the environmental and economic challenges facing this country, we must make the necessary investments in our research and education enterprise. Nowhere is this need greater than for our ocean, coastal and Great Lakes communities – which serve the economy of our entire nation. Failure to act now may put us in a position from which we cannot recover.

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<sup>i</sup> Spinrad, R. W. (2016), *The new blue economy: A vast oceanic frontier*, *Eos*, 97, doi:10.1029/2016EO053793. Published on 08 June 2016.

<sup>ii</sup> *State of the U.S. Ocean and Coastal Economies – 2016 Update*, Center for the Blue Economy, Middlebury Institute of International Studies at Monterey.



## Ocean Priorities

Ocean science and technology strengthen our national and homeland security, support a safe and efficient marine transportation system, underpin our economy, contribute to improved human health, and further understanding of complex ocean and coastal processes important to our everyday lives – today and tomorrow.

### Ocean Science Investments Strengthen Our Nation

- **Improve national and homeland security**

Ocean science and technology provide us with a knowledge advantage against myriad maritime threats we face now and in the future.

- **Enhance economic prosperity**

Ocean science data and information allows for analysis and understanding of our rich ocean resource. From this, businesses and communities can build new ocean-dependent enterprises around and maintain and grow current endeavors, all while effectively managing risk.

- **Foster food safety and security**

Whether considering ocean conditions to better understand drought forecasts, to model changes in fish distributions, or to develop aquaculture, data and information from the sea strengthen the nation's ability to understand and predict crop loss, food availability and pricing, contamination, and disease.

- **Promote a healthy human population**

Whether considering the direct health impacts of extreme weather events (e.g., drought, wildfires, and floods) or indirect effects (e.g., risk multipliers of freshwater access, sanitation, or easier pathogen distribution pathways), increasingly the changing Earth (and ocean) is a global health crisis. Better understanding the ocean's role in human health leads to innovative solutions.

- **Build a dynamic workforce**

A secure, healthy, and prosperous nation belongs to a society willing to evolve its workforce to meet the needs of a changing world. A diverse, well-educated, ocean literate workforce provides the necessary base from which innovation grows.



## Ocean Priorities

Advancing the following research community goals has benefits that extend far beyond the scientific field – the well-being of our society at large is dependent upon them.

### Ocean Science and Technology Research Goals

- **Enhance our ability to observe and monitor our changing ocean**

Ocean observations are critical not only to maintain the economic prosperity that is historically linked to our rich ocean resource but also to unlock the incredible potential of the sea. Gaps in our nation's ocean observing capabilities limit prediction capabilities, weather forecasting improvements, search and rescue efforts, economic development, conservation of ecosystem integrity, and effective policy and management.

- **Advance scientific knowledge of the ocean**

Basic research and analysis of the coastal and marine environment is tantamount to our ability to forecast, understand, mitigate, and adapt to change. Every single study undertaken creates, confirms, or analyzes data and information, moving our national scientific enterprise ahead.

- **Increase ocean science education**

Prioritizing ocean education is how the United States will lift ocean literacy amongst its citizens, educating the next generation of scientists and technologists is how we will maintain and grow our nation's global competitiveness, and broadening participation in ocean science will bring new perspectives and solutions to ocean issues.

- **Improve access to the ocean and its science**

The ocean is too-often considered a remote and unreachable place. But without access to the marine world, its data and information, or the scientific enterprise itself, innovation and advances would be impossible.

- **Encourage adequate and sustained federal commitment to ocean science and technology**

Federal investment in ocean science and technology makes our nation safer and more prosperous. Federal commitment must be adequate and sustained to achieve these goals and must be more than just policy promises - budget prioritization needs to echo policy initiatives.

## **Ocean Research and Education Are Foundations for Economic Growth**

*Investments in ocean research and education benefit the economic well-being of nations through greater understanding of devastating environmental hazards, sustainable use of ocean resources, safer and efficient maritime transportation, and a healthier ocean environment for a changing world.*

Growing human populations and accelerating environmental change challenge our ability to provide food, energy and materials, as well as security from natural hazards. Our ocean plays a central role in all of these problems. AGU advances collaboration and international relationships across the sciences, works with private and government entities, and informs the public on the role of a changing ocean in our lives. AGU calls on policy makers, agencies, educational and research institutions, and private organizations worldwide to forge cooperation and make bold investments that enable scientific discovery and solutions to support the global economy.

The ocean and its resources are vital to life and to our livelihood on Earth. The ocean provides efficient global transportation routes and vast energy resources. It modulates weather and global climate, regulates the supply of fresh water on land, and supports a wealth of biological diversity. This diversity is a source of novel pharmaceuticals and the fisheries which provide essential protein for people the world over. Clean and productive seas play a central role in many cultures, and are pivotal for recreation and tourism in coastal communities.

The ocean is a major economic asset for most nations. For example, in the U.S., 52% of the population lives in coastal watershed regions<sup>i</sup> generating nearly 60% of the nation's GDP<sup>ii</sup>. Most imported goods (over \$1.1 trillion/yr) and exports move through coastal waterways and ports<sup>iii</sup>. Commercial fishing generates over \$36B in income and more than one million jobs, while recreational fishing supports \$14B in income and hundreds of thousands of additional jobs<sup>iv</sup>. Over 25% of U.S. domestic oil is produced from coastal and offshore waters<sup>ii</sup>. Oil refineries and wind farms, military installations and assets, rail and road networks, all crucial for national security, energy, commerce, and transportation, are concentrated along coasts. In our globally connected world, land-locked nations derive many benefits from the ocean such as general commerce and ocean products, and they are impacted by the ocean's influence on the distribution of rainfall and heat. Innovative opportunities exist in ocean resources, technology, energy, transportation, and tourism. Nations, people and economies worldwide face mounting risks today from rapid changes in the ocean. Protection of life, property, and critical infrastructure requires objective

scientific analysis, but it also necessitates an engagement between decision makers, the public and scientists to address our vulnerabilities to rising sea level, extreme storms, floods, droughts and tsunamis. We need to know how the atmosphere and ocean function together to affect weather and climate through the exchange of heat and moisture. We need to understand the influence of land use on pollution in coastal seas. Science provides the new knowledge we need to respond to rising ocean temperatures, the decline of fisheries, expansion of low oxygen zones, and changes in the chemistry of the ocean caused by increased carbon dioxide. The ability to predict and prepare for changing ocean conditions will depend on scientific research programs, disciplinary and interdisciplinary, international in scope, and involving the ocean sciences with other earth and social sciences. Greater knowledge and prediction skill are urgent when we consider the effort, time and costs of protecting infrastructure along coasts, rebuilding fish populations in our seas, developing new water resources for manufacturing and agriculture, and restoring communities in the wake of hazards. Education and engagement of the research community and the public will promote the advancement of shared goals for a healthy environment and vibrant economy.

Enhanced international cooperation is required to observe, understand and predict the ocean on a global scale for the near future and over decades of change ahead. Public-private-academic partnerships can empower the robust research and education programs needed to understand natural processes and the intersections with human activities. Increased investments in ocean science, technology, and education will be needed to decrease vulnerability of coastal communities; improve safety at sea for the transportation industries; produce new medicines from unique marine bioactive compounds; and improve weather and decadal climate forecasts. These investments will build a foundation for healthy environmental and economic futures of nations around our world.

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<sup>i</sup> U.S. Census Bureau. 2011. Census 2010. <http://factfinder2.census.gov/faces/nav/jsf/pages/index.xhtml>

<sup>ii</sup> <http://stateofthecoast.noaa.gov>

<sup>iii</sup> U.S. Census Bureau, Foreign Trade Division. 2012. FT920: U.S. Merchandise Trade: Selected Highlights December 2011. [http://www.census.gov/foreign-trade/Press-Release/ft920\\_index.html#2011](http://www.census.gov/foreign-trade/Press-Release/ft920_index.html#2011) (accessed April 17, 2012)

<sup>iv</sup> National Marine Fisheries Service. 2011. Fisheries Economics of the United States, 2010. U.S. Dept. Commerce, NOAA Tech. Memo. NMFS-F/SPO-118, 175p. Available at: <https://www.st.nmfs.noaa.gov/st5/publication/index.html>.



# Geoscience for America's Critical Needs



Invitation to  
a National  
Policy  
Dialogue



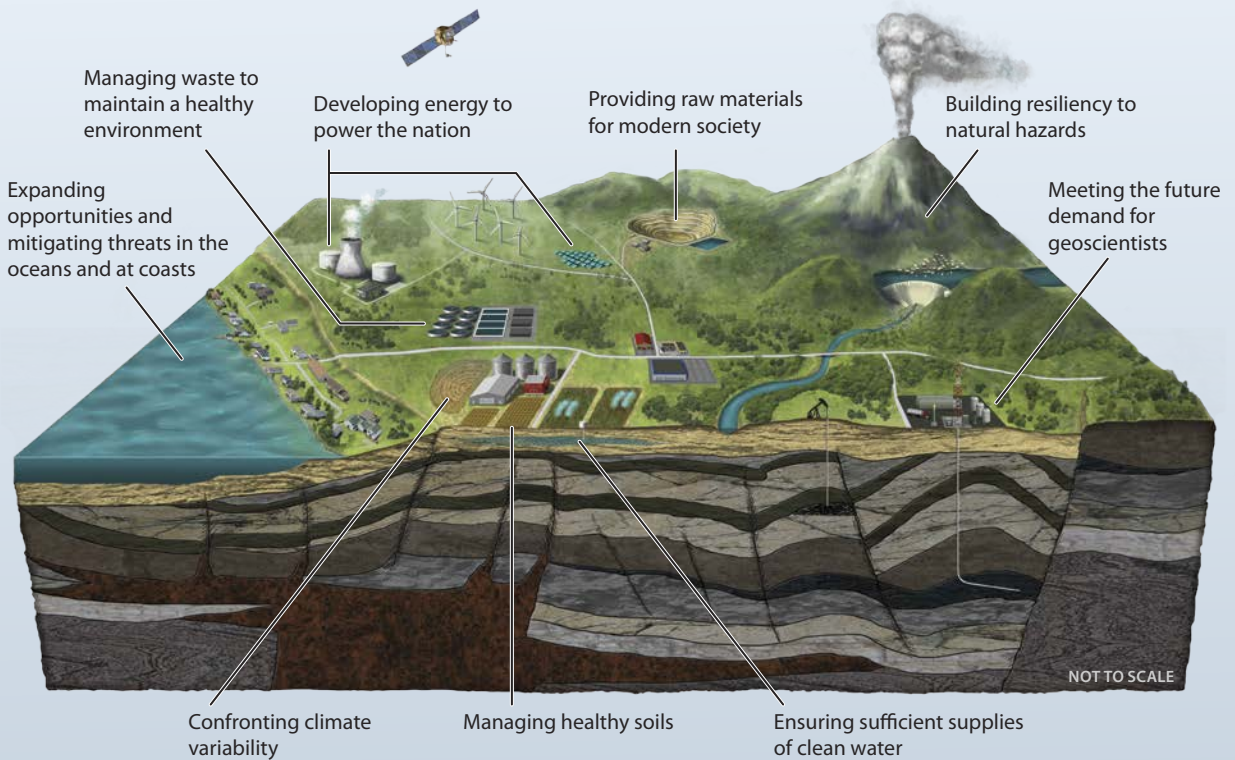
 **AGI** american  
geosciences  
institute

connecting earth, science, and people

2016



# Geoscience and Society



K. Cantner/AGI

This illustration shows some of the major contributions the geosciences make to society. Investments in geoscience information and research increase our ability to strengthen economies and protect public health and safety while living on Earth in a responsible and sustainable manner.

