February 20, 2015

Honorable Lamar Smith Chairman Committee on Science, Space, and Technology U.S. House of Representatives Washington, D.C. 20515	Honorable Eddie Bernice Johnson Ranking Minority Member Committee on Science, Space, and Technology U.S. House of Representatives Washington, D.C. 20515
Honorable Barbara Comstock Chair Subcommittee on Research and Technology Committee on Science, Space and Technology U.S. House of Representatives Washington, D.C. 20515	Honorable Dan Lipinski Ranking Minority Member Subcommittee on Research and Technology Committee on Science, Space and Technology U.S. House of Representatives Washington, D.C. 20515

Dear Chairman Smith, Ranking Member Johnson, Chair Comstock, and Ranking Member Lipinski:

In a recent meeting of the Committee, Chairman Smith said, "…If we do our jobs right, we will increase productivity, raise Americans' standard of living, and create more jobs…This Committee's jurisdiction over our Nation's 'scientific research, development, and demonstration' makes possible America's technological innovations, industrial competitiveness, and space explorations…"

As the Committee prepares to mark up legislation to authorize the National Science Foundation (NSF) in this new Congress, the undersigned research institutions would like to provide information via this document that demonstrates investing in the geosciences is inextricably linked to furthering innovation, increasing productivity, raising the standard of living of our citizens, creating more jobs, and ensuring the safety of our citizens. We hope the examples contained in this letter and the attachment will result in a renewed appreciation for the importance of the geosciences and ensure full and balanced funding by the Committee for NSF with strong support for the geosciences.

<u>Geoscience Graduates – Source of Technical Talent for Oil and Gas Industry</u>

The geosciences research NSF supports also educates and trains the next generation of geoscientists. According to the Bureau of Labor Statistics (BLS), there were a total of 296,963 geoscience jobs in 2012, and this number is expected to increase by 14% by 2022 to a total of 339,737 jobs. Approximately 143,000 geoscientists are expected to retire by 2022, but over the next decade, approximately 51,000 students will be graduating with their bachelor's, master's, or doctoral degrees in the geosciences. Therefore, according to the American Geosciences Institute's (AGI) *Status of Recent Geoscience Graduates 2014*, assuming minimal non-retirement attrition from the geoscience workforce, there is expected to be a deficit of approximately 135,000 geoscientists by 2022. Texas leads the nation in the number of geoscience undergraduates and graduate students enrolled within geoscience departments.

The AGI report, *Status of Recent Geoscience Graduates 2014* also documents that the oil and gas industry hires more geoscience graduates than any other industry. The survey showed that 36% of graduates with bachelor's degrees in geosciences in 2014 went on to high-paying positions in the oil and gas industry. Another 21% found employment in the environmental services industry, and 11% found employment in the mining industry. The survey also found that 74% of master's graduates were employed by the oil and gas industry. At the doctoral level, 22% were employed by the oil and gas industry. Other industries hiring geoscientists include: manufacturing or trade, construction, information technology services, and agriculture. NSF's support for the geosciences contributes significantly to the education and training of these individuals via NSF's programs in research, graduate student support, and undergraduate student support.

Improved Hurricane Prediction Saves Lives

While an estimated $60 billion in losses can be attributed to Superstorm Sandy, the ability we had at that time to make such a forecast probably saved thousands of lives. Imagine the quality of the forecast and the impact of such a storm if it had hit just fifteen years ago. Hurricane advisories extended only two or three days into the future. Forecast models did not yet reflect the fact that oceans were the source of heat and energy that fueled such storms – a fact vital for accurate hurricane forecasts that came from basic ocean sciences research. Without such information embedded in the models, forecasters would never have seen Sandy's last minute westward hook into New Jersey. We did not have the sophisticated weather information system that made it possible for the nation's weather enterprise to make the call and subsequent updates on Sandy as early, as often, and as accurately as was done which enabled residents, businesses, and public officials to prepare and take shelter. While still not perfect, these modern forecasts allowed for nearly a week of preparations by cities, businesses, institutions, and families – and undoubtedly made a life or death difference for thousands of people.

