HEARING ON OCEAN OBSERVING SYSTEMS

HEARING

BEFORE THE

SUBCOMMITTEE ON FISHERIES CONSERVATION, WILDLIFE AND OCEANS

OF THE

COMMITTEE ON RESOURCES
HOUSE OF REPRESENTATIVES

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CONTENTS

HEARING ON OCEAN OBSERVING SYSTEMS

THURSDAY, JULY 30, 1998

HOUSE OF REPRESENTATIVES, SUBCOMMITTEE ON FISHERIES CONSERVATION, WILDLIFE AND OCEANS, COMMITTEE ON RESOURCES, *Washington, DC.*

The Subcommittee met, pursuant to notice, at 10:05 a.m. in room 1324, Longworth House Office Building, Hon. Jim Saxton (chairman of the Subcommittee) presiding.

STATEMENT OF HON. JIM SAXTON, A REPRESENTATIVE IN CONGRESS FROM THE STATE OF NEW JERSEY

Mr. SAXTON. The Subcommittee will come to order.

I want to thank everyone for the extraordinary effort in preparation for this morning's hearing. And it is primarily because of that extraordinary effort that we are proceeding with the hearing at a rather difficult time. It is at this hour the funeral of one of the officers is being held over in Virginia, so we debated in our mind about whether we should move forward. But because of the distances that some of you traveled, and because of the great effort that went into this morning's hearing, in preparation for it that is, we decided to proceed.

The Subcommittee on Fisheries, Conservation, Wildlife and Oceans is meeting today to conduct an oversight hearing on our nation's ocean observing systems. The importance of the ocean is being recognized more each day for the role in the global climate and environment and the potential uses of the biological and mineral resources it harbors.

The United States needs to evaluate its marine observation systems and determine if the facilities and the technology in our current arsenal are sufficient to meet the requirements to understand, conserve, and use resources in the marine environment.

As some of you are aware, the Oceans Act of 1998, which was also interesting this week, establishes a commission to evaluate the state of our oceans research and technology and the laws that govern marine issues. This bill was approved by the House Resources Committee yesterday, and we expect it to move quickly through the House. The input and interest of some of today's witnesses has proved invaluable over these past months, and I thank you for the input and the expert information that you were able to provide us.

However, today's hearing was called to gain insight into the status of the Nation's oceans observing systems and determining the needs that exist for a further understanding of the marine ecosystem. By hearing testimony from both the administration and the scientific community, we hope to better comprehend the direction that policy needs to be taken in order to develop more sound policies when it comes to the ocean and its inhabitants.

We look forward to hearing from each of you this morning and hearing your perspective on a variety of current observing systems.

[The prepared statement of Mr. Saxton follows:]

STATEMENT OF HON. JIM SAXTON, A REPRESENTATIVE IN CONGRESS FROM THE STATE OF NEW JERSEY

Good morning. The Subcommittee is meeting today to discuss the status of the nation's ocean observing systems.

The importance of the ocean is being recognized more each day for its role in the global climate and environment and the potential uses of the biological and mineral resources it harbors. The United States needs to evaluate its marine observation systems and determine if the facilities and technology in our current arsenal are sufficient to meet our requirements to understand, conserve and use the resources in the marine environment.

As some of you are aware, the Oceans Act of 1998 establishes a commission to evaluate the state of our oceans, research and technology, and the laws that govern marine issues. This bill was approved by the House Resources Committee yesterday, and we expect it to move quickly through the House. The input and interest of some of today's witnesses has proved invaluable over these past months, and I thank you for your expertise.

However, today's hearing was called to gain insight into the status of the nation's ocean observing systems and determining the needs that exist to further our understanding of the marine ecosystem. By hearing testimony from both the Administration and the scientific community, I hope to better comprehend the direction that policy needs to be taken in order to develop more sound policies, when it comes to the ocean and its inhabitants.

I am looking forward to each of your testimony and hearing your perspective on a variety of current observing systems.

Mr. SAXTON. As I mentioned earlier, because of other events that are taking place at this time, I expect that I will be here alone for most of the hearing; that is, without other members. So I ask your understanding. And I ask unanimous consent that all Subcommittee members be permitted to include their opening statements in the record. And, obviously, that will occur.

[The prepared statement of Mr. Young follows:]

STATEMENT OF HON. DON YOUNG, A REPRESENTATIVE IN CONGRESS FROM THE STATE OF ALASKA

I would like to compliment Chairman Saxton for holding this oversight hearing. In light of the fact that the Oceans Bill was reported from the Resource Committee yesterday, this hearing is very timely.