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# Invitation to a Dialogue

The geoscience community has the knowledge, experience, and ingenuity to address a wide range of societal needs. We study Earth's systems, the complex geologic, marine, atmospheric, and hydrologic processes that sustain life and the economy. Geoscience expertise allows us to better understand and predict the interactions between people and Earth's systems; such expertise is essential to developing solutions to critical economic, environmental, health, and safety challenges.

As you develop policy, we in the geoscience community offer to share our scientific expertise and perspectives on topics such as:

- Ensuring sufficient supplies of clean water
- Developing energy to power the nation
- Building resiliency to natural hazards
- Managing healthy soils
- Providing raw materials for modern society
- Expanding opportunities and mitigating threats in the ocean and at coasts
- Confronting climate variability
- Managing waste to maintain a healthy environment
- Meeting the future demand for geoscientists

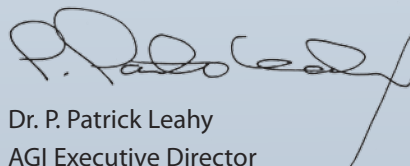
The American Geosciences Institute (AGI) connects Earth, science, and people by serving as a unifying force for the geoscience community. On behalf of the geoscientists represented by the 51 member societies of AGI, we invite you to join us in a dialogue on how to achieve our shared interests in meeting America's critical needs.

This document outlines high-level actions to address major policy issues where the geosciences play a significant role. We urge you to draw on the expertise of the geoscience community when crafting your policies. Together, we can achieve our nation's goals: a strong economy, thriving and resilient communities, and a healthy environment.

Sincerely,



Dr. Richard C. Aster  
Chair, Geoscience & Critical Needs Working Group.  
Department of Geosciences  
Warner College of Natural Resources  
Colorado State University



Dr. P. Patrick Leahy  
AGI Executive Director

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# Water

## Ensuring Sufficient Supplies of Clean Water

Clean water is fundamental to life and is essential for economic prosperity. However, the long-term security of water supplies is threatened by overuse, pollution, and climatic variability. Long-term planning and water management are critical for agriculture, electricity generation, fisheries, industry, transportation, recreation, municipal supplies, and healthy ecosystems.

Geoscientists provide the expertise necessary for effective water resource planning and management, and they conduct research to better understand and predict changes in the amount, quality, and location of water resources.

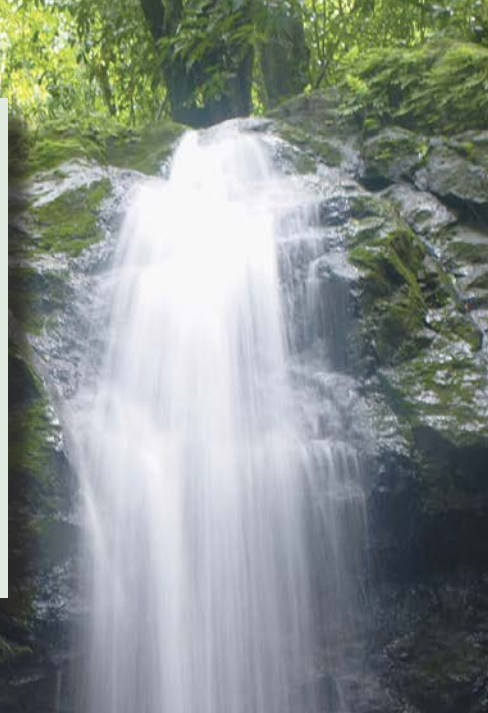


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### To optimize availability of clean water:

**Increase monitoring of both the quantity and quality of surface water and groundwater.** Knowledge of the state of water resources and how they are changing is critical for protecting, maintaining, and restoring the nation's water resources. It is important to collect and manage this information effectively and share it widely.

**Improve understanding of connections within the hydrologic cycle and between water resources and other critical issues.** We need to better understand the interaction between surface water and groundwater and integrate that knowledge into water and land management practices. Understanding links between water and other critical issues, including energy, agriculture, natural hazards, and waste disposal, will facilitate integrated planning and optimal decision making.

**Balance water use with ecosystem needs.** Healthy ecosystems purify water and air, mitigate floods, reduce erosion, and perform many other vital services, but ecosystem health depends on a sufficient water supply.

**Develop and maintain infrastructure to collect, treat, store, and deliver safe water and ensure sufficient capacity to meet changing needs.** The high costs of infrastructure development, maintenance, and replacement impose growing financial burdens and require long-term planning based on geoscience understanding and innovative engineering.

**Address persistent sources of contamination and identify threats to water quality in a timely manner.** Water quality is threatened by long-recognized contaminants, such as trace elements, pesticides, industrial spills, and excess salt and nutrients primarily from agricultural sources. Newly understood threats include naturally occurring contaminants, pharmaceuticals, and nanoparticles.



# Energy

## Developing Energy to Power the Nation

Energy supports economic growth, national security, and all the elements of daily life—food, water, transportation, communication, and entertainment. The United States' historically robust and secure energy systems have contributed to our high quality of life.

Geoscientists find and develop earth- and ocean-sourced energy, such as oil, natural gas, coal, uranium, and geothermal. They also find and develop the raw materials needed for renewable energy sources, such as cement and metals for dams, and rare earth elements for wind turbines and solar installations. In addition, geoscientists help determine suitable locations for energy infrastructure, including refineries, transmission lines, dams, and wind farms.

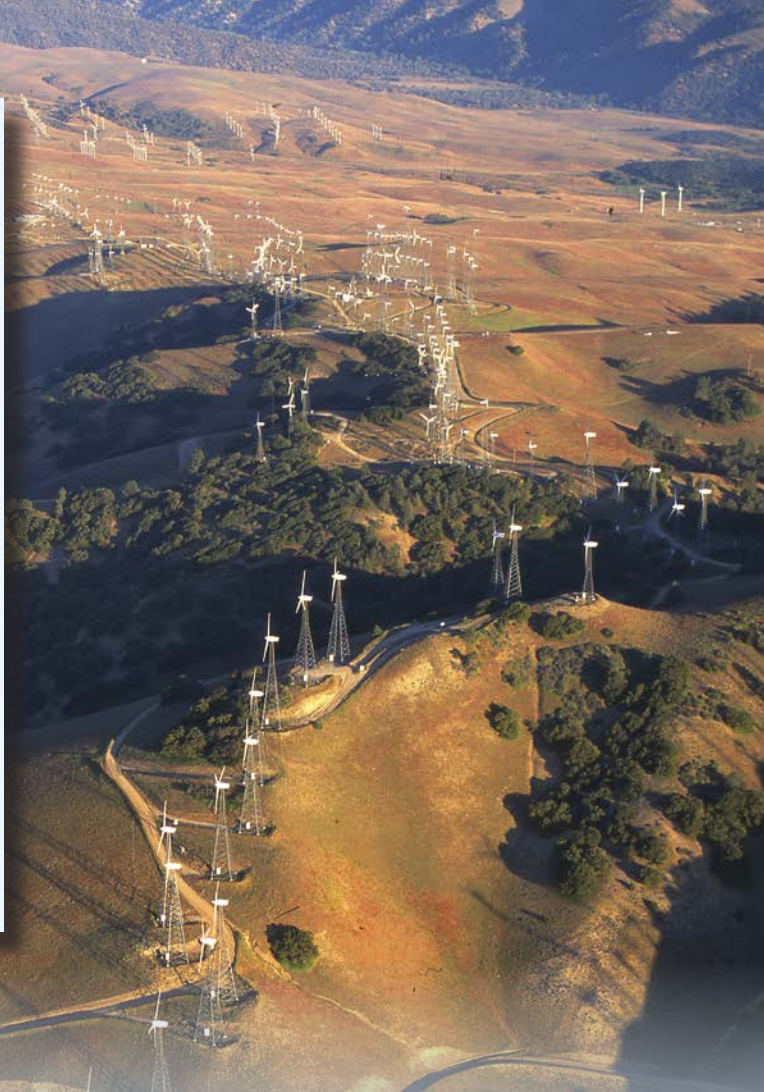


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### For an energy-secure nation:

**Assess the quantity and location of energy resources.** Geoscientists improve understanding of energy resources, helping decision makers to create robust energy policies and allowing energy producers to develop resources more efficiently.

**Develop the nation's diverse energy sources.** The United States relies on a variety of energy sources including petroleum, natural gas, coal, nuclear, hydroelectric, geothermal, and other renewables, like wind and solar. The continued responsible development of these resources, and the advancement of emerging energy sources, will ensure reliable supplies for the future.

**Study and develop solutions that reduce the environmental impacts of energy extraction and generation.** Geoscientists perform life-cycle analyses of the short- and long-term impacts of energy development, use, and waste disposal that help inform energy policy decisions.



# Natural Hazards

## Building Resiliency to Natural Hazards

Natural hazards affect every state in the nation. Earthquakes, volcanoes, landslides, sinkholes, wildfires, tornadoes, hurricanes, floods, extreme heat and cold, and drought, among others, result in billions of dollars in annualized losses to the United States. These hazards threaten lives and property, disrupt services, damage infrastructure, and weaken economies. A thriving nation requires resilient communities that help protect citizens from economic and social disruptions related to natural hazards.

Geoscientists help communities identify, mitigate, prepare for, respond to, and recover from natural disasters. In coordination with engineers, social scientists, public safety professionals, and emergency managers, geoscientists conduct natural hazards research, monitoring, training, education, and public outreach to create an integrated approach to developing resilient communities.



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## To minimize the potential impact of natural hazards:

**Encourage basic and applied research to strengthen community resilience.** Geoscientists study the links between natural hazards and Earth processes and the ways natural hazards impact society. They identify hazard-prone areas through geologic mapping, seismic monitoring, and other investigations.

**Prioritize natural hazard monitoring.** Geospatial tools such as satellites, lidar, seismic networks, and stream gauges help geoscientists collect data to assist in disaster assessment and response and develop better models, forecasts, and warnings.

**Support communication of the risks and vulnerabilities associated with natural hazards to the public.** Geoscientists translate technical data into actionable information, helping to include science in mitigation, preparedness, response, and recovery efforts.

**Mitigate hazard impacts on people, buildings, and infrastructure.** Geoscience research informs transportation planning, land-use practices, and building codes, leading to more resilient communities.



# Soils

## Managing Healthy Soils

The ability of soil to support plant life is vital to the food we eat and the air we breathe. Soils are primarily made of a complex and variable combination of minerals from rocks, organic matter from plants and animals, air, and water.

Geoscientists study the characteristics, history, and efficient management of soils to improve agricultural yields, purify water, treat waste, supply industrial and pharmaceutical goods, evaluate foundation stability for infrastructure, and reduce impacts from natural disasters.



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## To manage the nation's soils efficiently:

**Encourage monitoring of soil quality and moisture for optimal agricultural production.** Soil fertility and its ability to produce crops depend on the nutrients it contains. Better monitoring and management can improve crop yields and potentially reduce offsite contamination.

**Incorporate knowledge of soil characteristics and properties into the planning, design, construction, and modification of critical infrastructure.** Soil and rock provide the foundation for our nation's buildings, roads, bridges, water systems, and pipelines. Understanding soil properties and how they relate to the underlying geology can lead to more resilient infrastructure.

**Expand the use of soil as a filter to remove pollutants from water.** Environmental geoscientists use soil filtration as a natural and relatively inexpensive means to mitigate pollution and improve water quality, particularly for fertilizer application in agricultural settings.

**Characterize soil biodiversity and its relation to essential ecosystem functions.** Healthy soil supports a wealth of biotic diversity. Geoscientists help understand the link between soil microorganisms and the functions they provide to support plant growth, remediate contaminants, and contribute to a drought- and flood-resilient ecosystem.