How did we acquire such a sophisticated and important weather forecast system? The short answer is that we – led by this Committee, the Congress and ultimately the taxpayers – continuously invested in science, technology, engineering, mathematics, and education. These investments supported everything from basic research in mathematics and physical sciences, computer sciences, and the geosciences to the development of sophisticated models, satellites, radar, and parachute-borne instrument packages that could make the key observations. Those investments also allowed us to develop an understanding of how the earth, the oceans, and the atmosphere collectively impact our weather and the environmental conditions that ensued. They enabled us to develop and run forecast models on advanced computing systems that turned massive amounts of raw data into "actionable intelligence". This was coupled with investments in education and training that created the talented and dedicated workforce needed to put it all together. And it was a host of innovative technologies that allowed all of this information to be presented in a manner that most people—with or without smart phones—could understand.

The Oceans, the Coasts, and the Great Lakes - Drivers of the U.S Economy

Over 8.5 million people reside in the 100-year coastal flood hazard area. More than half of the United States population lives in 673 coastal watershed counties, and these counties generate 58% ($8.3 trillion) of the Nation's gross domestic product (GDP)—even though they comprise only 25% of the Nation's land area. Every day, the marine environment supplies a multitude of products and services that enhance and support the lives and livelihoods of citizens. In 2011, Americans, on average, ate 15 pounds of fish and shellfish per person – 4.7 billion pounds all together – making the U.S. second in the world in total seafood consumption. The United States has jurisdiction over 3.4 million square miles of oceans – an expanse greater than the land area of all 50 states combined. This vast marine area offers many environmental resources and economic opportunities, but also presents threats such as damaging tsunamis and hurricanes, industrial accidents and outbreaks of water borne pathogens. The 2010 Gulf of Mexico *Deepwater Horizon* oil spill, the 2011 Japanese earthquake and tsunami, and the 2012 Superstorm Sandy are vivid reminders that our understanding of our oceans, coastal areas, and the Great Lakes is far from complete. Developing sufficient capabilities to sustain ocean-based economies and protect our coasts and coastal communities from natural and man-made hazards will require a sustained investment in research, infrastructure and education and training.

The Great Lakes region boasts a massive geographic footprint, and is a major driver of the North American economy. With economic output of $4.7 trillion in 2011, the region accounts for 28% of combined Canadian and U.S. economic activity. By comparison, the region's output ranks ahead of Germany, France, Brazil and the U.K., and it would rank as the fourth largest economy in the world if it were a country, behind only the U.S., China and Japan. The Great Lakes are responsible for nearly 1 million manufacturing jobs; 217,000 jobs in tourism and recreation; over 100,000 in shipping; over 110,000 in agriculture, fishing and food production and about 10,000 related to mining. Understanding the complexity of the Great Lakes is vital for the future health and well being of this region of the country.

Research Underlying Fracking Technology Yields Economic Benefits

Investment in the geosciences provided the fundamental understanding of geologic structures and processes necessary to utilize hydraulic fracturing (fracking) processes to release oil from shale formations. The ability of U.S. companies to develop these natural resources is built upon decades of fundamental research and technology development in the earth sciences. According to a 2013 report from U.S. Chamber of Commerce's 21st Century Energy Institute, fracking has created a job boom even in states that don't actually have shale deposits, with 1.7 million jobs already created and a total of 3.5 million projected by 2035.

Conclusion

It is important to appreciate that the NSF's investments in the geosciences have addressed other important national and global challenges, spurred new economic sectors, and led to the development and implementation of advanced technologies that save lives, protect property, and support our economy. As an attachment to this letter, we have included a number of other examples where investments and advancements in the geosciences have yielded outcomes that spur economic development and/or the safety and security of our citizens. We appreciate the difficult decisions Congress must make within the constraints of the budget environment. Additionally, we believe the future of the nation is well served by a strong and sustained investment in the full scope of our research enterprise, which includes a central role for the geosciences.

