STATEMENT FOR THE RECORD
DR. LEONARD J. PIETRAFESA
ASSOCIATE DEAN, PROFESSOR OF OCEAN & ATMOSPHERE SCIENCES
NORTH CAROLINA STATE UNIVERSITY, RALEIGH
CHAIR, NATIONAL OCEANIC & ATMOSPHERIC ADMINISTRATION SCIENCE ADVISORY BOARD (FACA)
BEFORE THE
COMMITTEE ON COMMERCE, SCIENCE AND TRANSPORTATION
SUBCOMMITTEE ON TECHNOLOGY, INNOVATION, AND COMPETETIVENESS
UNITED STATES SENATE
562 DIRKSON SENATE OFFICE BUILDING
WASHINGTON, D.C.
29 MARCH 2006

A hearing on: the Importance of Basic Research to United States Competitiveness
The hearing is intended to explore how basic research in the physical sciences impacts both long-term economic development in the United States and the ability of American industry to remain globally competitive.

Mr. Chairman and Members of the Subcommittee, I am pleased to submit this statement in strong support of the role of basic research to United States competitiveness.

My name is Len Pietrafesa, and I am an Associate Dean and a Professor of Ocean and Atmospheric Sciences in the College of Physical and Mathematical Sciences at North Carolina State University. I also serve as Chair of the National Oceanic and Atmospheric Administration's (NOAA) Science Advisory Board.

The NOAA Science Advisory Board (SAB) was established by a decision Memorandum dated 25 September 1997 and is the only Federal Advisory Committee with responsibility to advise the Under Secretary of Commerce for Oceans and Atmosphere on long and short range strategies for research, education, and application of science to resource management and environmental assessment and prediction. SAB activities and advice provide necessary input to ensure that National Oceanic and Atmospheric Administration science programs are of the highest quality and provide optimal support to resource management. The SAB consists of 15 members with backgrounds and expertise ranging across the spectrum of NOAA's mission responsibilities.

I would like to thank the Chair of the Committee, Senator Stevens for inviting me to testify. This is truly an honor to be offering testimony, along with Dr. J. Marberger, Dr. A. Bement and Dr. W. Jeffreys.

More than seven decades ago, Dr. James B. Conant, former President of Harvard University and a chemist by profession, said "to advance scientific knowledge, pick a man (or woman) of genius, give him (or her) money and leave him (or her) alone" (parentheses added). While the paradigm has changed since then, Dr. Conant had a colleague, Mr. Alfred L. Loomis, a retired wealthy industrialist and a science geek, who in the 1930s, through his vast fortune, became the patron and benefactor for basic scientific pursuits to the world's foremost scientists and mathematicians of the 1930s (eg, Bohr, Compton, Einstein, Fermi, Heisenberg). These studies were conducted in the then state of the science and technology laboratory that Mr. Loomis constructed in his massive Tuxedo Park, New York mansion. This was a time when the government did not fund basic research. One of the subsequent scientific breakthroughs that he and colleagues Dr. E. Lawrence, a Berkeley physicist, Dr. R. Varian of Stanford, and others from the RadLab of the Massachusetts Institute of Technology led to the development of microwave radar. Realizing what he had in his laboratory, Mr. Loomis contacted President F.D. Roosevelt, who contacted Prime Minister W. Churchill. At that time, the Axis did not have micro-wave radar but in short order the Allies surely did. An enormous mismatch in capabilities was affected. This is an example of a basic scientific breakthrough that led to a technological advance that to great measure is responsible for the position in the world order that the U.S. has enjoyed since WWII.

This story both inspires and saddens my father, a WWII veteran seriously injured in Europe, who is enormously proud of what the United States accomplished by "saving the world" but who now in his 90^{th} year, fears for the economic future of the U.S. because of what he perceives as "misguided government spending priorities". "Why aren't we leading the world in new discoveries, like we used to", he asks.

Speaking of radars, in 1918 a flu epidemic broke out and killed 100 million people globally in 24 weeks; more than had died in over a century of the Black Plague. Now we may be facing another global pandemic, the Avian Flu. But in the U.S. we have a national network of radars that was funded by a prior Congress and is managed by the Department of Commerce's National Oceanic & Atmospheric Administration's Weather Service. Buried within the weather radar signal archives are the signals of flocks of birds. So, could mathematicians, statisticians and radar meteorologists apply methodologies to mine the radar data and figure out what the likely pathways that migratory birds might be to spread the flu virus across North America? Sure, why not. Basic research in mathematical and statistical methodologies and radar science could conceivably provide an advanced warning system. What will the value of this prior knowledge be worth to the health and the economy of the Nation? The point is that the investments made by this congressional body in the Modernization of the NOAA Weather Service over the past two decades could under-gird and enable new research that will couple the physical, mathematical, health and social sciences and result in saving American lives.