**Improve soil characterization and geologic mapping to identify underlying hazards.** Earthquakes, landslides, wildfires, droughts, and floods all affect soil stability, occasionally leading to loss of life and property. Identifying and mitigating potential weaknesses in soil layers will benefit society by reducing the likelihood and impact of disasters.



# Mineral Resources

## Providing Raw Materials for Modern Society

Daily activities, national security, and the greater economy all depend on an abundant supply of minerals — from gold for cell phones, to potassium for crop fertilizers, to rare earth elements for missile guidance and clean energy technology, to crushed stone in concrete for buildings and roads.

Despite the pervasiveness of minerals in everyday life, the full extent and accessibility of the nation's mineral resources is not known; supplies of some critical minerals are vulnerable to disruption; and mineral extraction, use, and disposal have environmental impacts that should be better understood and mitigated.

Geoscientists locate and characterize mineral deposits and provide essential information for efficient resource extraction and effective environmental stewardship.



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## To support a secure supply of minerals:

**Assess the nature and distribution of domestic mineral resources.** This basic information on the nation's natural wealth is essential for government, industry, environmental, investment, and community decision making.

**Quantify domestic and global supply of, demand for, and flow of minerals.** Industry relies on a stable supply of raw materials. Understanding and predicting the market forces that impact mineral supply is essential to anticipate and avoid supply disruptions and to make well-informed financial and policy decisions.

**Support socially, economically, and environmentally responsible domestic mineral production.** The United States relies on imports for more than one-half of its apparent consumption<sup>1</sup> of 43 mineral commodities,<sup>2</sup> including several that are considered critical to the national interest, such as rare earth elements.

**Foster innovative solutions to lessen the environmental impact of mining and mineral use.** Recycling and substitution are increasing, but mining is, and will continue to be, the primary source for most materials. New approaches to mining, mineral use, and product disposal can mitigate the impacts of mineral production and consumption.

<sup>1</sup> Apparent consumption is usually defined as (production + imports) – exports.

<sup>2</sup> Mineral Commodity Summaries 2015. U.S. Geological Survey. <<http://minerals.usgs.gov/minerals/pubs/mcs/2015/mcs2015.pdf>>

# Ocean & Coasts

## Expanding Opportunities and Mitigating Threats

The United States depends on the ocean and the Great Lakes for food, national security, energy resources, transportation, recreation, and myriad other critical needs. More than half of the United States population lives in coastal watershed counties that generate 58 percent of the nation's gross domestic product.<sup>1</sup> The United States has jurisdiction over 3.4 million square miles of ocean, more than the land area of all 50 states combined. This vast marine area offers environmental resources and economic opportunities. However, coastal communities are also threatened by tsunamis, hurricanes, industrial accidents, and water-borne pathogens. A better understanding of our ocean and coastal areas will strengthen our economy and protect our people.

Geoscientists provide information about how our planet's coasts, ocean, and seafloor operate now and how they have functioned in the past. They conduct research on marine energy and mineral resources, natural hazards, rising seas, and ocean acidification.

<sup>1</sup> National Coastal Population Report: Population Trends from 1970 to 2020. National Oceanic and Atmospheric Administration. < <http://stateofthecoast.noaa.gov/features/coastal-population-report.pdf> >



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## To ensure the long-term sustainable use of our ocean and coastal resources:

**Support basic and applied research on ocean and coastal issues.** Better knowledge of the ocean and its role in global processes now and in the past allows scientists to forecast for the future. An improved understanding of ocean and coastal processes will reduce damage and promote responsible growth of coastal communities.

**Enhance ocean observations.** The ocean drives global water and weather systems by absorbing, holding, and moving vast amounts of the Earth's heat, water, and CO<sub>2</sub>. A resilient nation needs sustained ocean observations from space, from the ocean surface, and at depth.

**Monitor, research, and respond to sea-level rise.** Sea level is rising at an increasing rate, changing coastal ecosystems and making vital coastal communities vulnerable to erosion and flooding associated with storm surges and high tides.

**Assess marine energy and mineral resources, and their environmental context.** The ocean not only hosts energy and mineral resources but also is a source of energy itself. Most of the marine world remains unexplored, making informed policy a challenge.



# Climate Change

## Confronting Climate Variability

Decades of scientific research show that Earth's climate, the long-term seasonal averages of weather on a regional or global scale, changes as a result of both natural and human causes. Over the past century, global average temperatures have increased significantly.<sup>1</sup> These changes drive sea level rise and exacerbate ocean acidification. Climate change will likely lead to greater storm surges, droughts, heat waves, flooding, and other events that could cost the nation billions of dollars and affect domestic and global security.

Geoscientists use rock and ice cores to study records of past climate, satellites and weather stations to monitor current climate, and sophisticated computer models to project future conditions. This information supports decisions about agriculture, human health, and critical infrastructure.

<sup>1</sup> Temperature Anomalies Time Series, June 2015. National Oceanic and Atmospheric Administration. <<https://www.ncdc.noaa.gov/sotc/global/201506>>



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## To better equip society for a changing climate:

**Encourage research and improve models to understand the connection between Earth's systems, human activity, and climate change.** For more than four billion years, land, water, ice, and the ocean have helped shape, and have been shaped by, a changing climate. Understanding past climates through evidence preserved in the geologic record increases the accuracy of today's climate models and the ability to forecast how ecosystems will respond to climate change.

**Plan for the diverse and complex societal impacts of climate change.** Holistic plans consider not just single weather events but extended effects, such as drought, crop failures, emerging diseases, and damage to ecosystems, which carry the potential for long-term social and economic impact. Information from geoscientists, who are familiar with the interrelated processes that impact climate, strengthens climate-change adaptation plans.

**Evaluate strategies for limiting carbon in the atmosphere.** Scientific evidence indicates that carbon in the atmosphere is a key factor in rising global temperatures. Reducing carbon generation and storing it in geologic formations, also known as carbon capture and storage (CCS), are effective ways to limit atmospheric CO<sub>2</sub>.

# Waste Disposal

## Managing Waste to Maintain a Healthy Environment

Waste is an inevitable byproduct of society. Waste types are as varied as human activities themselves, and many waste products are toxic. Protection of human health and the environment often relies on geoscience knowledge to isolate waste materials from people and ecosystems.

Geoscientists translate their understanding of complex Earth systems into meaningful approaches for isolating waste streams and remediating waste sites.



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## To optimize the balance between resource use and a healthy society:

**Assess the safety of disposing of liquid waste in deep wells.** This method of disposal is commonly used today to dispose of treated wastewater, chemicals, and oil field brines, but it can potentially induce earthquakes or contaminate groundwater. Geoscience investigations can help make disposal safer.

**Understand and minimize impacts of energy production and usage.** Energy byproducts include solid wastes such as fly ash, thermal pollution of water from power plant cooling, liquid wastes, and gaseous byproducts such as CO<sub>2</sub>.

**Mitigate the high risk associated with nuclear waste.** Large volumes of spent nuclear fuel are currently stored at multiple temporary sites in the United States, and more such waste continues to be generated. A long-term disposal option is still needed for this toxic radioactive waste, and a geologic repository may provide a long-term solution. Geoscientists provide information to help assess site suitability and selection.

**Support cleanup of abandoned mines, brownfields, and Superfund sites.** Landfills, dumps, and spills can introduce a wide variety of toxic chemicals into the environment. Geoscience provides a basis for evaluating risks, setting priorities for remediation, and assuring that expenditures yield substantial benefits.



# Workforce & Education

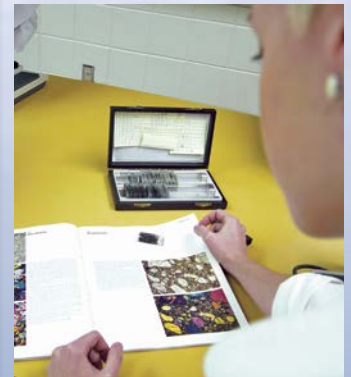
## Meeting the Future Demand for Geoscientists

The 300,000 geoscientists<sup>1</sup> currently working in the U.S. private and public sectors help the nation ensure a clean and sustainable water supply; explore, access, and manage its energy and mineral resources both on land and under the sea; monitor, forecast, and mitigate terrestrial and marine natural hazards; support agricultural soil productivity; research land-sea-atmosphere interactions to understand the changing climate; and safely clean up environmental contamination and dispose of waste. By sharing their knowledge with students and the public, geoscientists help to create a society that understands Earth's processes and recognizes resource, hazard, and environmental issues.

The economic demand for geoscientists will continue to grow within the United States and worldwide, yet increasing numbers of U.S. geoscientists are reaching retirement age. AGI estimates a shortage of 135,000 geoscientists within the U.S. economy by 2022.<sup>2</sup> The nation's schools, colleges, and universities must be ready to educate and train this next generation of geoscientists.

<sup>1</sup> Wilson, C.E., The Status of the Geoscience Workforce 2014. Alexandria, VA: American Geosciences Institute, 2014. <[www.americangeosciences.org/workforce/reports/status-report-2014](http://www.americangeosciences.org/workforce/reports/status-report-2014)>

<sup>2</sup> Ibid.



Images all from AGI's 2014 Life in the Field contest. Photographers, top to bottom: Arnaud Mansat; Alisa Kotash; Judah Epstein; Rob Thomas.

## To develop a knowledgeable, experienced, and innovative geoscience workforce:

**Sustain and grow programs to educate a diverse group of students in science, technology, engineering, and math (STEM).** Geoscience educators ensure that students across the U.S. at all levels have opportunities to learn about the Earth. They recruit, teach, and retain talented students and encourage them to pursue careers in geoscience and related STEM disciplines.

**Support federal investments in basic and applied geoscience research.** Federally funded research leads to scientific discovery and provides critical educational opportunities for students pursuing geoscience careers.

**Encourage partnerships between industry, government, and universities and colleges.** Private-sector research and development is essential to maintaining America's globally competitive, knowledge-driven economy. Partnerships between government, industry, and higher education promote innovation while enhancing the educational environment and preparing students graduating from U.S. colleges and universities for the workforce.

# What do the Geosciences Include?

Water research to **ensure water quality and quantity**

Petroleum geology to **identify and recover energy resources**

Natural hazard science to **help ensure safer, more resilient communities**

Soil science to **monitor soil quality and health for agriculture and construction**

Environmental geology to **protect and provide a healthy environment**

Engineering geology to **build stable infrastructure**

Economic geology to **locate and extract mineral resources**

Coastal geology to **support sustainable use of coastlines**

Oceanography to **protect maritime productivity and ocean commerce**

Atmospheric research for **weather forecasting and climate modeling**

Planetary science to **better understand Earth and other planets**

Geoscience education to **cultivate a society that understands the Earth**

Image credit: NASA Goddard Space Flight Center Image by Reto Stöckli (land surface, shallow water, clouds). Enhancements by Robert Simmon (ocean color, compositing, 3D globes, animation). Data and technical support: MODIS Land Group; MODIS Science Data Support Team; MODIS Atmosphere Group; MODIS Ocean Group Additional data: USGS EROS Data Center (topography); USGS Terrestrial Remote Sensing Flagstaff Field Center (Antarctica); Defense Meteorological Satellite Program (city lights).



## About AGI

AGI connects Earth, science, and people by serving as a unifying force for the geoscience community. With a network of 51 member societies, AGI represents more than a quarter-million geoscientists with specialized knowledge of the Earth and its interactions.

AGI was founded in 1948, under a directive of the National Academy of Sciences, as a network of associations representing geoscientists with a diverse array of skills and knowledge of our planet. The Institute provides information services to geoscientists, serves as a voice of shared interests in our profession, plays a major role in strengthening geoscience education, and strives to increase public awareness of the vital role the geosciences play in society's use of resources, resilience to natural hazards, and the health of the environment.