The science community's needs to study the widely unknown ocean must be established in conjunction with the Ocean Commission that we hope to pass. By coordinating the efforts of the scientific community and the elected officials both here and outside Washington, a more concerted effort can be developed.

Without widespread understanding of the oceans, many problems, ranging from fisheries conservation to those of pollution, will go either completely unaddressed or inadequately resolved. Therefore, through the testimony we will hear today, I am optimistic that we will gain some perspectives from the Administration and also some valuable insights into the needs and hopes of the scientific community.

I look forward to hearing from this extraordinary group of witnesses that have been assembled today.

[The prepared statement of Mr. Pallone follows:]

STATEMENT OF HON. FRANK PALLONE, JR., A REPRESENTATIVE IN CONGRESS FROM THE STATE OF NEW JERSEY

Mr. Chairman,

Thank you for holding this hearing today on such an important and timely issue, the oceans. Our oceans are critically understudied and while they cover roughly three fourths of the planet, observations have lagged far behind those on land.

If anyone doubts the importance of ocean observations, they need only to look as far as our most recent El Nińo predictions. These predictions, based on models and ocean observations, gave state and local managers the information they needed to take precautionary measures before disaster struck, saving millions of dollars and countless lives.

There are yet other ocean observations that have yielded tremendous benefits. The Ocean Drilling Program has produced sediment cores to study long-term climate variability. Submersible observations have discovered hydrothermal vents where entire communities of unique marine organisms flourish. These organisms which live without sunlight, and under intense heat and pressure, show tremendous promise in the cutting-edge field of biotechnology.

Past ocean observations have also yielded exciting medical benefits. Today over half of all new cancer drug discoveries are coming from marine organisms. Further research in this area could lead to even further breakthroughs.

At the National Ocean Conference in Monterey, California, the President announced several initiatives to explore, restore and protect our ocean resources. I am particularly interested in two initiatives announced: Exploring the Last U.S. Frontier and Monitoring Climate and Global Warming.

I look forward to hearing from today's witnesses on the current state of our ocean observations, what areas need additional research, and what partnerships are taking place to meet these needs.

Mr. SAXTON. We are going to hear something a little unusual this morning. One of our witnesses, Dr. Gagosian, the director of Woods Hole Oceanographic Institute, will be showing us a film on some recent undersea research taken by the scientists there. It will take about 5 minutes. Immediately following the film we will introduce the first panel.

I would like to introduce the film. Are we all set? We have two monitors. So it looks like we are all set. You might want to dim the lights a bit, and we will go ahead and watch this video.

Dr. GAGOSIAN. Mr. Chairman, I have been asked today to speak to the issue of the deep sea. For this video presentation, I will present how we explore the deep sea floor 2 to 3 miles below the surface of our blue planet and what we see down there. During my testimony, I will talk about why we need to explore the deep sea and what technical improvements we need to produce the best science.

But first, what tools do we need to explore this blue planet? How do we explore our inner space where buoyancy is important and gravity is not? We use human-occupied vehicles. HOVs, like Alvin, with its support vessel Atlantis, Alvin is part of the National Deep Submergence Facility located in Woods Hole, Massachusetts. Alvin holds three people, two scientists and a pilot, and can dive to a depth of 14,000 feet. It averages roughly 180 dives a year. It can explore 86 percent of the ocean floor.

The National Deep Submergence Facility also has remotely operated vehicles and autonomous vehicles. You are all familiar with the remote vehicle Jason. It was used to explore and discover the Titanic. Jason has a depth capacity of 20,000 feet, can operate 20 hours a day, and is tethered to the ship with a fiberoptic cable. It works by a team approach both on the ship and on land. It is linked by satellite to a global audience.

And there are autonomous vehicles, such as the autonomous benthic explorer, Abe. It is untethered. It drops off the side of the ship, goes through the water column, goes down to the bottom of the ocean, goes into a cradle, and goes to sleep, wakes up on command, and runs around the bottom of the ocean sensing different events that occur down there.

Another example is REMUS, the remote environmental monitoring unit. There are several in operation. This is a cartoon, if you will, an animation of a futuristic robotic colony on the sea floor. What you are seeing here in the black sections are the areas covered by side scan sonar used to map the sea floor topography. The use of these robotic colonies clearly is for mine warfare and monitoring earthquakes, as a couple of examples, as shown here; also to monitor waste dump sites. You can also see from this particular animation the autonomous benthic explorer involved in this surveying the bottom of the ocean in this futuristic effort.