Given the new lives that most of us and all of our children and grandchildren will lead, via the Internet, it should be remembered that the Internet was derived from Arpanet (which was funded out of DARPA for the purpose of defense contractors communicating and exchanging technical reports) and other standalone networks such as Omnet which was created by oceanographers (with funding from the Office of Naval Research and the National Science Foundation, so that these scientists could communicate with each other); a basic, fundamental advance in communications that has created new jobs, new industries, new products and services and led to the virtual flattening of the World; all in the relative blink of an eye. Have you used www.gotomeeting.com? Try it, you'll love it.

The U.S is the hub of global networks and communications. Space weather research and forecasting is a scientific and technological jewel at the NOAA Space Environment Center in Boulder, CO. Space weather describes (http://www.sec.noaa.gov/) the conditions in space that affect Earth and its technological systems. Space weather is a consequence of the behavior of the Sun and the nature of the Earth's magnetic field and atmosphere. Solar disturbances categorized in space weather terms are: Radio Blackouts, Solar Radiation Storms and Geomagnetic Storms. These storms interfere with the normal operation of communications used by airlines and emergency response teams, military detection and early-warning systems, Global Positioning Systems (GPS) which control the spatial referencing network, satellite components and spacecraft operations. Solar storms also have the potential to impact power transformers, cause large-scale blackouts in North America. and also create a biological threat to both astronauts and people flying in aircraft. Basic research in the physical, mathematical and statistical sciences is very important in space weather and without the advances made and hopefully to be made, U.S. competitiveness would be severely compromised. The mathematics of the plasma physics of "space weather" is daunting and one cannot design the experiments, they come pre-designed so there are no options. They are dealt with on the fly.

As an example of mathematical enabling in experimental design, the SAS Institute in Cary, North Carolina, the world leader in data analysis software, with billions in annual revenues, had its origins with a group of North Carolina State University researchers, Drs. Goodman and Saul, focused on the statistics of experimental design. The researchers made some breakthroughs in statistical methodologies and formed a company. These advances have resulted in a strongly competitive, well run U.S. corporation (featured on CBS's "60 Minutes").The software itself is used to deliver decision support such as data mining to help other companies make more informed choices.

In the arena of experimental design for quality improvement, carefully constructed settings for factors that affect production allow the maximum information extraction for a given amount of experimental effort. For example, a grinding experiment to efficiently create an optical lens (like an eyeglass), with 12 factors (like wheel speed, grit size, etc.) each of which can be at a high or low level, would require 2048 runs to see the effect (on say, surface roughness) for every combination of the 12 factors. But through the magic of statistical optimization, a carefully designed experiment would require only 192 runs for all factors. This is an incredible shrinking in an economy of scale resulting in huge savings to the optical industry.

Another area of basic statistical research is in "anomaly detection", whereby statistical methods have been utilized to discover hot spots of activity, such as disease outbreaks, a topic of current basic research. Also methods for automatic flagging of unusual or outlier values and methods of detecting change points in data taken over time have potential not only for controlling manufacturing processes but might be used in a homeland security context and in environmental data assessment. This approach would be valuable for flagging outliers, unusually extreme or potentially bad data, as these data are streaming in; such as data transmitted in real time from the NOAA Weather Service national monitoring network or the upcoming Department of Defense (DoD) and NOAA NPOESS Satellite constellation. Terabytes (or petabytes?) of data must be evaluated on the fly and the results of basic statistical research could provide new methodologies to evaluate the trillions (or 10s thereof) of points of data on the fly; thus ensuring that the multi-$B dollar investment of this Congress in our needed satellite systems (eg. NOAA GOES and the DoD/NOAA NPOESS) yields maxima benefits in data utilization.

To paraphrase a popular ad campaign, you could say that statisticians don't make the decisions; they make the decision process better. Basic research in statistics provides tools just as a violin maker provides an instrument rather than making the music. One cannot play beautiful music without a well crafted instrument made for that purpose.