AGI logo shape images: lava: USGS, ESW Image Bank; Aztec sandstone: ©Michael Collier, ESW Image Bank; farm: Digital Vision; waves: Digital Vision; clouds: Digital Stock; space: Digital Vision.

### AGI Programs

**EARTH magazine:** This monthly publication explores the science behind the headlines. EARTH magazine gives readers definitive coverage on topics from natural resources, energy, natural disasters and the environment to space exploration and paleontology and much more.

**Education and Outreach:** AGI Education offers products and services for K-12 educators, including NSF-funded curricula, high-definition videos, classroom activities, teacher professional development, and online resources.

**GeoRef:** GeoRef is a comprehensive, bibliographic database containing over 3.6 million references to geoscience journal articles, books, maps, conference papers, reports, and theses.

**Policy and Critical Issues:** Geoscience Policy works with AGI member societies and policy makers to provide a focused voice for the shared interests of the geoscience profession in the federal policy process. Critical Issues provides a portal to comprehensive, impartial geoscience information for decision makers.

**Workforce:** AGI Workforce studies the human resources of the geoscience community, produces the Directory of Geoscience Departments, collects data on the supply of and demand for geoscientists, and works to ensure that the health of the profession is understood and improved.

**Earth Science Week:** Reaching over 50 million people a year, Earth Science Week promotes awareness of Earth science and appreciation of the geosciences' role in society. This international public awareness campaign, organized each October by AGI, provides informational resources, educational materials, and a variety of events and activities for students, teachers, and others. Program partners in government, industry, and the nonprofit sector unite to advance these efforts and continue the solid track record of success of this nearly two-decade-old initiative ([www.earthsciweek.org](http://www.earthsciweek.org)).

**Center for Geoscience and Society:** The Center links geoscience information to diverse, non-specialist audiences, with a particular emphasis on communicating with decision makers at all levels and with educators in non-geoscience disciplines.

**AGI Foundation:** The Foundation is the principal source of U.S. tax-deductible endowment and programmatic contributions to the American Geosciences Institute from industry, private foundations, and individual donors.

# AGI Member Societies

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American Association of Petroleum Geologists (AAPG)  
American Geophysical Union (AGU)  
American Institute of Hydrology (AIH)  
American Institute of Professional Geologists (AIPG)  
American Rock Mechanics Association (ARMA)  
Association for the Sciences of Limnology and Oceanography (ASLO)  
Association for Women Geoscientists (AWG)  
Association of American Geographers (AAG)  
Association of American State Geologists (AASG)  
Association of Earth Science Editors (AESE)  
Association of Environmental & Engineering Geologists (AEG)  
Clay Minerals Society (CMS)  
Council on Undergraduate Research, Geosciences Division (CUR)  
Environmental and Engineering Geophysical Society (EEGS)  
Friends of Mineralogy (FOM)  
The Geochemical Society (GS)  
Geo-Institute of the American Society of Civil Engineers (GI)  
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National Association of Black Geoscientists (NABG)  
National Association of Geoscience Teachers (NAGT)  
National Association of State Boards of Geology (ASBOG)  
National Cave and Karst Research Institute (NCKRI)  
National Earth Science Teachers Association (NESTA)  
National Ground Water Association (NGWA)  
National Speleological Society (NSS)  
North American Commission on Stratigraphic Nomenclature (NACSN)  
Paleobotanical Section of the Botanical Society of America (PSBSA)  
Paleontological Research Institution (PRI)  
Paleontological Society (PS)  
Petroleum History Institute (PHI)  
Seismological Society of America (SSA)  
SEPM (Society for Sedimentary Geology) (SEPM)  
Society for Mining, Metallurgy, and Exploration, Inc. (SME)  
The Society for Organic Petrology (TSOP)  
Society of Economic Geologists (SEG)  
Society of Exploration Geophysicists (SEG)  
Society of Independent Professional Earth Scientists (SIPES)  
Society of Mineral Museum Professionals (SMMP)  
Society of Vertebrate Paleontology (SVP)  
Soil Science Society of America (SSSA)  
United States Permafrost Association (USPA)  
**International Associate Societies**  
Canadian Federation of Earth Sciences (CFES)  
Geological Society of Africa (GSAf)  
International Association for Promoting Geoethics (IAPG)  
YES Network

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Date: November 2016

From: Dr. Antonio J. Busalacchi  
President, University Corporation for Atmospheric Research (UCAR)

To: The Administration of the 45<sup>th</sup> President of the United States  
The Members of the 115<sup>th</sup> Congress

Subject: **Recommended Research and Education Priorities for the Federal Investment in the Academic Atmospheric, Earth, and Related Sciences**

### **Executive Summary**

UCAR, representing more than 100 member colleges and universities, respectfully submits a set of research priorities for the academic atmospheric, earth, and related sciences to the new Administration and the 115<sup>th</sup> Congress. A focused investment of federal resources in the atmospheric, earth, and related sciences will make significant contributions towards meeting societal concerns including: protection of American lives and property; expansion of new economic opportunities; enhancement of national security; and strengthening the U.S. leadership in research and development.

**Weather:** Accurate weather forecasts are critical in providing important information for short term and longer term forecasts as well as early warnings of impending severe weather. The goal of weather prediction is to provide timely and accurate information that will serve to reduce weather-related losses, protect life and property, improve public health and safety, support economic prosperity and national security, and improve the quality of life for all citizens.

**Water:** Water challenges are facing communities and regions across the United States and the world, impacting billions of lives and costing billions of dollars in damages. These challenges are particularly problematic in predominantly poor, minority, or rural communities. Weather and climate models are fundamental for understanding the earth's water cycle and issues related to availability, quality, water resource management, energy production, flooding, and drought.

**Climate:** Understanding climate change is critical to the world's welfare. Fundamental use-inspired research, made possible by cutting-edge tools for collecting and analyzing data, can provide the knowledge that governments, businesses, and communities need as they address the climate-related changes that pose growing risks to life, property, natural resources, and the economy. Such research depends on sustained programmatic investments in multidisciplinary observations, process studies, and modeling.

**Air Quality:** Air quality affects broad sectors of society, from human health to crop yields to enjoyment of our national parks. Particulate matter, in addition to ozone, triggers most air quality alerts and health effects. Scientists are improving pollutant tracking and developing detailed air quality predictions. Research is also focused on developing detailed air quality forecasts days in advance. Improved forecasts offer the promise of significant benefits to society.

**Space Weather:** Space weather can disrupt vital technology that forms the backbone of this country's economic vitality and national security, including satellite and airline operations, communications networks, navigation systems, and the electric power grid. Research and observations will help drive advances in modeling capability and improve the quality of space-weather products and services. Transition of the latest scientific and technological advances into space weather operations centers will enable an improved rate of forecast improvement.

For more information contact Scott Rayder, Senior Advisor to the UCAR President at [rayder@ucar.edu](mailto:rayder@ucar.edu) or 303-497-1673. Postal Address: P.O. Box 3000, Boulder, Colorado 80307-3000.



**Education:** The success of the research challenges above is dependent on a science, technology, engineering and mathematics (STEM) education system that produces a diverse and well-prepared workforce of scientists, technicians, engineers, mathematicians and educators and a well-informed citizenry that have access to the ideas and tools of science and engineering.

These recommendations relate directly to the Federal agencies for which the atmospheric, earth, and related sciences play an important role in their various missions – including the Office of Science and Technology Policy (OSTP); the National Science Foundation (NSF), the National Oceanic and Atmospheric Administration (NOAA), the National Aeronautics and Space Administration (NASA), the Department of Energy (DOE), Department of Agriculture (USDA), the Federal Aviation Administration (FAA); the Department of Defense (DOD), the Department of Homeland Security (DHS), the Department of the Interior (DOI), the Environmental Protection Agency (EPA), and others.

The recommendations are also consistent with pending legislation including the American Innovation and Competitiveness Act, the Weather Research and Forecasting Innovation Act of 2015, the Seasonal Forecasting Improvement Act, the Space Weather Research and Forecasting Act, as well as current and past guidance provided by the House and Senate Appropriations Committees.

This UCAR white paper also **supports** and **builds** on the May 2016 American Meteorological Society (AMS) [Policy Statement on Weather, Water, and Climate Priorities](#). In that statement the AMS outlined the need for continued development of people, knowledge, observing capabilities, physical and cyber infrastructure, and the evolving partnership between the public, private, and academic sectors of the weather, water, and climate enterprise.



## **Background Information**

UCAR is a nonprofit consortium of more than 100 North American member colleges and universities focused on research and training in the atmospheric, earth, and related sciences. Founded in 1960 to manage the National Center for Atmospheric Research (NCAR) on behalf of the NSF. Today UCAR's mission is to empower its Member Institutions and NCAR by: promoting research excellence; developing fruitful collaborations; managing unique resources; creating novel capabilities; building critical applications; expanding educational opportunities; and engaging in effective advocacy.

NCAR was established as a center of excellence for research and education in the atmospheric sciences; and providing research support, facilities, and services for the atmospheric, earth and related sciences and the wider geosciences community. NCAR is designated as an NSF Federally Funded Research and Development Center (FFRDC) with approximately 750 full-time equivalent staff. The NCAR mission is to understand the behavior of the atmosphere, earth, and related systems; to support, enhance, and extend the capabilities of the university community and the broader science community, nationally and internationally; and to foster the transfer of knowledge and technology for the betterment of life on earth. This mission is accomplished through scientific research; the development, improvement, and operation of a number of facilities; and educational and outreach programs.

In collaboration with the university research and education community, NCAR focuses on fundamental research aimed at improving our ability to predict meteorological, air quality, and space weather hazards and increasing our understanding of the variability in and changes to the earth's climate system at regional and global scales. These research themes are enabled by NCAR-operated facilities such as unique aircraft; petascale supercomputing capabilities; and state-of-the-art community models. Partnerships with researchers in complementary fields, such as hydrology, cryospheric science, oceanography, terrestrial biology, public health and social sciences, broaden NCAR's activities beyond the traditional atmospheric, earth, and related sciences.

UCAR, as the manager of NCAR for NSF, is responsible for:

- Planning, executing, staffing, and managing the NCAR program;
- Providing and maintaining advanced observational, computational, and modeling facilities and services to support the research and education community;
- Operating and maintaining the NCAR buildings and facilities, developing and incorporating new facilities, as appropriate;
- Recruiting, developing and retaining a highly competent and diverse staff;
- Planning for and implementing future initiatives in partnership with UCAR Member institutions and the research and education community;
- Overseeing and sustaining an innovative and vigorous program of basic and applied research in support of the atmospheric, earth, and related sciences.

UCAR believes that in order for the research and education community to contribute both the knowledge and human resources needed by society, it is essential that the NSF, NOAA, NASA and the other related mission agencies receive priority support for their research and education activities as well as the continued improvement of operational programs. In addition, the agencies should be commended for and encouraged to build on their highly collaborative relationships not only within the Federal enterprise, but also with the academic and private sector.

UCAR provides important scientific support not only for the university based atmospheric, earth, and related sciences community, but also for the agencies with missions that require research, data analysis and management, and training in these disciplines. UCAR endorses a set of core values to ensure the Nation's research and education enterprise remains strong, vital, and productive. These values include:

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- Dependence on merit review and the pursuit of objectivity in research;
- The federal investment in research and education should to be broad and inclusive if we are to be successful in the endeavors discussed below; and
- The responsibility of the research and education community to enable the beneficial use of scientific discovery by society.