Now let's talk about other advances in technology. Cameras. The Titanic was discovered in 1986 by Woods Hole Deep Submergence Laboratory, headed by Bob Ballard. This is a low-light video, high-altitude imagery of Titanic. Remember, Titanic is 2½ miles below the ocean floor water.

In the early 1990's, broadcast quality three-chip cameras came along, and as you can see, there is extraordinary clarity with respect to the 1986 video. There are a lot of particles in the water. And so these new camera systems have allowed scientists to look at things and ask questions they were not able to do just 5 years earlier. So due to progression in wider area and angle views, clarity and resolution, and higher light power, a scientist can do, as I mentioned, things they could not even dream of doing 5 to 10 years earlier.

An excellent example of this is the telemotor. This is linkage to the rudder of Titanic. The steering wheel is attached to it. Note the clarity of the bolts. I would like to remind everyone in the room that this is 2½ miles below the ocean surface. It is not in my office.

One of my favorite pictures is this cup which is found in the debris field of Titanic. If you look carefully, you will not only see the white star, but you will be able to read "White Star Line."

Another example of the use of this technology is in a forensic survey that was just completed of a bulk cargo carrier named the Derbyshire, 964-foot, 2,000-ton iron ore and bulk carrier which sank off Okinawa in a typhoon in 1980 in 14,000 feet of water. This, by the way, is HDTV of a half-inch cable from that sunken carrier. Forty-four lives were lost. The question is why and how did it sink?

One hundred thirty-seven thousand digital still images and 500 hours of color and HDTV video imagery were taken, and as you can see, it is really quite extraordinary, the detail. This is a fracture in the hatch cover at, again, 14,000 feet. This is a plastic tie wrap. Those lines are 1 millimeter apart.

The synthesis of the imagery, and you will see in a moment the bow section, has allowed the people that were working on this project to understand why and how it sank. Now, that is the technology.

Let me take you to a place where few people have been before, where the heat of the earth drives this engine creating a 40,000-mile-long volcanic mountain chain below the sea surface at an average depth of 2½ miles, the longest mountain chain on earth, moonless mountains. These are areas where hot lava is entering the ocean from deep below in the earth's interior creating underwater mountains. You probably think this is a volcano on earth, but actually it isn't. It is 2½ miles below the ocean's surface. It is at the underwater volcanoes where new sea floors are made. It is the most hostile environment on earth.

This is the world of hydrothermal vents. They were discovered just 20 years ago, where sea water circulates deep below the ocean floor through cracks in the crust from previous earthquakes, recycling and heating the water to 700 degrees Fahrenheit as it rises to the surface. The pressure is 5,000 pounds per square inch. It is a world of metal sulfides, iron, zinc, copper, and silver, as they condense in the cold water creating chimneys that grow several stories high at the rate of a foot a week.

It is also the world where bacteria is the basis of life. And what you are seeing here is thick bacterial mat, not snow. It is also where chemical reactions, not light, provide the energy for life. It is a world of incredible diversity and density, where over 300 species have been found, two-thirds of which have never been seen before, with an overall growth rate as high as the most fertile rain forest in the world.

It is a world of unusual animals, like these tube worms that you are seeing here, which can grow up to 14 feet. They grow at a rate of an inch a week. They are the fastest growing invertebrates on earth. These organisms coexisted with the dinosaurs. Vent organism fossils have been found in 400-million-year-old ore deposits.

This never-dreamed-of oasis of life has created a whole new thinking of the origin of life on this planet and the possibility of life on others. The red tips, by the way, I might add, are hemoglobin.

This is another kind of worm. This is an Alvinella worm, named after Alvin. The tip of this worm is in 34 degree Fahrenheit water, and the tail is in 175 degree Fahrenheit water, and it is only 2 feet long, the highest known temperature in which an animal has survived. And a 140-degree Fahrenheit gradient over a 2-foot body length is extraordinary.

Higher up in the food chain, as you can see, are crabs.

The red light, by the way, is a laser from Alvin. It is used to maneuver the submarine.

So these cameras are indeed our microscopes under the sea. And this extraordinary picture of a shrimp actually is a great example of that. Shrimp, I might add, on the midocean ridge of the Atlantic are teeming in their masses as they feed on bacteria. There are literally thousands of them. The light on their backs is thought to be coming from light-seeking sensors which attract them to the vent.

There are golden-colored mussels, as well. They do not feed on the bacteria like the shrimp, but the bacteria reside inside them, producing the mussels' food source. They grow as large as a 12-inch dinner plate.