How about Nano-Science? Here are some recent headlines and universities involved:

- Nanotechnology Find and Treat Breast Tumors, Dec. 12, 2005, *Nanotechwire* — Rice University physical scientists offer enticing insights into how these minute particles can be manipulated to have different properties, and tagged with antibodies to target them specifically at cancer cells.
- Nano for Brain Cancer Imaging, Treatment Nov. 14, 2005, *Small Times/Richmond Times - Dispatch* — University of Virginia researchers are loading tiny, hollow carbon balls with metals and medicine to detect and destroy brain-cancer cells.
- Nanoparticles Create Anti-fog Coating Sep. 7, 2005, *Nanotechweb* **—** Massachusetts Institute of Technology (MIT) researchers have devised a silica nanoparticle coating that causes water droplets to flatten into a thin uniform sheet rather than form the usual annoying light-scattering beads eliminating fog on windows, spectacles and other glass surfaces.
- Carbon Nanotube Sheets Aug. 18, 2005, *PhysOrg* — University of Texas at Dallas scientists have produced transparent carbon nanotube sheets that are stronger than the same-weight steel sheets and have demonstrated applicability for organic light-emitting displays, low-noise electronic sensors, artificial muscles, conducting appliqués and broad-band polarized light sources, switched in one ten-thousandths of a second.
- Nanotubes For Healing Broken Bones Jul. 8, 2005, *Science Daily* — University of California Riverside physical scientists have shown that carbon nanotubes make an ideal scaffold for the growth of bone tissue allowing doctors to inject a solution of nanotubes into a fracture for healing.
- Nanotechnology and Hydrogen, Mar. 29, 2005, *Eurekalert*- Rutgers scientists are using nanotechnology in chemical reactions that could provide fuel for tomorrow’s fuel-cell powered clean energy vehicles.

Thank you NSF, and the DoD research arms for sponsoring pioneering basic research in “nano” science and technology. This basic research will enable all other areas of “S&T”. Still, much more of an investment is needed. And the paybacks to society will be great.

Instruments and sensors deployed in or above the ocean environment are often at risk due to high winds, waves, currents, sea spray, bio-chemical fouling and the marine transportation community not to mention the occasional presence of humans. To that end, nano-technology may have much to offer in the development of more reliable and durable sensors and instruments. As a corollary, the same technology might advance the state of observing science in the atmosphere. Measurements made from moving vehicles, such as Autonomous Undersea Vehicles, Unmanned Aerial Vehicles and Remotely Operated Vehicles would all be greatly enhanced with more durable sensors and greatly reduced payloads. Data gathering by flying in and out of hurricanes and through the waters below the hurricanes via unmanned vehicles is a very attractive operational possibility. Likewise for noxious atmospheric plume events. The U.S. Department of Energy (DOE) supported a robust atmosphere and ocean instrument development program that was especially visionary and produced many of the off the shelf ocean instruments that are available today. The DOE Brookhaven National Lab, the Woods Hole Oceanographic Institution, the University of Washington, Texas A&M University and many other institutions, advanced the state of technology and science with funding from DOE in the 1970s,80s and mid-90s. That DOE program no longer exists. But basic research is still needed in all of the above areas. Perhaps NOAA could be the facilitating agency.

Speaking about the environment, can basic physical and mathematical sciences research be conducted on environmental topics that are of value in the competitive position of the U.S.? The answer is a resounding “yes”. Examples and some challenges are given below.

The long time series of basic state environmental variables constitute our climate record; generally difficult to decompose and understand. Albeit, a National Aeronautics & Space Administration (NASA) scientist/mathematician developed a new mathematical empirical methodology in his studies of the fluid mechanics of water waves and in the process of doing this basic research, has opened up an entire new field of data analysis, for which he was elected to the National Academy. This advance has enabled new breakthroughs in voice recognition, aircraft wing deterioration, etc. Colleagues and I have used this empirical methodology to determine that the modern rate of sea level rise is the second fastest over the past 18,000 years, and that the frequency of occurrence of hurricanes in the North Atlantic has 3-5, 10-12, 25-30 and 45-55 year modes of variability. So there are enormous implications for climate studies to be derived from the mathematical breakthrough of this NASA scientist. Incidentally, the NASA scientist was recently informed by NASA that he needed to acquire more non-NASA sponsored research dollars, at a time in the U.S. when basic research dollars are more difficult to obtain. So he has chosen to retire from the agency and to accept an offer to join a university in Taiwan where the success rate for proposals is closer to 80% vs. the U.S. NSF rate which is presently 10-20% and in which a reported $2B of proposals rated “excellent” went un-funded last year. The U.S. has lost a National Academy member to a foreign country because he can no longer afford to pursue the funding for basic research in the U.S.