**Recommended Research and Education Priorities for the Academic Atmospheric  
Earth and Related Sciences**

**WEATHER:** Accurate weather forecasts are critical in providing important information for short term and longer term forecasts as well as early warnings of impending severe weather. The goal of weather prediction is to provide timely and accurate information that will serve to reduce weather-related losses, protect life and property, improve public health and safety, support economic prosperity and national security, and improve the quality of life for all citizens.

According to the National Academies, the benefit of investing to improve public weather forecasts and warnings is substantial: the estimated annualized benefit is about \$31.5 billion, compared to the \$5 billion spent annually by the Federal Government for generating the baseline information.

Improvements in short term and seasonal forecasting would benefit society in many ways beyond being better prepared for severe weather events. Weather-related aircraft delays could be reduced which would reduce operational costs for the commercial airline industry. Use of weather information will allow for better options in the decision-making of various stake holders in the transportation sector, such as commuters or tourists, transport infrastructure owners and transport service and maintenance operators. Improved seasonal forecasts would be of value to the agricultural sector of the economy allowing farmers and others to either take full advantage of predicted beneficial weather conditions as well as prepare for forthcoming challenging weather conditions such as drought or flooding.

The United States should unambiguously lead in operational numerical weather prediction and earth observing capabilities yet by some measures, our capabilities lag behind our international competitors. This suggests the U.S. could be mitigating the economic, national security, and public safety implications of severe weather more effectively.

The university community is working to develop a better fundamental understanding of the integration of earth system sciences as well as better models (and the computing capabilities needed to use such models) to simulate local, regional, national and global-scale conditions that impact severe storm development.

In addition, the university community strongly supports the need for the sophisticated integration of the social sciences in the design and execution of future weather and climate research activities as well as the dissemination of weather and climate relevant information. Such research will enable better predictions of and responses to storms and other forms of severe weather that can reduce loss of life and property, and limit economic damage to areas experiencing severe weather.

Fundamental research and research training, via support provided by the National Science Foundation and, to a more limited extent by other Federal agencies, underpins any meaningful effort to improve the quality of weather forecasts. This includes such areas as: studies of the physics, chemistry, and dynamics of earth's upper and lower atmosphere and its space environment; research on weather and climate processes and variations; and research to understand the natural global cycles of gases and particles in earth's atmosphere.

Given the continuing evolution of the weather enterprise – particularly the significant growth of the private sector's ability to provide unique weather related products and services, and the demise of some observing capabilities, there is a real need for one or more forums that enable public-private sector strategic planning. A valuable contribution would be a National Academies' decadal survey related to weather, involving representatives of the public and private sectors. Such a survey could develop a prioritized set of Federal (domestic and defense related) research and operational priorities for weather research and weather forecasting which

should be useful for decision and policy makers in an era of constrained resources.

**WATER:** Water challenges are facing communities and regions across the United States and the world, impacting billions of lives and costing billions of dollars in damages. These challenges are particularly problematic in predominantly poor, minority, or rural communities, where water inequality can go hand-in-hand with socioeconomic inequality. Recent events, including record-breaking drought in the West, severe flooding in the Southeast, and the water-quality crisis in Flint, MI, have elevated a national dialogue on the state of our Nation's water quality, resources and infrastructure. This dialogue is increasingly important as a growing population and changing climate continue to exacerbate these water challenges. Issues related to water quality, energy production, water resource management, and water infrastructure are even more challenging in developing countries. Accordingly, we must work together to build a sustainable water future—one in which everyone has access to the safe, clean, and affordable water they need, when and where they need it.

Weather and climate models are fundamental for understanding the earth's water cycle and issues related to availability, quality, water resource management, energy production, flooding, and drought. One focus of water research is to reduce uncertainty through improved understanding and integration of the water cycle in weather and climate models. Another component of the effort is the examination of the impact of climate change on water systems, and to determine potential effects on water management policy.

Research support is needed in areas related to improving modeling that will deliver more timely and detailed flooding forecasts. Water managers and planners need advancements in estimating snowpack and stream flow that will provide more information about spring runoff, flooding, and municipal water supply availability. Research that will result in reliable drought forecasting a year or more in advance would give the government and private sector the time and information to prepare accordingly.

Changing precipitation patterns and growing populations have made the regions, such as the

Southwest, increasingly vulnerable to water shortages and drought. Science is needed to improve flood forecasts and anticipate drought far in advance. Research can facilitate the improvement of the nation's existing urban water systems through the development of innovative water technologies, management tools and systems-level analysis. Urban water management would benefit from a set of decision-support tools that will allow utilities to quantify regional urban water resiliency and sustainability; promote the diversification of urban water supply portfolios by enabling virtual trading in regions with shared water resources; and support integrated management of water reuse and storm water recharge systems.

A complete understanding of the water system requires an approach that extends beyond the atmosphere to include how the earth's water system is linked with climate change, land use and ecosystems.

**CLIMATE:** Today's global climate changes are having a noticeable impact via heat waves, extended drought, wildfires, migration of disease-carrying insects and pests, warming oceans, and other events. Global climate change has already had observable effects on the environment. Glaciers have shrunk, ice on rivers and lakes is breaking up earlier, plant and animal ranges have shifted and trees are flowering sooner. Effects that scientists had predicted in the past would result from global climate change are now occurring: loss of sea ice, accelerated sea level rise and longer, more intense heat waves.

Global climate change is projected to continue to change over this century and beyond. The magnitude of climate change beyond the next few decades depends primarily on the amount of heat-trapping gases emitted globally, and how sensitive the earth's climate is to those emissions. Temperatures will continue to rise. Because human-induced warming is superimposed on a naturally varying climate, the temperature rise has not been, and will not be, uniform across the country or throughout the world thus impacting different regions in different ways. Frost-free and growing seasons will lengthen impacting world-wide agricultural food production.

Changes in precipitation patterns will continue. For example, more winter and spring precipitation is

projected for the northern United States, and less for the Southwest, over the course of this century. More extensive droughts and heat waves are expected to occur and severe storms, such as hurricanes and typhoons are expected to become stronger and more intense. Sea level rise could increase anywhere from 1 to 4 feet by 2100 depending on the location. Sea level rise has national security implications for relevant coastal facilities and may also contribute to societal unrest in developing countries.

As a public policy issue, global climate change presents a number of key issues: climate is changing; people are causing climate to change; the societal consequences of climate change are highly uncertain but include the potential for serious impacts; and there are numerous policy options for climate change risk management. Global climate change risk management approaches generally fall into the following categories: mitigation; adaptation; geoengineering or climate engineering; and knowledge-base expansion—efforts to learn and understand more about the climate system, which can help support proactive risk management.

Comprehensive global climate change risk management includes a combination of policy responses. However, policy choices necessarily integrate both objective information about the climate system and our relationship with it, and subjective value judgments such as whether we are more averse to the risks of changes in climate or the policy responses, the ways we assess issues of fairness among nations and peoples, and the consideration we give to cultural heritage or nonhuman species. This creates a complex and often contentious risk management challenge.

Nevertheless, understanding global climate change is critical to this country's and the world's welfare. Fundamental use-inspired research, made possible by cutting-edge tools for collecting and analyzing data, can provide the knowledge that governments, businesses, and communities need as they address the climate-related changes that pose growing risks to life, property, natural resources, and the economy. Research advances understanding of the interacting physical, chemical, biological, and societal components of the earth system; the vulnerability and resilience of its natural and human dimensions; and the means by which scientific

knowledge can effectively inform responses to global change. Such research depends on sustained programmatic investments in multidisciplinary observations, process studies, and modeling. These foundational components of scientific inquiry require their own expertise, infrastructure, and planning horizons, but they ultimately work together to produce a more comprehensive and integrated understanding of global change.

**AIR QUALITY:** Air quality affects broad sectors of society, from human health to crop yields to enjoyment of our national parks. Particulate matter, in addition to ozone, triggers most air quality alerts and health effects. Scientists are improving pollutant tracking and developing detailed air quality predictions. Research is also focused on developing detailed air quality forecasts days in advance. Improved forecasts offer the promise of significant benefits to society.

Additional work is needed regarding the development of modeling tools to characterize air quality and predict exposures at local to urban scales, regional to continental scales, and global to hemispheric scales; and the linkage of air modeling tools with modeling tools for other media (e.g. water) and development of an integrated multi-media modeling system. More than 110,000 people in the U.S. die each year due to outdoor air pollution, and the annual cost to the nation is estimated at nearly \$150 billion due to disease, missed work, and damage to crops and forests. Scientists are improving particulate matter and pollutant tracking, and developing detailed air quality predictions as both play an important role in improving modeling and forecasting.

**SPACE WEATHER:** Space weather can disrupt vital technology – both space based as well as ground based -- that forms the backbone of this country's economic vitality and national security, including satellite and airline operations, communications networks, navigation systems, and the electric power grid. Effective actions to prepare for space weather events require a better understanding of the sun-earth connection. Benchmarks will help government and industry assess the vulnerability of critical infrastructure, establish decision points and thresholds for action, understand risk, and provide points of reference to enable mitigation procedures

and practices and to enhance response and recovery planning.

Opportunity exists to improve the fundamental understanding of space weather and increase the accuracy, reliability, and timeliness of space-weather observations and forecasts (and related products and services). The underpinning science and observations will help drive advances in modeling capability and improve the quality of space-weather products and services. A better capacity to develop and transition the latest scientific and technological advances into space weather operations centers will enable an improved rate of forecast improvement.

To advance space weather capabilities, it is essential that relevant Federal agencies coordinate their actions and their assets to improve, and design appropriately, observation systems. A mix of assets is needed: space-based measurements that provide the coverage necessary for detecting space weather hazards, some of which cannot be discovered from the ground, and ground-based measurements that provide more extensive spatial coverage.

**EDUCATION & TRAINING:** The success of the research challenges above is dependent on a

science, technology, engineering and mathematics (STEM) education system that produces a diverse and well-prepared workforce of scientists, technicians, engineers, mathematicians and educators and a well-informed citizenry that have access to the ideas and tools of science and engineering. STEM education – at all levels, from K-12, to the undergraduate level, and graduate level -- will contribute to the enhancement of the quality of life of all citizens and the health, prosperity, welfare and security of the nation.

The goals for this Nation's STEM education activities should be to: prepare the next generation of STEM professionals – in the geosciences and beyond -- and attract and retain more Americans to STEM careers; develop a robust research community that can conduct rigorous research and evaluation that will support excellence in STEM education and that integrates research and education; increase the technological, scientific and quantitative literacy of all Americans so that they can exercise responsible citizenship and live productive lives in an increasingly technological society; and broaden participation (individuals, geographic regions, types of institutions, STEM disciplines) and close achievement gaps in all STEM fields.

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Understanding how the earth system works and transforming this knowledge into action will allow our nation and the world to effectively respond and adapt to changing environmental conditions. National investment and leadership combined with enhanced partnerships across all levels of government, the private sector, the academic sector, and the nongovernmental organization sector are necessary to make this vision a reality. Enhancing research and education support in the areas outlined above will better enable individuals, communities, businesses, and governments to manage risks, adapt and mitigate in due to changing environmental conditions, and enhance national security and economic and social prosperity.

The UCAR university community stands ready to assist policy makers as requested, including serving on agency and interagency advisory and policy making boards, testifying at hearings, conducting briefings for policy makers, engaging in workshops and other exercises designed to develop knowledge and implement relevant strategic plans, recommending candidates for key positions within the Executive Branch, and responding to requests from the Congress and its committees for scientific and technical information as it relates to policy and legislative issues under review.

## **American Meteorological Society Policy Statement on Weather, Water, and Climate Priorities**

Understanding how the Earth system works and transforming this knowledge into action will allow our nation and the global community to effectively respond and adapt to changing weather, water, and climate conditions. National investment and leadership combined with enhanced partnerships across the public, private, academic, and nongovernmental organization sectors are necessary to make this vision a reality.