So, only 20 vent sites have been explored on this 40,000-mile mountain chain. Many more have been hypothesized. Imagine the discoveries to come. This is the earth at night, and it shows pretty clearly how much more we have to explore on the planet ocean.

Thank you.

Mr. SAXTON. Doctor, thank you very much. That was impressive, to say the least, and we thank you.

Doctor, we understand that you are going to be here with us and be part of the second panel. And, so, we look forward to chatting with you further.

Permit we to welcome Mr. Farr aboard, my ocean partner. I am his ocean partner. One way or the other. Anyway, we work closely together and have been, for the last several weeks, seing a lot of each other.

Let me just introduce the first panel at this time. No stranger to the members of the Committee, Dr. Jim Baker, Under Secretary of Oceans and Atmosphere, Department of Commerce; Dr. Rita Colwell, Director of the National Science Foundation; and Rear Admiral Paul Gaffney II, Chief of Naval Research, United States Navy.

We remind each of you that, for purposes of keeping things going, we operate here under 5-minute rule. Obviously, your entire written statement will be included in the record, but if you would try to summarize it in the allotted 5 minutes, we would be most appreciative.

Dr. Baker, why do not you begin.

STATEMENT OF D. JAMES BAKER, UNDER SECRETARY FOR OCEANS AND ATMOSPHERE, DEPARTMENT OF COMMERCE

Dr. BAKER. Thank you, Mr. Chairman, for this opportunity to testify on ocean observations and related activities and also to highlight some of the details from the National Ocean Conference.

Mr. Chairman, I know you had planned to attend the National Ocean Conference. I am sorry your schedule would not allow you to be there, but I would like to, in my short testimony here, summarize some of the results that came out of that important meeting.

But let me say first that this wonderful film that Bob Gagosian just showed is a perfect example of the kind of partnership that we have between the Federal Government, the oceanographic institutions, and the academic community that work so well.

The Woods Hole Oceanographic Institution, the Scripps Institution of Oceanography, and you will also be hearing from Rutgers, are three examples where Navy, NOAA, NSF and other agencies all work together to make new things happen; and it could not happen without that long-term partnership that has worked very well.

Let me start by saying that the support of this committee has been critical to the successful forecast of El Nińo this past year. Our array of buoys in the tropical Pacific called the Tropical Atmosphere Ocean array, the TAO array, provide the key data for researchers and NOAA forecasters to provide the first-ever forecast for El Nińo.

This forecast has brought important economic returns to the country and has introduced ocean and climate science to homes across all regions of the United States. Just one example, benefits to the Nation's agricultural industry alone of the forecast are estimated to be somewhere between $240 and $266 million. That is just for one forecast.

But despite recent advances, our understanding of the surface and interior ocean, the variability of the ocean, and the interaction with the atmosphere and of the subsurface processes and resources is just at the beginning.

Recognizing this fact, President Clinton and Vice President Gore, at the recent National Ocean Conference, launched several major initiatives for the exploration, restoration, and protection of America's ocean resources. These measures will provide new scientific insight into the ocean, open new opportunities for jobs and economic growth, and also preserve our oceans for all time.

We are proposing an additional $224 million through 2002 to support these efforts beginning in fiscal year 2000. The initiatives particularly relevant to ocean observations are exploring the last U.S. frontier and monitoring climate and global warming.

Understanding our ocean observation programs will require some discussion of the tools and processes used for observation. The tools include submersibles, profiling floats, buoys, state-of-the-art satellites. They are all in a process of almost constant evolution as our abilities to understand the oceans deepen and our needs for scientific data expand.

In addition to these tools, NOAA has created various partnerships with various agencies, oceanographic institutions, universities, and other countries to share the responsibilities of resources that ocean observations require. And I am pleased that we have been able to start a new joint institute at Woods Hole Oceanographic Institution, an important new activity for us.

The El Niño observing system is focused on the tropical Pacific Ocean, but scientists recognize a climate variability results from interactions among different oceanic regions. So improved predictability requires the integration of observing systems over all of the oceans which need to be combined to create critical climate information for all of the U.S. and foreign climates.

We need to have a system, Mr. Chairman, in the ocean that is as good as the atmospheric system that we have today. Thus, in 1998, the International Year of the Ocean, all of the agencies are committed to participating in the building of a global ocean observing system that is essential to improving the basis for our climate forecasting. This observing system will include what we have today provided by NOAA, Navy, the National Science Foundation, and other agencies, plus new profiling autonomous tide gauge circulation explorer floats. These are floats that float in the midwater. They go up and down. They are profiling. They are independent of any connections, so they are autonomous and they float with the currents. They promise a very cost-effective approach for large-scale ocean measurements.