The development of "empirical orthogonal functional" (EOF) analysis in the 1950s by an MIT physicist was an important mathematical advance. This analysis has recently been used in the development of a hurricane land-fall forecast capability. In the NOAA (National Environmental Space & Data Information Service and National Ocean Service) sponsored cooperative Climate and Weather Impacts on Society & the Environment (CWISE), scientists at North Carolina State University combined EOF analyses of past hurricanes and tracks with statistical regression, and are able to predict several months in advance, the number of hurricanes most likely to strike the Gulf/Caribbean and U.S. East coasts. The 2006 forecast for the east coast is due on 01 April and the Gulf on 01 June.

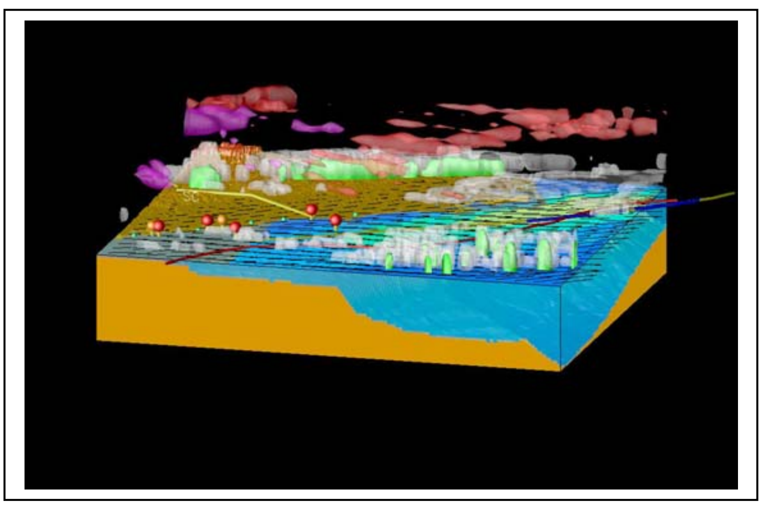
A scientist from Columbia University was studying plate tectonics off of the coast of Asia using an acoustic sound array in December 2004. He discovered that the acoustic signals generated by the 26 December undersea earthquake that resulted in the tsunami that killed several hundred thousand people in Sri Lanka, India and Phukut without warning are evident in his data archive. The key here is that the speed of sound in water is 1500 meters/second while the speed of the tsunami wave itself is more like 200 meters/second. So the warning of an approaching tsunami can be delivered in $1/7^{th}$ the time using acoustic devices. This is a serendipitous finding in an all-together unrelated basic research project funded by NSF.

In the early 1980s an air-sea monitoring network was deployed along the equator in the Pacific Ocean. Development of the Tropical Atmosphere Ocean (TAO) array was motivated by the 1982-1983 El Nino event, the strongest of the century up to that time, and not detected until nearly at its peak. The event highlighted the need for data from the tropical Pacific for an improved understanding of the El Nino Southern Oscillation (ENSO). So a modest array was deployed to assess how these enigmatic events occurred. What we learned was that ENSO was well structured and affected climate and weather patterns globally; thus agriculture, fisheries, the global supply of protein, landslides in California and so on. Again, basic research in mathematics and computational science and in the technological development of related monitoring and computational instrumentation has resulted in huge leveraging for U.S. industries in the global marketplace. Today there are 70 moorings in the TAO array and NOAA makes seasonal forecasts of atmospheric state variables for the U.S. based on the disposition of ENSO.

The area of basic research in the understanding of how the atmosphere and oceans exchange heat, buoyancy, energy and momentum is extremely important for environmental prediction; such as understanding the causes of and forecasts of our weather and climate. We are learning a great deal in university laboratories, on NSF, ONR and NOAA field expeditions and by using high performance computing for better data collection and analysis. What are the potential benefits of this research? Well, what is the value of better forecasts of atmospheric storms with heavy precipitation, snow, ice and rain, annually? The ski and snowboarding industry cannot prosper without snow and they need to plan well in advance to anticipate what the upcoming season holds in store. Water managers need this information seasons in advance because they need to plan for upcoming allocations; overages and shortfalls. Emergency managers, the highway patrol and power companies need to know where precipitation will fall, how much, in what form and when and whether or not flooding will occur. The average annual costs of snow storms alone to the U.S. are: removal ~ \$3B; road closures ~ \$20B; flight delays ~ \$4B; public utilities ~ \$2B; and flooding from snowmelt ~ \$6B; a total of \$35B annually. And agricultural crop and timber damage can be up to \$2B/ice storm. The cost of flooding to the U.S. in 2005 will likely total more than \$300B. Okay, so 2005 was an unusual year with Katrina, Rita and 25 additional tropical cyclone events. Or was it? More climate research will reveal the rest of the story. Unfortunately there are presently too few observing systems that monitor air-sea interactions and thus the basic research that can be conducted on two fluid interactions is seriously limited.