**Introduction.** Access to reliable, accurate, timely, and understandable weather, water, and climate (WWC) information is vital for the safety and well-being of society. Decision-makers at all levels need this information to formulate and implement effective strategic, tactical, and policy decisions across all interconnected sectors of society, including health, energy, food, water, infrastructure, transportation, and national security. Extreme weather events like hurricanes, tornadoes, blizzards, floods, wildfires, severe coastal storms, and heat waves, and the impacts of longer-term climate changes such as droughts, changing snowpack, and sea level rise threaten the social and economic security of our nation and society as a whole. While these challenges pose serious risks, they also offer a remarkable national opportunity for enhanced knowledge, advanced tools, leadership, and actionable information.

WWC observations, science, and services are critical national infrastructure essential for meeting human needs. They have led to technological innovations, fueled economic growth, stimulated social prosperity, and mitigated potential WWC-related disasters. AMS public, private, and academic-sector members acknowledge the ongoing vital commitment and support of the American public and its leaders to the advancement of WWC observations, science, and services. This support improves forecasts, makes new information products possible, trains the next generation of scientists and decision-makers, and enables more effective communication. As a result, people have been better prepared for disruptive WWC events, and many lives have been saved.

The value of WWC tools and information to economic growth is increasing as is the cost of WWC-related disasters<sup>1</sup>. Individuals and business and government leaders are shaping decisions and actions based on detailed knowledge of meteorological, hydrological, oceanographic, geophysical, and ecological conditions, and on an understanding of how society responds. As society responds to the increasing frequency and severity of extreme WWC events, it needs and expects ever more reliable and actionable information to deal with pressing local, regional, national, and global economic and societal challenges that can range in time scales from minutes to centuries.

**Recommendations.** Economic and social prosperity belong to a society that understands and effectively responds to Earth's changing WWC conditions. To meet this challenge the following actions are required:

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<sup>1</sup> <http://www.esa.doc.gov/economic-briefings/value-government-weather-and-climate-data>



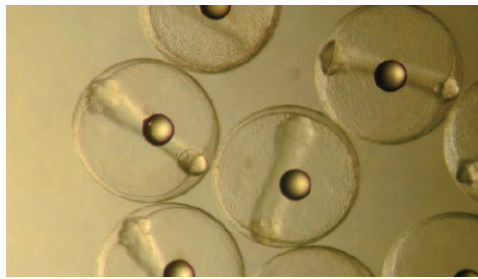
6 May 2016

1. **Develop the Next Generation of WWC Experts.** To ensure we have a diverse workforce equipped to communicate uncertainties and inform WWC decisions, investments must continue to: (i) educate and train students for careers in science, technology, engineering, and mathematics; and (ii) develop the next generation of WWC researchers that can advance the science and its applications to meet society's evolving information needs.
2. **Invest in Research Critical to Innovation and Advanced Services.** To ensure continued leadership in understanding our complex and changing planet and application of this understanding for the benefit of society, increased investments are needed to support new discoveries, innovation, applications, and model development in the geosciences, engineering, and relevant social sciences.
3. **Invest in Critical Observations and Computing Infrastructure.** To ensure advances in scientific knowledge and more accurate and timely delivery of WWC products and support services at scales useful to decision makers, and to preserve national security, targeted investments are required for: (i) atmosphere–ocean–land–ice observational infrastructure, (ii) techniques to translate the resulting large data sets into forms suitable for information services and prediction models, and (iii) leading-edge high-performance computers and software.
4. **Create Services that Harness Scientific Advances for Societal Benefit.** To ensure society's most pressing needs are met and its capabilities are optimally utilized, mechanisms for engaging users and moving research into practical applications in a timely and effective fashion must be encouraged, developed, and implemented.
5. **Prepare Informed WWC Information Users.** To ensure we have informed users who can take full advantage of advanced WWC information and tools, education and communication programs must continue to focus on enhancing WWC skills and understanding by both decision-makers and society at large.
6. **Build Strong Partnerships Among WWC Public, Private, and Academic Sectors.** These sectors have always worked together to meet America's WWC challenges. As the job grows more consequential, urgent, and complex, a coordinated Federal effort is needed to support, strengthen, and encourage strategic inter-sector partnerships, including efforts to increase the global suite of Earth observations, advance long-term stewardship of environmental data, and improve national and international community-level resilience to climate change and variability.
7. **Implement Effective Leadership and Management.** To ensure that WWC investments are made in the best interests of the nation, effective leadership and management approaches will be needed, including: (i) appointing strong, qualified, and diverse leaders to top WWC policy positions in the White House and Federal agencies, and (ii) implementing management structures that support integrated WWC research and services planning and budgeting across Federal agencies and the Congress. These structures should proactively engage the academic

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and private sectors.

**Expected Outcomes and Conclusion.** Implementing these recommendations will better enable individuals, communities, businesses, and governments to manage risks and explore opportunities associated with changing WWC conditions. Economic and social prosperity will be enhanced, and further progress will be made toward saving lives, enhancing commerce, protecting property, and adapting to a changing world. In so doing, our nation will advance its leadership in promoting technological innovations that are critical to the success and well-being of a global society.



# 10-YEAR NOAA SEA GRANT AQUACULTURE VISION

*March 2016*

Prepared by the  
Sea Grant Association



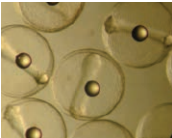
## On the Cover

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*These juvenile Pacific geoducks, *Panacea generosa*, are large saltwater clams.*

*Photo Credit: Washington Sea Grant*



*Fertilized Summer Flounder eggs are a part of ongoing marine aquaculture research at Virginia Tech – Virginia Seafood Agricultural Research and Extension Center.*

*Photo credit: Michael Schwarz, Virginia Seafood Agricultural Research and Extension Center/Virginia Sea Grant*



*Virginia Sea Grant has funded marine ornamental industrial development at the Virginia Tech – Virginia Seafood Agricultural Research and Extension Center.*

*Photo credit: Stephen Urick, Virginia Seafood Agricultural Research and Extension Center/Virginia Sea Grant*



*A worker unloads harvested oysters from a vessel owned by Bloom Oyster Company in Norwalk, Connecticut.*

*Photo credit: Connecticut Sea Grant*



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# 10-YEAR NOAA SEA GRANT AQUACULTURE VISION

March 2016

**NOAA Sea Grant's 10-Year Aquaculture Vision:** Sea Grant's integration of research, outreach and education will be instrumental in creating and applying aquaculture products, tools and services to foster the expansion of a sustainable U.S. marine and Great Lakes aquaculture industry.



## INTRODUCTION

For nearly 50 years, the National Oceanic and Atmospheric Administration's (NOAA) National Sea Grant College Program (NSGCP) has invested in the development of sustainable marine and Great Lakes aquaculture businesses. For example, a \$26-million investment in aquaculture research and technology transfer from 2012-2015 led to an economic impact of \$200 million and included the creation or retention of 8,000 jobs (personal communication, Chris Hayes, National Sea Grant Office).

Sea Grant will likely be investing \$50 to \$100 million in aquaculture research and technology transfer over

the next 10 years. A clear vision will help guide strategic investments to support and expand the aquaculture industry. In March 2015, the Sea Grant Association established a committee to develop a 10-year vision for aquaculture investments by NOAA's NSGCP. The purpose of this 10-year vision is to (1) determine Sea Grant's most appropriate roles over the next 10 years, and (2) identify priority research and outreach strategies leading to sustainable economic development, environmental conservation and social well-being.

The remainder of this document describes Sea Grant's 10-year aquaculture vision.

## BACKGROUND

The U.S. government has invested in developing the country's aquaculture industry for decades. Recently, the White House and Congress placed additional emphasis on aquaculture development. They outlined plans and implemented strategies to accelerate technology development and increase U.S. aquaculture production (NSTC, 2014; NOC, 2013; DOC, 2011; NOAA, 2011; NOAA, 2007).

Over the 50 years of its existence, NOAA's NSGCP has made substantial investments in aquaculture research and outreach. These investments have led to the creation of new industry sectors including abalone, clams, oysters, shrimp, striped bass, sturgeon, yellow perch and assorted marine finfish. Continued Sea Grant investments in research and sustained technology transfer will help existing businesses to become more sustainable and significantly advance current production level species and new types of shellfish, finfish and crustacean aquaculture. Sea Grant's past investments have had positive and significant impacts on small businesses that have taken advantage of Sea Grant information, tools and services. Wise future investments in various areas, such as animal health, business



*Striped bass and their hybrids are popular food fish grown in multiple regions in of the United States. They are found on menus of fine-dining restaurants.*

management, economics, genetics, husbandry, law and policy, nutrition, production systems and reproduction, will allow Sea Grant to support the aquaculture industry.

### Other federal and state programs involved in aquaculture

Numerous federal and state-supported entities and industry associations invest significant resources in freshwater and marine aquaculture. Examples include:

- NOAA's Office of Aquaculture
- Aquaculture Interagency Working Group
- U.S. Department of Agriculture Regional Aquaculture Centers
- National Association of State Aquaculture Coordinators
- U.S. Food and Drug Administration
- U.S. Fish and Wildlife Service
- National, regional and local industry associations

Achieving Sea Grant's aquaculture vision will be impossible without nurturing existing partnerships and building new ones among the industry, academia, and federal and state programs. These partnerships will expand aquaculture production in a way that increases production and profitability, enhances the environment and complements our traditional fisheries. The importance of collaborating to the fullest extent possible cannot be understated and underpins Sea Grant's long-term vision (Figure 1).

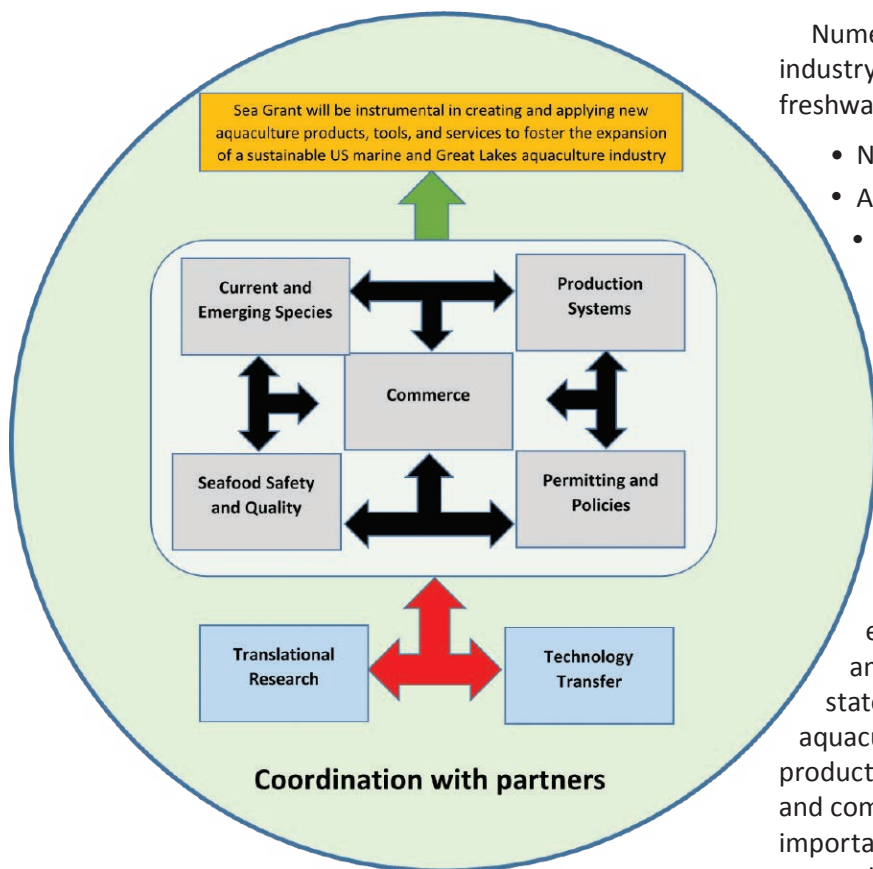


Figure 1. Conceptual model of Sea Grant's aquaculture vision



## PRIORITY FOCUS AREAS

The National Sea Grant Office and state Sea Grant programs contributed to the development of the five Sea Grant Aquaculture Focus Areas in this document.