Thank you for the opportunity to present these views.

Sincerely,

University Corporation for Atmospheric Research
Consortium for Ocean Leadership
Incorporated Research Institutions for Seismology
Lamont Doherty Earth Observatory, Columbia University
Woods Hole Oceanographic Institution
Scripps Institution of Oceanography, University of California San Diego
National Association of Marine Laboratories

Association of Public and Land-grant Universities
SRI International
University of California System
Texas A&M University
Oregon State University
University of Colorado
University of New Hampshire
University of New Mexico
University of Connecticut
University of Wisconsin – Madison
Florida State University
University of Delaware
University of Nebraska-Lincoln
University of Massachusetts Dartmouth
Michigan Technological University
University of Hawaii at Manoa
University of North Carolina at Wilmington
University of Oklahoma
University of Rhode Island
Skidaway Institute of Oceanography, University of Georgia
The University of North Carolina at Chapel Hill, Institute of Marine Sciences
Great Lakes WATER Institute, University of Wisconsin-Milwaukee
Humboldt Marine and Coastal Science Institute, Humboldt State University
Moss Landing Marine Laboratories
Grice Marine Laboratory, College of Charleston
University of South Florida - College of Marine Science
Center for Marine Sciences and Technology – North Carolina State University
Louisiana Universities Marine Consortium
American Anthropological Association
Soil Science Society of America
Bigelow Laboratory for Ocean Sciences, Maine
Friday Harbor Laboratories, College of the Environment, University of Washington
American Geosciences Institute
National Association of Geoscience Teachers
American Meteorological Society
Marine Biological Laboratory
Seismological Society of America
College of the Environment, University of Washington
College of Earth and Mineral Sciences, Penn State University
Department of Geography and Meteorology, Valparaiso University
The College of Arts and Sciences, Valparaiso University
Metropolitan State University of Denver
Saint Louis University
Department of Earth & Planetary Sciences, The Johns Hopkins University
Oregon Institute of Marine Biology
University of Oregon
Annis Water Resources Institute – Grand Valley State University
The Institute of Earth, Ocean, and Atmospheric Sciences at Rutgers University
Whitney Laboratory for Marine Bioscience, University of Florida
Seahorse Key Marine Laboratory, University of Florida

Marine Science Research Institute-Jacksonville University
Galbraith Marine Lab, Eckerd College
Western Washington University, Shannon Point Marine Center
Belle Baruch Institute for Marine and Coastal Sciences, University of South Carolina
University of California, Davis
University of Maine
Michigan State University
Dauphin Island Sea Lab, Dauphin Island, Alabama
Desert Research Institute, Nevada
The University of Kansas
University of Minnesota
The Institute at Brown for Environment and Society, Brown University
The University of Texas at Austin

Attachment: Examples of the Economic Importance of and the Life Saving Outcomes that Result from Investments in the Geosciences

A more robust weather enterprise is responsible for $9 billion a year in direct and indirect economic impacts, employs over 20,000 people, and generates $1 billion a year in tax revenues. The commercial weather industry leverages U.S. investments in weather observation, atmospheric research, and computer modeling to produce tailored products for a wide variety of clients, including the general public. There are now more than 350 U.S. commercial weather companies, according to the American Meteorological Society, and they are estimated to generate nearly $3 billion in annual revenues. The growth rate is estimated to be about 10% per year. A nationwide survey indicates that the U.S. weather enterprise generates an estimated $31.5 billion in benefits compared to costs of $5.1 billion.

Rough estimates are that it costs on the order of $500,000 or more per mile to evacuate a typical stretch of coastline for a hurricane warning. National Hurricane Center data show that the average error of track forecasts 48 hours before the hurricane's center is expected to make landfall (i.e., the point at which a warning is typically issued) have been reduced from about 300 miles in 1970 to about 150 miles in 1995 and less than 100 miles today. This implies hundreds of millions of dollars saved, on average, per hurricane warning. The improvement in forecasting is in part the result of sustained investment in meteorology and related geoscience disciplines.