How good are we at forecasting precipitation, rain, snow and ice? Well the NOAA NWS National Centers for Environmental Prediction (NCEP) does a good job, considering the data available to initialize and be ingested and assimilated into NOAA NCEP models. But it could be better. It could be vastly improved with better information available in real time. There are but ~ 140 marine buoys that collect air and near surface water temperatures and provide those data in real time, around the Nation's coastal waters including the Atlantic, Pacific and Gulf coasts, the Great Lakes, Alaska and Hawaii. Is that coverage adequate? The short answer from those of us who do ocean-atmospheric coupled fluid research is "no". The coverage is an order of magnitude too low.

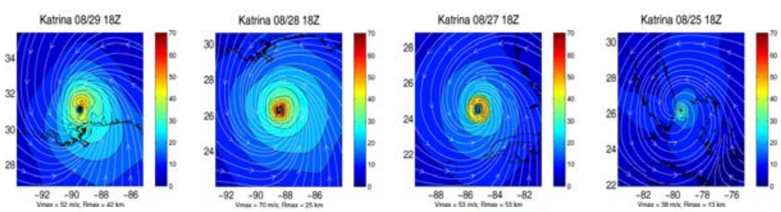
Here is an image of a two-way interactively coupled atmospheric and ocean numerical model system output that shows a winter storm, a "nor'easter" forming off the Carolinas coast in 1996. The white represents clouds, green is rain, pink is ice and purple is snow.

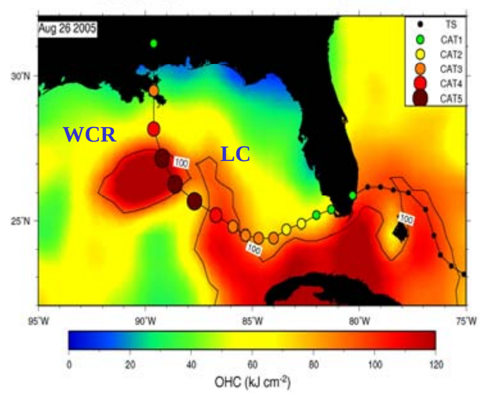


The total of each can be estimated by integrating across the volumes of each form of precipitation. How valuable is it to DC, MD, PA, NJ, NY, CT, MA, MN, etc..to know these numbers ahead of time?

In this entire storm area stretching from S.C. to the VA border, there are only three permanent coastal NOAA National Data Buoy Center buoys providing air-sea information. The red dots are new observing sites in a NOAA National Ocean Service sponsored program called the Carolinas Coastal Ocean Observing and Prediction Program, led by the University of South Carolina, presently extending from southern S.C to southern N.C. However, the average centroids of these storms tends to be closer to Cape Hatteras, N.C. well to the north, near the yellow-green patch shown in the storm, so more sites are needed to the north. The reason that this 1996 storm model output is so robust is that there were 29 ocean-atmosphere university research (DOE and NSF sponsored) moorings in the region at the time of the storm and the assimilation of these data into the model greatly improved our ability to more properly hind-cast the storm. The conclusion: a greatly expanded observing network is needed to make better weather predictions, over the ocean, along the coasts and over land. Why: to better understand very complex, air/sea interactive couplings. This is basic research to a scientist like me. The value: greatly improved forecasts of the type and quantity of precipitation in a storm, improvements in storm track forecasting, improvements in forecasts of ocean current and wave fields, improved forecasts of where and how much coastal erosion, coastal mass wasting, inlet migration and new inlet formation will occur, and so on. By the way, the program alluded to in the winter storm figure shown above was the last of the DOE sponsored field expeditions and modeling programs linking the atmosphere to the ocean, coastal ocean and estuaries and rivers of the U.S. It ended in 1997. It was responsible for enormous advances in new instrumentation, new science and new scientists and was worth every dollar of investment by Congress.

Is the story any better for the modeling of hurricanes in transit; especially the potential interaction of the hurricane with the ocean beneath it? Do exchanges between the air in hurricanes and water masses below serve to further intensify or to de-intensify the intensity of the wind-field of the hurricane? The figure below (from University of Miami and NOAA Hurricane Center scientists) suggests this may well be the case. Katrina was more intense over warmer waters and less intense over cooler waters. In the Spring 2005 Undersecretary of Commerce for Oceans and Atmosphere, VAMD C.C. Lautenbacher, requested that the NOAA SAB commission a study of wind intensity forecasting for hurricanes. The external evaluation is in progress.