The focus areas are:

- **COMMERCE**
- **PERMITTING AND POLICIES**
- **CURRENT AND EMERGING SPECIES**
- **PRODUCTION SYSTEMS**
- **SEAFOOD SAFETY AND QUALITY**

Twenty-two of the 33 state Sea Grant programs provided input for this vision document via an online survey during the summer of 2015. Sea Grant programs identified up to three national-level and three state-level marine and Great Lakes aquaculture issues. Follow-up questions guided the most appropriate response to the issue, the resources needed to respond and a description of a successful response.

### Focus Area: **COMMERCE**

#### Priority

Provide economic and marketing research and associated outreach programming to increase the profitability and environmental sustainability of aquaculture businesses.

#### Background

The United States imports a majority of its edible seafood supplies, creating an annual seafood trade deficit exceeding \$12 billion. The development of the U.S. aquaculture industry will require that it is competitive in the global marketplace.

On the domestic front, interstate commerce is challenging because many state and federal agencies are involved. Efficient trade across state lines will require increased coordination and a better understanding of regional and interstate commerce policies and legal issues.

Cost competitiveness and the use of proven business models, especially for indoor recirculating aquaculture systems (RAS), are two of the main bottlenecks to aquaculture development in the United States. While turnkey business models exist for outdoor

systems, such as salmon in net pens, channel catfish in ponds, rainbow trout in raceways and shellfish in coastal environments, there are mixed results for indoor RAS for cobia, tilapia, hybrid striped bass, shrimp and other species. Appropriate business planning would result in job creation, reduced reliance on imported seafood, reinvigorated coastal and Great Lakes working waterfronts and diversified local seafood production. Sea Grant's past investments have had a positive and significant impact on small businesses that took advantage of Sea Grant information, tools and services.

#### What Sea Grant should do

- *Research*
  - Investigate international trade issues (e.g., effects of tariffs); identify major drivers of seafood trade into the United States; and analyze the economic impact of trade on the domestic seafood industry.

*Recirculating aquaculture system tanks are used to rear Russian sturgeon at Atlantic Caviar and Sturgeon located near Lenoir, North Carolina.*

*Photo credit: Jeff Hinshaw,  
North Carolina State University*





**Focus Area:** *PERMITTING AND POLICIES*

**Background**

The aquaculture permitting process varies by state, culture system employed and purpose (research versus production). In addition, one aquaculture venture may need permits and approvals from multiple agencies at various levels of government. This situation forms a complex permitting landscape for agencies, research institutions and businesses to navigate. In addition, some agencies have a goal of ensuring that seafood in the marketplace is safe, wholesome and properly labeled. Other agencies aim to limit the risk of spreading aquatic animal diseases across state lines through commerce. As a result, agency activities regarding oversight of seafood commerce can be confusing due to overlapping and, at times, complex regulations. Aquaculture is already at the interface of industry and government regulations with some strong legal components. Interstate legal issues, in particular for shellfish and selected finfish, may adversely affect aquaculture operations if they prevent the implementation of desirable projects. It is important that there is a clear understanding of policies because of the diverse nature of aquaculture species and culture systems.

- Conduct economic analyses of using public waters for aquaculture, including an assessment of ecological and socio-economic impacts.
- Support comprehensive research and outreach targeting behavioral and consumer sciences; consumer perception and preferences; food safety; labeling and certifications; seafood demand studies; and promotion of local seafood.
- **Outreach**
  - Develop niche markets.
  - Coordinate and liaise among states and synchronize efforts among industry, government, and research and extension communities.
  - Develop optimal business models for diverse species, which would include hatcheries and grow-out for freshwater, low-salinity and marine species and systems.
  - Provide training on business planning and aquaculture business assessments related to capital investments, financing, insurance and risk.

*Commercial oyster farmers work in Willapa Bay, Washington.*



*Photo credit: Washington Sea Grant*



## What Sea Grant should do

- **Research**
  - Identify common policies that will ensure uniform regional governance. Sea Grant should guide implementation of consistent interstate aquaculture rules that industry and government support.
- **Outreach**
  - Provide technical assistance to researchers working with the aquaculture industry to scale up technologies. Sea Grant Legal Programs should facilitate dialogue between government agencies, researchers and the aquaculture industry to increase understanding of current laws and policies, the needs of the aquaculture industry, and options for legal and regulatory reform.
  - Facilitate the development of model state laws and guidance to address typical legal and regulatory barriers to the aquaculture industry.
  - Conduct extensive outreach programs for aquaculture stakeholders to increase awareness of the legal responsibilities of state agencies as managers of public trust lands and waters, the challenges of balancing multiple uses of coastal lands and waters, and the legal authority of local governments to regulate land uses in certain zones.

### Focus Area:

## CURRENT AND EMERGING SPECIES

### Priorities

1. Increase domestic production of currently farmed and promising new species through research and extension efforts that support improvements in nutrition, reproduction, larval rearing and genomics to enhance growth, improve health and adapt to changing conditions, such as ocean acidification and climate change.
2. Improve hatchery production to produce reliable shellfish seed, macroalge seedlings and finfish juveniles to accelerate industry growth.

### Background

Doubling U.S. aquaculture would create 50,000 jobs and increase farm gate value by more than \$1 billion (Knapp 2008). Nash (2004) proposed a reasonable goal of increasing domestic U.S. aquaculture production by 1 million tonnes per year to reach a yearly farm gate value of more than \$2 billion by 2025. The lion's share of this production, 760,000 tonnes, would have to be from



Photo credit: Michael Schwarz, Virginia Seafood Agricultural Research and Extension Center/Virginia Sea Grant

*Sexing anesthetized wild cobia broodstock at Virginia Seafood Agricultural Research and Extension Center prior to transit to commercial land-based fish hatchery in a collaborative effort supported by Virginia Tech's Virginia Seafood Agricultural Research and Extension Center and Virginia Sea Grant.*

finfish aquaculture of which 590,000 tonnes would be marine finfish. Additional production would be 47,000 metric tonnes from aquaculture of red swamp crawfish, *Procambarus clarkii*, and penaeid shrimp. Finally, shellfish production would increase 245,000 tonnes through aquaculture targeting American oysters, *Crassostrea virginica*; hard shell clams, *Mercenaria mercenaria*; Pacific oysters, *C. gigas*; Mediterranean mussels, *Mytilus galloprovincialis*; and blue mussels, *M. edulis*.

### Finfish

There have been significant advances in the husbandry and domestication of several promising new marine



Photo credit: South Carolina Sea Grant Consortium

*Wally Jenkins, left, of the South Carolina Department of Natural Resources, describes the red drum (*Sciaenops ocellatus*) stocking program funded by the South Carolina Sea Grant Consortium.*

finfish species. Sea Grant should continue to support development of this industry sector. Promising species, such as red drum (*Sciaenops ocellatus*), Florida pompano (*Trachinotus carolinus*), Atlantic and Pacific amberjack species, (*Seriola dumerili*, *S. lalandi* and *S. rivoliana*), red porgy (*Pagrus pagrus*), cobia (*Rachycentron canadum*) and sablefish, (*Anoplopoma fimbria*) are all commercially grown with potential for significant increases in production. In addition, other species used for bait and marine ornamentals offer significant potential for business and conservation interests.

### Crustaceans

There is potential to produce marine penaeid shrimp in high-density recirculating production systems close to high-value domestic urban markets. Increases in production of red swamp crawfish in ponds could also expand crustacean farming.

### Molluscan shellfish

There is a common need for genetics research to improve yield, survival, growth, quality and safety of commonly cultured species, such as oysters, hard shell clams and mussels. Work in this area should consider the changing marine and estuarine environments caused by climate change.

While there are a number of potential emerging species, the following molluscan shellfish have shown promise as viable commercial candidates that warrant further research to improve production: Olympia oysters (*Ostrea conchaphila*), geoduck clams (*Panopea generosa*), sunray Venus clams (*Macrocallista nimbosa*), butter clams (*Saxidomus gigantean*), soft shell clams (*Mya arenaria*), purple-hinge rock scallops (*Crassadoma gigantean*), and razor clams (*Siliqua patula*).

For emerging molluscan species, there are critical research needs to optimize production in all stages, from hatchery through nursery and grow-out. In addition, adoption and commercialization of new species will benefit from extension support.

*A sign at Southern Cross Sea Farms in Cedar Key, Florida, advertises aquacultured clams.*

*Photo credit: Florida Sea Grant*



*Photo credit: Connecticut Sea Grant*

*Sea Grant researcher Charles Yarish, center, and colleagues harvest kelp from a pilot underwater farm off Bridgeport in Long Island Sound in May, 2012.*

### Marine algae

The most valuable macroalgae are the kelps and a few species of red algae. The kelps are the largest of the macroalgae, and all have food, feed, extract, bioremediation, habitat and biomass market potential. There are many kelp species on the Atlantic and Pacific coasts. All have the same life cycles, and farming programs can use the same basic cultivation techniques. The other seaweeds with high cultivation potential, especially for food, feed and extract production, include the red dulse species (*Palmaria* spp.), nori or laver species (*Porphyra* spp.) and *Gracilaria* species. Research and development efforts are needed in the nursery phase for seed production (to include development of reliable seed stock, breeding, efficiency and density optimization), farm technology (to include sufficient and affordable moorings, harvest technology and biofouling mitigation), harvesting technology, processing technology and product development. Another area that will need research is food safety and analysis for seaweeds grown in different types of classified waters. All aspects of farming will require development of efficient culture methods to reduce the costs of production.

### What Sea Grant should do

- *Research*
  - Develop sustainable alternative and emerging species including reproductive biology, nutrition and feeding, health, husbandry practices and other species-specific research.
  - Improve the efficiencies of existing marine and Great Lakes species.



- *Outreach*
  - Support the creation of collaborative, multidisciplinary research partnerships involving academia, private industry and NOAA and U.S. Department of Agriculture scientists to bring promising new species into commercial production.
  - Guide the use of sustainable alternative and emerging species.

**Focus Area:** *PRODUCTION SYSTEMS*

**Priority**

Link industry needs to basic and applied research efforts, including establishing demonstration centers to develop and refine aquaculture systems and disseminate applied information to end users.

**Background**

The U.S. marine and Great Lakes aquaculture sector uses several production systems. In most cases, these systems are developed outside the United States or are non-standardized systems developed domestically. In addition, there is limited domestic research on system optimization and fewer demonstration efforts

to transfer the existing research findings to the private sector. For example, the United States has largely developed recirculating aquaculture system technologies. However, producers typically do not have an available source of information to select the most appropriate system or assess the system’s economics. Sea Grant should take the lead to develop production systems research and translate validated research to potential and established producers to enhance the sustainability and profitability of these systems.

Table 1 includes a list of current and emerging production systems used by the U.S. aquaculture sector and brief descriptions of information needed to enhance those systems.

Finally, as the U.S. marine aquaculture industry grows, there will be a need to adapt existing or develop new types of production systems for emerging species, such as seaweeds (marine macrophytes) and marine invertebrates (including ornamentals). There is also a need to develop energy efficient production systems, such as integrated multi-trophic aquaculture systems. The economic feasibility of commercial size operations must be demonstrated to encourage the growth of these sectors.