Hurricane reconnaissance flights have demonstrated the role of improved observations in warning the communities most at risk. Dropsondes (parachute-borne instrument packages) are released during the flights, taking crucial measurements that are fed into forecast models. Dropsonde information has led to an average 10–20% improvement in track forecasts. Those warnings are estimated to save an average of about 200 lives yearly.

In the state of Colorado alone, according to a 2013 study by the Leeds School of Business of the University of Colorado, federally funded geoscience-related research facilities contributed approximately $2 billion in output in 2012. In total, these facilities added nearly 8,000 full time, part time, contract, and student jobs with an additional 7,716 indirect jobs.

Technologies and observing systems developed to examine fundamental Earth structure have also provided data and enabled models necessary for forecasting and predicting earthquakes, tsunamis and volcanoes. Understanding of disaster events enables business and government to engage in informed risk management, mitigation and develop response strategies. When an event does occur, early warnings for evacuation based on timely forecasts of these disasters has the potential to save billions of dollars and countless lives.

Research on hot spring-dwelling microbes in Yellowstone National Park resulted in development of the polymerase chain reaction (PCR), a technology that made the molecular biology revolution possible. Scientists discovered that hot spring microbes utilize enzymes that are resistant to the high temperatures required for PCR. PCR is the process by which scientists are able to generate copies of a single strand or piece of DNA and is indispensible for the multi-billion dollar biotechnology industry.

Examination of jellyfish by marine biologists led to the discovery of green fluorescent proteins (GFP), providing scientists with a critical tool for understanding the inner workings of living cells. GFPs can be attached to cell components such as proteins or cancer cells, or can be attached to infection vectors such as viruses or bacteria, and then tracked they move through the cell or organism. GFP and derivative methods have become critically important tools for the medical research industry that is one of the largest segments of the US economy.

Data from the FAA gathered in the early 2000s associated weather with about 70% of all flight delays in the National Airspace System. For accidents and incidents, weather was a contributing factor 23% of the time. And estimates were that the combined cost to the nation from delays, accidents, and unexpected operating costs was $3 billion per year.

With support from the Federal Aviation Administration, the National Center for Atmospheric Research (NCAR) has been at the forefront of development of new detection, warning, and decision systems to reduce weather hazards to aviation and their considerable costs. Researchers were instrumental in developing a landmark warning system in the 1970s to warn against dangerous microbursts near airports. In the last decade, new systems designed to alert traffic controllers and pilots have been designed to steer aircraft around in-flight icing and turbulence while providing more-efficient routing, and thus time and fuel savings. Today's decision support systems – the result of basic and applied research in the atmospheric sciences -- improve efficiency and cost savings of de–icing operations, runway plowing activities, gate-hold planning, and flight coordination.

Seismologists have developed and deployed instruments for the Global Seismographic Network that serve the needs of multiple U.S. agencies, including the NSF for earth structure research, the USGS for prompt assessment of global earthquakes, NOAA for tsunami warning, and the DOD for supplementary data regarding underground nuclear tests.

Geoscientists have developed and manage a pool of portable instruments that have been used in deployments to measure aftershocks for additional data used in earthquake risk reduction, to monitoring earthquakes that may be induced by injection of waste fluids into the earth, and to improve calibration of permanent seismic stations around the world operated by the U.S. government.

Earth scientists have built and operate a system for long-term management and distribution of seismographic and other geophysical data from numerous seismographic networks, ensuring the quality, reliability, and utility of data collected by hundreds of independent organizations, and facilitating use of the data by U.S. and state government agencies for their diverse missions.

Natural hazards remain a major cause of fatalities and economic losses worldwide. Several areas in the United States are vulnerable to damages from earthquakes, tsunamis, volcanoes, and landslides – as evidenced by the recent landslide in Washington. NSF research that improves our understanding of these geologic hazards will allow for better planning and mitigation in these areas that will reduce future losses.