Katrina's Path and Strength Relative to Pre-Storm OHC and 10 m surface winds from the NOAA HRD's HWIND.

The NOAA SAB has strongly endorsed the Integrated Ocean Observing System (IOOS) put forward by the U.S. Commission on Ocean Policy. These observations offer critical information not only for atmosphere and ocean and Great Lakes interactions but also on coastal processes necessary for addressing issues, such as the health of humans and marine life, broadly defined weather and climate now-casts and forecasts, homeland security, and resource management. Coastal and marine laboratories have been at the forefront in addressing this need. However, funding for existing subsystems is difficult to sustain, and significant additional funding is required to implement the national integrated system. Although efforts have been made in the past to coordinate Federal agencies involved in ocean and coastal research and national and international programs regarding coastal, ocean, and Great Lakes observing systems, further investment and strengthened cooperation at all levels is still needed to ensure that these systems are sustained and that they incorporate the long-term monitoring efforts of the nation's coastal and marine laboratories. The SAB, and both marine and atmospheric science organizations, enthusiastically support the development of a sustained IOOS to be managed by NOAA. Attached to my testimony is a copy of a “community generated” resolution endorsing IOOS. However, the university community has an important role to play in that it can conduct basic research on data recovery, data quality assessment, data assimilation into models, data mining and coupled model architecture.

The examples above lead the SAB to strongly support enhanced funding for ocean, atmospheric, coastal, and Great Lakes basic research in the physical and mathematical and other natural sciences, the social sciences, education, outreach, and related infrastructure. Part of the basic research challenge is the connecting of the physical sciences through the life sciences and to the social and economic sciences. This per se is a very challenging research topic that must be resolved if science is to properly serve the various sectors of U.S. society and ensure that the U.S. will be globally competitive.

Improving our knowledge of the ocean, atmospheric and hydrologic sciences has much to offer the Nation as it seeks to strengthen its ability to innovate and compete in today’s global economy. These sciences are inherently interdisciplinary, push the envelope in terms of technology development, test the boundaries of our data collection and analysis systems, and offer an effective training ground for future scientists, mathematicians, statisticians and engineers; particularly in a setting of working as a team. As the Nation seeks to augment its investment in the physical and mathematical sciences to increase its international competitiveness, the SAB calls on policy makers to recognize the integrated nature of the environmental sciences, particularly the ocean and atmospheric sciences and to support an enhanced investment in these as well as other science and engineering disciplines as part of any long term economic competitiveness policy.

Human and environmental health are critical factors in the quality of life of the citizenry of the society of the U.S. NOAA has and is conducting and supporting important research in such areas as atmospheric chemistry tracking and forecasting, coastal nutrification monitoring and modeling, remote detection and monitoring of emissions or other airborne contaminants, marine debris detection and source tracking, and development of technologies to detect and predict the pathways of oil spills and harmful algal bloom outbreaks.

The SAB supports increased federal funding for the National Science Foundation (NSF) consistent with the President’s budget for FY 2007. Basic research and the transfer and use of the knowledge developed through research are vital for the long term economic competitiveness and national security of this Nation. It is increasingly important for the Nation to maintain and enhance its scientific edge in a global community with emerging new capacities for scientific research. NSF provides vital support for basic research and education which enhances public understanding of the atmosphere, oceans, coastal areas, and the Great Lakes. NSF also provides important support for basic laboratory facilities, instrumentation, support systems, computing and related cyber-infrastructure, and ship and aircraft access. The final report of the U.S. Commission on Ocean Policy makes recommendations on the need to develop and enhance ocean, coastal and Great Lakes research infrastructure; including research vessels, ocean observing systems, and the shore-based instrumentation and equipment needed to collect and analyze the data and observations made by research vessels and the observing systems. Additionally, kids are science geeks and the physical and environmental sciences are great vehicles to ride to ensure a scientifically, technologically and environmentally literate future U.S. society.

NOAA is the lead operational environmental mission agency for the U.S. NOAA maintains the Nation's environmental weather and climate observing networks, oversees environmental management and is responsible for operational environmental forecasting. It provides decision makers with important data, products and services that promote and enhance the nation's economy, security, environment, and quality of life. It was NOAA, and its underlying science enterprise, that enabled the delivery of accurate and timely information regarding the impending landfall of Hurricane Katrina in 2005, a forecast that saved tens of thousands of lives. While that forecast could be cast as the result of "applied research", in point of fact, the ability to model the hydrodynamics and thermodynamics of an anti-symmetric vortex, moving through and interacting with larger scale and smaller scale atmospheric systems and interacting in real time, over compatible spatial and temporal scales, with a moving interactive body of water that has its own boundary current and eddies, was and remains a basic research challenge.