At the conference in Monterey, the President proposed an additional $12 million to expand the array of these floats in the north Pacific and north Atlantic. This new array will provide the backbone of the sustained global ocean observations needed to improve climate forecast skill.

In addition to these sea surface and satellite-based platforms, NOAA has developed a suite of undersea ocean observation systems. Submersible and hydroacoustic technologies supported by all the agencies have brought scientists to a new frontier in fields of underwater research. Recent advances have allowed us access to thousands of square miles of virtually unexplored sea floor resources. With strong congressional support, NOAA has maintained sea floor observatories and is providing significant new support for various efforts, including the Aquarius, the long-term environmental observatory off New Jersey, and the VENTS program in sites along the Pacific coast.

The costs of ocean observation programs are high, and NOAA is not fully able to fully underwrite the costs alone. Therefore, we are working in cooperation with our sister agencies and other nations on oceanographic research and satellite observations.

Mr. Chairman, as we move to a more global ocean observation system, we must learn enough about the ocean to design such a system. The World Ocean Circulation Experiment was a good start. Now scientists have proposed the next steps, which NOAA is pleased to help with. The Global Ocean Data Assimilation Experiment, called the GODAE, will create a means to provide up-to-the-minute analysis of ocean conditions. We are committed to supporting this effort through our Oceans Observation Program.

Part of this will also be the Climate Variability and Predictability Experiment, CLIVAR, the leading international scientific program. These will the basis for the next step, and NOAA will be a partner. A critical limiting factor for improved climate and weather predictions is our limitation on computing power. We need better computers, and we will be working to make those happen.

Mr. Chairman, let me conclude with a note about living marine resources, a special interest of yours. More efficient management of our Nation's living resources would result from better information about the current status of biological and physical components of the marine environment. We need to have better fisheries stock assessment information to manage fisheries.

On average, our fishery vessels, as you know, are more than 34 years old. We are looking for ways to replace the capability of the vessels. We have a team that has been doing that. Admiral Craig Dormand recently reviewed NOAA's plan and strongly supported our need for acoustically quiet vessels. The report supports construction of four dedicated fishery research vessels. In Monterey, the President proposed $194 million to do the design and construction of those new vessels.

Mr. Chairman, your timing for holding this hearing, after a very powerful El Niño and before what we are forecasting to be a La Niña event, the flip side of El Niño, underscores how vital congressional leadership will be in ensuring the long-term sustained investment that science requires for ocean observations.

The CLIVAR experiment, the GODAE experiment are critical to these; and we are prepared to be a partner. The President has indicated his support for ocean observations. We are prepared to undertake his specific proposals.

I commit to you that NOAA, through our laboratories and our academic partners, will work with our sister Federal agencies represented here today, we will work closely with NASA and DoD, with satellites, and we will be looking closely to work with the private sector in collecting, disseminating, and applying ocean data. We will work with the Congress and the administration to implement these plans.

Thank you very much.

Mr. SAXTON. Dr. Baker, thank you very much.

[The prepared statement of Dr. Baker may be found at end of hearing.]

Mr. SAXTON. Dr. Colwell.

STATEMENT OF RITA COLWELL, DIRECTOR, NATIONAL SCIENCE FOUNDATION

Dr. COLWELL. Chairman Saxton, as the newly confirmed NSF director, I am still sort of wet behind the ears, so I particularly appreciate the opportunity to testify today on this very important topic of ocean monitoring and assessment, and in particular the substantial, very fundamental role that the National Science Foundation plays in the Nation's oceanographic monitoring and assessment capabilities.

In fact, this hearing speaks very directly to one of the most exciting themes that has emerged from the past decade of ocean sciences research, and that is the complexity and variability of the oceans, so dramatically demonstrated in the video Dr. Gagosian just showed us.

Frequently, we find significant physical, chemical, and biological variations on very small spatial scales, as small as a half a mile. It is clearly impossible to monitor the entire global ocean or even coastal waters with minute spatial resolution. For that reason, it is important to understand the underlying processes sufficiently well to be able to interpret them. This allows researchers to make a small number of key observations that will very reliably tell us over time how the system works. The research supported by NSF helps us determine what measurements will best characterize changes in the ocean and, more importantly, how many measurements are required and where they should be located.