Mineral resources are essential to modern civilization, and a thorough understanding of their distribution, consequences of their use, and the potential effects of mineral supply disruption is important for sound public policy. The NSF's Division of Earth Sciences supports proposals for research geared toward improving the understanding of the structure, composition, and evolution of the Earth and the processes that govern the formation and behavior of the Earth's materials. This research contributes to a better understanding of the natural distribution of mineral and energy resources for future exploration.

The devastating droughts in California highlight our dependence on water. Geoscience research addresses major gaps in our understanding of water availability, quality, and dynamics, and the impact of both a changing and variable climate, and human activity, on the water system. Increased public investment is needed to improve the scientific understanding of water resources, including improved representation of geological, biological, and ecological systems, for informed decision making.

Forecasting the outcomes of human interactions with Earth's natural systems, including climate change, is limited by an incomplete understanding of geologic and environmental processes. Improved understanding of these processes in Earth's deep-time history can increase confidence in the ability to predict future states and enhance the prospects for mitigating or reversing adverse impacts to the planet and its inhabitants.

Research in earth science and geoscience education is fundamental to training the next generation of earth science professionals. The United States faces a looming shortage of qualified workers in these areas that are critical for national security. A 2013 report by the National Research Council, *Emerging Workforce Trends in the Energy and Mining Industries: A Call to Action*, found, "Energy and mineral resources are essential for the nation's fundamental functions, its economy, and its security… In mining (nonfuel and coal) a personnel crisis for professionals and workers is pending and it already exists for faculty."

Only near the end of twentieth century did scientific evidence make it apparent that cataclysmic impact by solar system debris has likely been responsible for multiple species mass extinctions. It is a breathtaking achievement of scientists studying the near-Earth space environment that mankind can now identify impact threats, and possibly prevent, this natural threat to all of humanity. The geoscience community has driven the commercialization of space through navigation, communication, and surveillance systems in orbit, and the economic promise of advancing those activities is at our fingertips in the twenty-first century.

Modern society depends heavily on a variety of technologies that are vulnerable to the effects of intense geomagnetic storms and solar energetic particle events. Strong auroral currents, which wreaked havoc with the telegraph networks during the Carrington event of 1859, can disrupt and damage electric power grids and may contribute to the corrosion of oil and gas pipelines. Magnetic storm-driven ionospheric density disturbances interfere with high-frequency (HF), very-high-frequency (VHF), and ultra-high-frequency (UHF) radio communications and navigation signals from GPS satellites. Exposure of spacecraft to energetic particles during SEP events and radiation belt enhancements can cause temporary operational anomalies, damage critical electronics, degrade solar arrays, and blind optical systems such as imagers and star trackers. Moreover, intense solar energetic particle (SEP) events present a significant radiation hazard for astronauts on the International Space Station during the high-latitude segment of its orbit as well as for future human explorers of the Moon and Mars who will be unprotected by Earth's magnetic field.

In addition to such direct effects as spacecraft anomalies or power grid outages, a complete picture of the impact of severe space weather events on contemporary society, with its complex weave of dependencies and interdependencies, must include the collateral effects of space-weather-driven technology failures. For example, polar cap absorption events can degrade—and, during severe events, completely black out—HF communications along transpolar aviation routes, requiring aircraft flying these routes to be diverted to lower latitudes, at a not inconsiderable cost to the airlines and inconvenience to the passengers.

Soil science research is critical to our understanding of the underlying functioning of food, fiber, and biofuel production, as well as biological diversity. Rich soil biological diversity has allowed economic development of waste treatment, purification of water, sequestration of soil organic matter and has led to major breakthroughs in treating human disease. Soils teem with microorganisms that have given us many life-saving medications, including the antibiotic streptomycin, and cyclosporine—a drug widely used to prevent transplant patients from rejecting their new organs.