Moreover, the ability to quality assess, ingest and assimilate satellite data, ocean buoy data and aircraft data into the models is of itself a mathematical research challenge. The competitive position of the nation must be viewed not only on positive advances and successes but also on the role of science in advancing fundamental knowledge to the point of leading to success in reducing the negative impacts that environmental events can have on the Nation's economy. Basic science, conducted to a significant degree by university scientists external to NOAA, has led to improved forecasts within NOAA. This science was conducted over several decades and melded together creatively by NOAA scientists to meet the agency's mission needs.

For that reason, the SAB supports a $4.5 billion budget for NOAA in FY 2007 for NOAA. As suggested by an ad hoc coalition of NOAA stakeholders, this amount would fully fund the President's FY'07 budget request, restore funding for core programs, and address all the areas of concern and priority that have traditionally been supported by Congress. It would allow enhancements in the development of an integrated ocean and atmospheric observing system; increased research and education activities and expanded ocean conservation and management programs; and provide critical improvements in infrastructure (satellites, ships, high performance computers, facilities), and data management. It would allow the external university community to conduct the basic research that will lead to improved forecasts by the agency.

In August 2004, a Congressionally requested study of NOAA's research programs, entitled, *Review of the Organization and Management of Research in NOAA* concluded that extramural research is critical to accomplishing NOAA's mission. The access to such enhanced research capacities provides NOAA with world class expertise not found in NOAA laboratories; connectivity with the planning and conduct of global science; means to leverage external funding sources; facilitation of multi-institution cooperation; access to vast and unique research facilities; and access to graduate and undergraduate students. Academic scientists also benefit from working with NOAA, in part, by learning to make their research more directly relevant to management and policy. It is an important two-way interaction and exchange of information and value.

Climate and long range weather prediction are substantial basic science challenges. Coupling global climate models to regional scale models at the appropriate scales of temporal and spatial variability are significant physical, mathematical and cyber science challenges. The couplings must properly include all components of the Earth system, the atmosphere, the oceans, ice and terrestrial components. The couplings must be capable of being downscaled, from larger spatial and temporal scales to smaller scales and upscaled (from smaller to larger). But this is computationally demanding. The university community and the NSF sponsored National Center for Atmospheric Research anxiously await next generation national computing facilities that can be accessed broadly by U.S scientists so that community models can be run and our nation's knowledge base extended. Business, industry and the military await the further development of this fundamental, basic research. The future competitiveness of the U.S. will depend to great degree on the outcome of what these studies show for the future climate of the U.S. and other countries throughout the world.

The SAB strongly supports a robust NOAA extramural research activity and calls on the Senate Subcommittee on Technology, Innovation and Competitiveness to support the NOAA's Ocean & Atmospheric Research programs, including the National Sea Grant Program, the Ocean Exploration Initiative, a true venture into the great ocean abyss on our planet, the National Undersea Research Program which Ocean Exploration will embrace, as well as research related to aquaculture, invasive species, harmful algal blooms and the various joint and cooperative institutes at levels envisioned in last year's Senate version of the Commerce-Justice-State Appropriations bill. These partnership programs are not only consistent with the findings of the Congressionally mandated August 2004 review of NOAA research, but are also consistent with the NOAA strategic plan and enable NOAA to carry out its mission at state and local levels.

The SAB strongly supports implementation of the recommendations from the U.S. Commission on Ocean Policy (COP) and the initial efforts of the Administration's Interagency Committee on Ocean Policy to develop a response to COP's recommendations. COP's analysis of policies governing oceans, coasts, and Great Lakes has resulted in a collection of bold and broad-reaching recommendations for reform. Implementation of these recommendations by the Federal government will enable the U.S. to maintain and strengthen its role as a world leader in protecting and sustaining the planet's oceans, coasts, and Great Lakes. The SAB is particularly supportive of COP's recommendation to double the federal investment in ocean, coastal, and Great Lakes research as well as its recommendation to promote a strong federal investment in ocean, coastal, and Great Lakes education, outreach, and stewardship and in IOOS.

By any measure, basic scientific research has made monumental contributions to technology and to the national priorities of the U.S. The bond between basic research and the development of both novel and current technologies has been and is well in place. Science and U.S. society must continue to co-evolve. The nature of this evolution will certainly be affected by the extent to which this Senate sets funding priorities. Hopefully this Senate will recognize that the dependence of the development of successful novel technologies on broadly supported basic research will lead to a future nation that is healthier and more economically prosperous than at present. Because of the unpredictability of the details of the new science and technology that will evolve, the details of social evolution are also unpredictable. But the future health and prosperity of this nation are inextricably coupled to the investments made in basic research today.