A good illustration, I think, is the NSF-funded Tropical Ocean Global Atmosphere, the TOGA program. As its name implies, this research program is focused on the physical processes occurring in the tropical ocean and the atmosphere. TOGA enabled us to recognize the forces that underlie the El Niño phenomenon, which in turn led to the design and deployment of the existing El Niño Southern Oscillation, the ENSO, observing system.

The question is, how can we possibly monitor such a vast and complex system as the oceans? A helpful way to characterize the scientific requirements is to consider three classes of monitoring systems. One is that we need sustained monitoring that provides data to detect the subtle changes that occur over a period of a decade or so in the short term. These measurements can provide early warning of changes in the earth's system.

Then along with that, we need selected long-term observations that allow us to predict changes in the oceans and weather systems and to be able to alleviate negative impacts. For instance, this year's El Niño activity is a very good example of the long-term observation that allowed us to make predictions.

And finally, we need measurements, observations, and experiments to help us understand the physical, chemical, and biological processes that were responsible for the changes. An associated challenge is tracking what is going on in the miles and miles of ocean that exist between sensors. This is an area in which we have seen remarkable innovation over the past 5 years. That innovation was primarily fueled by the needs of the World Ocean Circulation Experiment, WOCE.

At this moment there are about 500 robotic vehicles distributed over thousands of square miles of the north Atlantic oceans. These drift along with the ocean currents about a half a mile below the ocean's surface; and about every 2 weeks, each one of these small instruments pops up and rises to the surface collecting data on temperature and salinity as it moves up to the surface; and then, via satellite, these data are transmitted, as well as the position of these instruments, to investigators on shore. After being on the surface for about a day, they are sent back down to a profiling depth of about half a mile. And this cycle goes on month after month after month.

So these examples, in conclusion, demonstrate how technology is changing the way we do oceanography. Permanent sea floor observatories, new optical and acoustical imaging methods, long-term moorings, deep-diving manned submersibles, satellite communications, robotic vehicles, these are all vehicles for discovery that NSF supports.

I will conclude by saying we are in a time of very rich opportunities for research in oceanography. We have seen, in a very rapid series of events, hurricanes, droughts, floods, destruction of coral reefs, coastal erosion, climate change, El Niños, fisheries decline and in some cases simply collapsing, and also human health effects, an area of personal interest. We can now use ocean monitoring to predict cholera epidemics. So there is a very close linkage between what we study in the oceans and the welfare of human populations. These are all phenomena that are affected by, and in some cases controlled by, the oceans.

The United States oceanographic investigators are world leaders. We do not lack talent, ideas, or plans, and given the adequate resources, the future is spectacular for discovery and understanding.

Mr. Chairman, thank you very much for the opportunity to share with you and the members of the Committee the exciting research that is being supported by NSF. The testimony will be, of course, in the record; and I would be very pleased to answer any questions you might have. Thank you.

Mr. SAXTON. Thank you very much, Dr. Colwell. It does not sound like you are wet behind the ears. Thank you for being here. That was great testimony.

Dr COLWELL. My pleasure.

[The prepared statement of Dr. Colwell may be found at end of hearing.]

Mr. SAXTON. Admiral Gaffney may proceed.

STATEMENT OF REAR ADMIRAL PAUL G. GAFFNEY, II, CHIEF OF NAVAL RESEARCH, UNITED STATES NAVY

Admiral GAFFNEY. Good morning, Mr. Chairman and Mr. Farr. Thank you for the opportunity for me to appear before you this morning to talk about a topic that is very dear to me, our oceans. I would like to begin by showing you a graphic.

This graphic represents our planet. The green part is the land, and the blue part is the water, a little more than two-thirds of our planet. It is about 197 million square miles, this whole disk. If you can see that little white square on there, that is the amount of the water part of our planet that has been imaged or completely explored since we have been alive on this planet, or since anyone has been alive on this planet. It is about 5 percent, a little bit more than that.

Again relative to the same size, this is the moon. It represents all sides, top, bottom, backside, and front side of the moon. It is equivalent to about 11 percent of the ocean, twice as much as we have surveyed of our ocean. It has been completely imaged, 100 percent, front side, back side, top, and bottom.

I will leave this for your grandchildren.

Mr. SAXTON. We would like to share that with some of the folks that were here with us yesterday.

Admiral GAFFNEY. We have, in fact, characterized 100 percent of the ocean. We have used satellite altimetry to characterize it at a resolution of about 15 kilometers. But 100 percent of the moon has been characterized at 100 times better resolution than we have characterized our entire planet. This concerns me, and I believe we should do something about it.