Species	Type of Production	Information Needs
Finfish	Recirculating aquaculture systems (RAS)	Comparisons among different systems. There is no template in place to guide potential and established producers in the selection of the best system for their particular needs.
	Offshore pen systems	Technology development for offshore aquaculture systems. Demonstration scale projects of offshore production systems using most appropriate species.
Finfish and Crustaceans (shrimp)	Ponds	Better information on the system dynamics of marine ponds. Better management strategies for brackish and saltwater shrimp ponds.
Crustaceans (shrimp)	RAS-based raceway culture systems	Improved production systems and management practices for producers.
Molluscan shellfish	Surface and submerged gear	Optimization of a variety of nursery and grow-out technologies including longlines, raft and floating container systems for large-scale production systems. Development of best management practices and examination of the use of alternative designs and materials.
Seaweeds	Surface and submerged gear	Improved production systems and management practices for producers. Development of new species.
All Species	Reproduction and hatchery systems	Improved hatchery production, larvae feeds and health for all species produced. Sustained technology transfer to commercial operations to ensure consistent supply of and economically viable production of high-health seed stock.

Table 1. List of current and emerging production systems used by the U.S. aquaculture sector and a brief description of information needed to enhance those systems.



## What Sea Grant should do

- *Research*
  - Develop new and optimize existing culture systems and practices.
  - Develop new and optimize existing integrated multi-trophic systems for marine aquaculture development. Ensure that outreach is a significant and well-funded aspect of each project.
  - Improve the efficiency of technology and input use in production.
  - Improve the economics of commercial scale production in the United States
  - Develop cost-saving technologies for production, harvest and processing.
- *Outreach*
  - Establish a network of regional aquaculture demonstration centers where systems and culture practices can be refined, validated and demonstrated to the private sector. These centers should be encouraged to foster commercially based collaborative research and development where the private sector can test production technologies on a small scale to evaluate investment risks for commercial scale production.
  - Ensure that outreach and technology transfer is a significant and well-funded aspect of each project.



Photo credit: Rosa Zirolott, Murder Point Oysters

People learn about oyster aquaculture at a business training area in Alabama.

## Focus Area: **SEAFOOD SAFETY AND QUALITY**

### Priority

Conduct research and provide technical assistance and outreach to aquaculture producers, resource managers, scientists and consumers to ensure the safety and quality of sustainably cultured seafood products to meet public demand.

### Background

There are multiple human health and seafood safety issues facing U.S. aquaculture, and they include:

- Maintaining existing or developing new regulatory requirements to ensure a safe and sustainable seafood supply for export and import.
- Developing rapid, affordable and FDA-approved tests to detect human pathogens and toxins.
- Identifying and reducing impacts from existing and emerging contaminants and biotoxins.
- Enhancing product quality and consumer confidence.
- Managing a sustainable resource.

### What Sea Grant should do

- *Research*
  - Develop or improve environmental monitoring tools, forecasting models and faster biotoxin analyses.
  - Assess rising concerns about bacteria and viruses, such as *Vibrio* species and norovirus, in a changing environment.
  - Develop value-added aquaculture products.
  - Improve the understanding of aquaculture interactions with wild stocks and the natural environment relative to diseases and other factors affecting product quality and sustainability.
- *Outreach*
  - Provide extensive consumer education programs on seafood quality and food security.
  - Continue Hazard Analysis Critical Control Point (HACCP) research, technical transfer and outreach to ensure a safe and wholesome seafood supply.
  - Conduct outreach and technical assistance regarding seafood contaminants.
  - Strengthen consumer confidence and build markets by working with seafood handlers, such as meat

cutters and fishmongers, to improve seafood quality and safety and provide information to consumers.

- Guide development of product diversity.
- Provide technical assistance and outreach to develop value-added aquaculture products.
- Provide technical assistance and outreach to improve the understanding of aquaculture interactions with wild stocks and the natural environment relative to diseases and other factors affecting product quality and sustainability.



*Photo credit: Mark Drawbridge/  
Hubbs-SeaWorld Research Institute*

*California Yellowtail (Seriola dorsalis) is a popular species proposed for farming in federal waters off San Diego, California.*

## AREAS FOR INVESTMENT TO ACHIEVE THE VISION

Investments in an integrated program of research, outreach and partnership building and a balanced focus area portfolio will enable Sea Grant to achieve its vision. Table 2 provides a matrix summarizing recommended investments.

Focus Area	Areas to Invest Resources		
	Research	Outreach	Partnership
<b>Commerce</b>	Detailed economic analysis of cost of production for various species and systems.	Business and marketing workshops.	Nurture partnerships with ongoing marketing programs with industry organizations and other marketing efforts.
<b>Permitting and Policy</b>	Extensive background analysis of state laws and policies.	Law and policy workshops and facilitate dialogue among permitting agencies.	State and federal permitting agencies and the private sector.
<b>Current and Emerging Species</b>	Hatchery and seed stock production technologies and production protocols for emerging species.	Applied demonstration workshops, support outreach personnel to work directly with existing and new aquaculture producers.	Research institutions, agencies and the commercial sector.
<b>Production Systems</b>	Production system and emerging species hatchery and seed stock production technologies and production protocols.	Applied demonstration workshops and support outreach personnel to work directly with existing and new aquaculture producers.	Integrate and leverage existing infrastructure capacity at partner institutions to enhance outreach and demonstration capacity.
<b>Seafood Safety and Quality</b>	Develop new and enhance existing seafood safety tools and new products.	Develop new and enhance existing seafood safety services and technology transfer programs.	Develop new partnerships and leverage existing partnerships with seafood safety agencies (e.g. FDA and USDA).

*Table 2. Areas to invest Sea Grant resources by focus area and broad research, outreach and partnership categories.*

## WHAT WILL HAPPEN BY ACHIEVING THE VISION

Realizing Sea Grant's aquaculture vision will lead to a vibrant U.S. coastal aquaculture industry able to augment traditional harvest and support fishing communities through increased employment and revenues. This, in

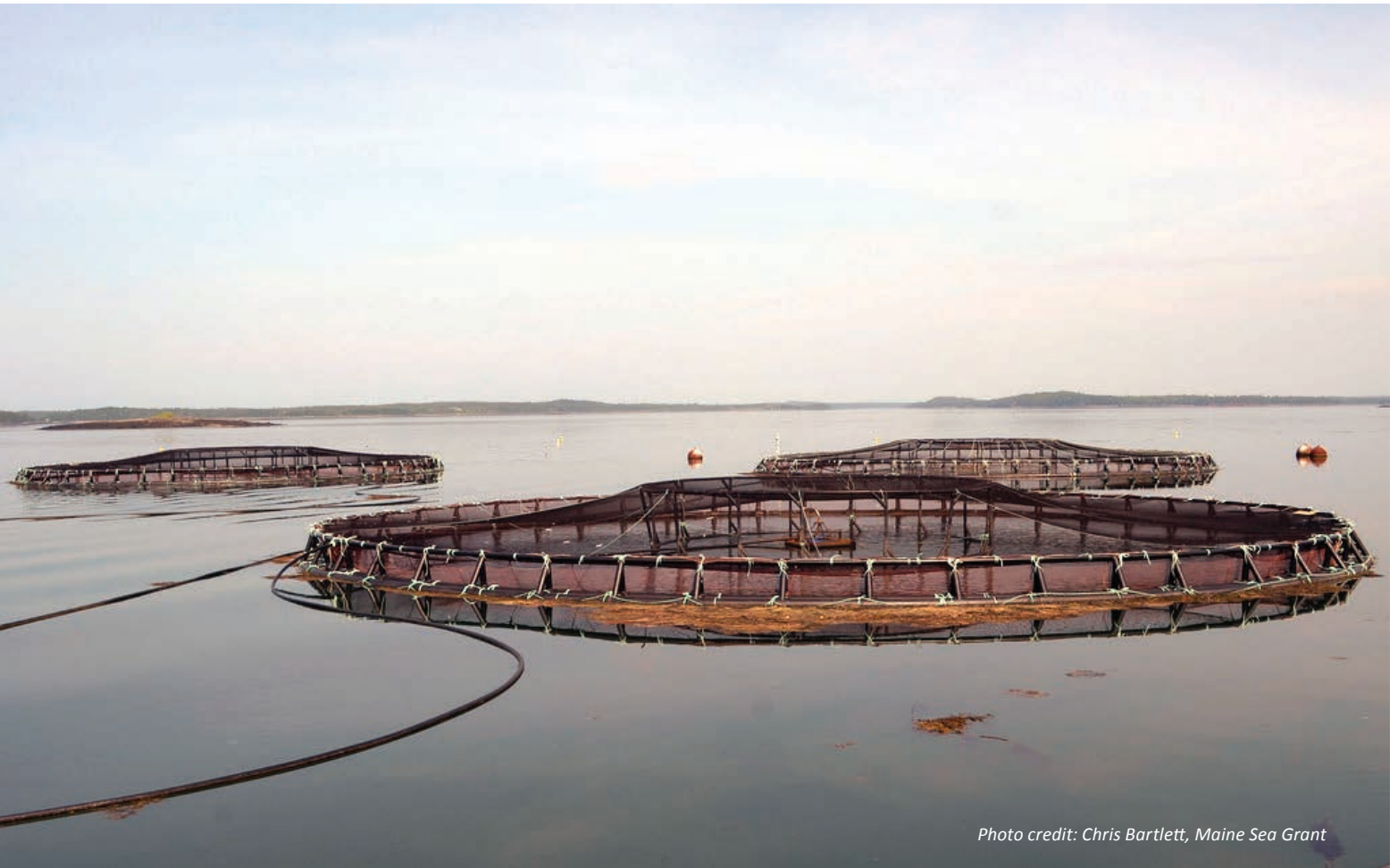
concert with traditional capture fisheries, will increase domestic seafood production and maximize the economic, employment and health benefits of increased supplies of sustainable seafood.

### Successful implementation of this vision document will INCREASE:

- U.S. jobs
- Aquaculture production
- Value and quality of products
- Exports of high-quality seafood
- New markets because of stronger and uniform product standards and better monitoring
- Seafood safety and security
- Seafood consumption and consumer confidence in farmed seafood
- Consistent and fair application of aquaculture laws and policies

### Successful implementation of this vision document will DECREASE:

- Unemployment
- The national seafood trade deficit
- The number of illnesses from consumption of aquaculture products
- Legal barriers to implement new techniques



*Photo credit: Chris Bartlett, Maine Sea Grant*

*These Atlantic salmon aquaculture net pens are located in Lubec, Maine.*



## CONCLUSION

Achieving the aquaculture vision requires Sea Grant to continue to invest resources in high-priority areas identified by all stakeholder groups. The greatest return on Sea Grant investments will occur by following these principles:

- Cause no harm to the environment or the seafood industry.
- Focus on the small business community.
- Invest in priorities that target critical issues and needs as identified throughout the coastal United States, but allow maximum flexibility to address regional,

state and local issues and needs relevant to the aquaculture industry.

- Support projects and activities that are multi-dimensional in scope and focus, address issues and opportunities holistically, apply an integrated mix of research, education, extension and/or communications approaches, and when applicable, directly involve stakeholders and the industry.
- Invest in geographically and topically diverse integrated aquaculture research and outreach efforts.

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*Dr. Han-Ping Wang presents a fish in his genetically improved yellow perch line at The Ohio State University South Centers in Piketon, Ohio. In addition to faster growth, the fish have also shown higher survival rates than local unimproved fish in the current experiments.*

*Credit: Ken Chamberlain/Marketing & Communications Ohio State University*



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