We see that we have no birthright to global economic leadership and a high standard of living. These are things that we have to continue to earn. The pressures and opportunities are relentless and inexorable. At the core of these unprecedented challenges, is the requirement for the highest caliber of human capital, the need for us to educate and challenge students to push the limits of innovation, technology and discovery. We need national commitments to drive advancements in energy, health, environment, food safety, security, solutions to world poverty and much more.

The SAB recognizes the extraordinary fiscal constraints and difficult choices the Subcommittee must make. Nevertheless, the research and education programs under the Subcommittee's jurisdiction are vital investments in the future of this Nation and deserve the maximum support possible. Thank you for the opportunity to provide this statement.

End of Statement.

Appendix: Community Resolution on Integrated Ocean Observing System (IOOS)
Endorsed by the Coastal States Organization, Consortium for Oceanographic Research and Education, National Estuarine Research Reserve Association, National Federation of Regional Associations for Coastal and Ocean Observing, U.S. Chamber of Commerce Space Enterprise Council

Recognizing that the oceans and coastal waters affect all our lives – driving weather and storms, influencing climate, providing transport for millions of tons of cargo, and sustaining coastal and marine resources;

Further Recognizing that more than a century ago, the United States began creation of a comprehensive weather forecasting and warning system and today, daily weather reports are central to the nation's social, economic, and environmental vitality.

Acknowledging that the Nation's coastal regions, including the Great Lakes, are home to more than half the nation's population, but lack basic information to protect those communities and their environment, to track, understand and predict change, and to provide quality information to those who work on or near the water .

Understanding that deployment and operation of a sustained Integrated Ocean Observing System will: (1) improve the safety and efficiency of marine operations, (2) improve prediction of weather and natural hazards (including tsunamis and storm surges) to reduce resulting damages and costs, (3) improve predictions of climate change and its socio-economic consequences, (4) improve national security, (5) reduce public health risks, (6) help protect and restore healthy ecosystems, and (7) sustain and restore living marine resources.

Aware that many elements of a national system are already in place, but most now operate independently, the IOOS would combine these elements into interconnected global and coastal components. **T**he global component focusing on the physical observations associated with climate and weather prediction, including tsunami detection. The coastal component, comprising a federal "national backbone" of observations and data management and regional coastal observing systems, addressing the complex physical, chemical, and ecological observations needed to assess and manage coastal regions.

Further aware that the national backbone and regional associations must work closely with end-users- including state and local governments, non-profit organizations, industry, and citizens -- to identify and meet their needs and to build partnerships that facilitate the opportunity for them to participate and invest in the observing system.

Affirming that implementation of the IOOS system will require a substantial sustained investment in research, pilot projects, and related infrastructure to develop new data products and system enhancements and incorporate new technologies into the system.

Cognizant that the United States and the world are facing critical decisions about the future stewardship and management of the oceans, coastal waters, and fresh water resources, including the Great Lakes and improved data and predictions resulting from the IOOS is needed to support these decisions.

Our organizations resolve that we are committed to the development of an ocean and coastal observing network endorse the following:

An integrated ocean observing system should include:

a) A national program to fulfill national observation priorities, including marine commerce and the Nation's ocean contribution to the Global Earth Observation System of Systems and the Global Ocean Observing System.
b) A network of regional coastal and ocean observing and information programs that collect, measure, and disseminate data and information products to meet regional and national needs, managed by certified regional associations.
c) The designation of the National Oceanic and Atmospheric Administration as the lead Federal agency for implementation and administration of the system
d) An Interagency Program Office within the National Oceanic and Atmospheric Administration that is responsible for program planning and coordination of the observing system.
e) Data management, communication, and modeling systems for the timely integration and dissemination of data and information products from the national and regional systems.
f) A sustained research and development program to advance knowledge of coastal and ocean systems and ensure improvement of operational products, including related infrastructure and observing technology and large scale computing resources and research to advance modeling of coastal and ocean processes.
g) A coordinated outreach, education, and training program that integrates and augments existing programs to ensure the use of data and information for improving public education and awareness of the Nation's coastal and ocean environment and building the technical expertise required to operate and improve the observing system.
h) Data products and information that meets the needs of end-users- including state and local governments, non-profit organizations, industry, and citizens.

2) Action either by Executive branch and/or Congress to establish an integrated national system of ocean, coastal, and Great Lakes observing systems to address regional and national needs for ocean information.