The Navy has long considered the study and exploration of the oceans to be a required competency. We must do it. We do not do it because we love it. We do not do it because it is interesting. We do not do it because we have a charter. We do love it. It is interesting. We do not have a charter. But we do it because it is the foundation that provides information required for every single Navy and Marine Corps operation that you can imagine.

Over the past 50 years, we have invested billions of dollars in research, instrument and technique development, global ocean surveys, data archiving, and predictive capabilities. The results of these efforts are seen in many ocean monitoring tools and platforms used around the world in civil and military oceanography.

For example, SWATH bathymetry, SWATH sonar, laser line scan optical scanners, sensors, the global positioning system, acoustic thermometry, long-range acoustic monitoring, deep stable moorings, some of the people in this room and the institutions that they represent have developed these for us, to name just a few.

In the future, and I will make a commitment right now for the future, for the Navy, we are committed to an ocean science and technology program that is robust. It is a national responsibility, we think, that the Navy has. It is a core capability the Navy must foster. We will focus on understanding the processes of the ocean and develop the tools to better understand those processes.

We will continue to rely on ships and manned submersibles. Frankly, I am quite worried about that part of our repertoire of tools at this point. But long-term ocean monitoring and assessment need other tools as well, companion tools, tools like those that come from our investment in autonomous systems that can either be moored or drifting or independently moving, small unmanned systems, as Bob Gagosian showed you in his videotape that started this session off.

We are currently working on networks of inexpensive autonomous underwater vehicles through a program called the Autonomous Ocean Sampling Network. Also on the horizon are new remote sensing instruments, such at the Naval Earth Map Observer Satellite, or NEMO, which will provide hyperspectral images when it is launched in the year 2000.

NEMO is interesting because it is a partnership between the Navy, the Office of the Secretary of Defense, and industry, each sharing in the cost of about a $120 million effort, the government coming up with about $60 million of that and industry coming up with about $60 million.

It is interesting, because like most big oceanographic programs, no one group or agency can support all the cost alone for oceanographic research, ship operations, surveying, and modeling that needs to be done on a global scale to address the issue that we are testifying about today. We formed partnerships with agencies and institutions like those represented on this panel today and through programs such as the National Ocean Partnership Program, which was actually born out of a set of hearings that this Subcommittee participated in a couple years ago. NOPP, the National Ocean Partnership Program, is unique in that agencies that are working together can actually create critical mass to address our neglected ocean.

The Navy is proud to have taken an organizational and financial lead in the early parts of the NOPP, but our partners are strong partners in NOAA, and our vice chairman seated right here at the table, Dr. Jim Baker, NSF, NASA and six other agencies are stepping up to the plate with us.

At the National Ocean Conference, I mentioned a notion that we should begin the millennium with a focused exploration and mapping effort, 100 percent coverage of one important area near our United States, a necessary baseline, a precursor to long-term monitoring.

I hope to see the National Ocean Partnership Program agenda, and its leadership council on their agenda, a discussion about the coordination of Federal ocean monitoring efforts, how they can be comprehensively sustained, and how we can comprehensively baseline them before we start.

It will take decades to understand the majority of our water planet as well as we understand the moon today, but we need to begin.

Thank you for the opportunity to be here. My formal testimony is submitted for the record, sir; and I am looking forward to answering any questions you may have.

Mr. SAXTON. Admiral, thank you very much.

[The prepared statement of Admiral Gaffney may be found at end of hearing.]

Mr. SAXTON. Since you referred to the National Ocean Partnership Act in the latter part of your testimony, let's just begin by exploring that some.

The National Ocean Partnership Act, obviously, was established pursuant to legislation that passed the Congress in 1995. I am just curious as to generally how you view it in terms of how successful it has been, how has funding worked out, how much was requested by the partnership, how much was added by Congress.

Just in general, can you fill us in on the details, what your level of resourcing is, what you need, and how well you think things are going?

Admiral GAFFNEY. Yes, sir.

Well, we started out, of course, with initial—some initial Navy money and money added by the Congress that was not in the President's budget for the first couple of years. The Navy has increased its contribution from $5 million to $10 million, and we intend to have, for as long as we can imagine, $10 million or so in the President's budget as our contribution to the National Ocean Partnership Program.

We have a different budget development process in the other agencies, and we are able to, I would say, react faster, not to be pejorative, but to act faster to the opportunity of the partnership act. So we got our money in, and the other agencies are adding money out of whole cloth, if you will, not separate line items yet. But we note that there are requests in from several agencies to add to that program.

We have had great cooperation among the several agencies. While it has been principally Navy money or Navy money plused-up by the Congress but put in the Navy line item, all of the agencies have worked to select the programs. It would be hard to imagine any oceanographic program that would not be Navy-relevant. So we are very happy to spend our money in a deliberate way, debating it with our fellow agencies.

Good results have come out in education, in data exchange and ocean monitoring, and a great dialogue has gone on that I have not seen in my 25 years in this town involved with oceanography.

Mr. SAXTON. Thank you.

Dr. Baker, Dr. Colwell, would any of you like to comment?

Dr. BAKER. Thank you, Mr. Chairman.

I think this has been a wonderful example of pulling together the agencies and having an interaction also with the academic community. And the role of Admiral Watkins has been absolutely critical in making this happen, and I would like to thank him for that, because this gives us a formal structure to work from, the partnership program, which has started in the Navy. And the Navy has done a very good job of accepting the leadership there.

Other agencies, like NOAA have proposed funding for the partnership program and, hopefully, will be able to make that happen. And the National Ocean Leadership Council, which involves a variety of different members, I think, is another piece of this proposal or this current structure which I think can be very useful in helping advance the ocean's agenda.

Dr. COLWELL. I would add that the National Science Foundation is pleased to be one of the Federal partners in the National Oceanographic Partnership Program, in NOPP. In fact, the NSF is contributing half a million dollars to its funding the awards that came out of the NOPP interagency program announcement.

And in addition, NSF has contributed about $200,000 toward the NOPP Educational Drifter program and $100,000 to the Ocean Science Bowl, which is a nationwide high school science competition.

NOPP is really a very critical component of bringing resources together. We are very pleased to be active in it, and I also commend Admiral Watkins for his leadership.

Thank you.

Mr. SAXTON. Thank you.

Before I ask my next question, let me just observe that Mr. Delahunt has joined us. And I am supposed to ask unanimous consent that he be permitted to sit. So asked.

The gentleman from Massachusetts, Cape Cod and Martha's Vineyard and Nantucket, to us sailors known as the land of fog.

Mr. DELAHUNT. And Woods Hole.

Mr. SAXTON. And Woods Hole. And incidentally, if you have never tried to sail past Woods Hole in the fog, you need to try that.

Also, I might note that Karen Steuer is now working for Mr. Delahunt, and, also, I understand there is a close association with the Woods Hole folks.

Mr. DELAHUNT. May I, Mr. Chairman?

Mr. SAXTON. Please.

STATEMENT OF HON. WILLIAM D. DELAHUNT, A REPRESENTATIVE IN CONGRESS FROM THE STATE OF MASSACHUSETTS

Mr. DELAHUNT. I was just having this chat with Mr. Farr.

Mr. SAXTON. That is "Farr."

Mr. DELAHUNT. Thank you for the translation, Mr. Chairman. And he said, "Boy, this is real exciting stuff."

Let me just compliment Mr. Farr, who also had an opportunity to visit Woods Hole, for the work that he is doing in terms of these issues. And particularly I want to compliment Chairman Saxton, who has really exhibited great leadership in this area. And it is really exciting to look out and to see representatives from disparate agencies.

It is exhilarating to really have a chance to visit WHOI to see what is occurring down there. I am sorry I missed the testimony of Bob Gagosian. But this really is the future. And, you know, I think oftentimes the public is skeptical about what is happening here in Washington, DC, but if they only could participate in hearings such as this, they would see that we are on the verge of doing some wonderful things.

I want to thank you, Mr. Saxton, and you, Representative Farr, for really leading this effort in the U.S. Congress.

Mr. SAXTON. Thank you for being with us this morning.

Let me just ask one further question. Then I will pass the baton over to Mr. Farr.

The Administration recently promised $12 million through fiscal year 2002 to assist in the exploration of the ocean. Included in this proposal were expansion to two shallow-water observing programs, to the development of two deep-sea observing programs, and the development of two submersibles.

How will these funds be spent? What will the research goals be? And which agencies will be involved? Of course, I am particularly interested as to whether or not LEO–15 will be included.

Dr. BAKER. Mr. Chairman, let me answer that question.

That money was aimed at NOAA to expand our ocean observation capabilities, something that we have been trying to do for a long time and, as you know, have been urged by Congress to expand our activities centered on the NURP program and also, hopefully, trying to look at some other areas also.

We will be, in fact, coming forward, hopefully, in the year 2000 budget with an initiative that reflects what the President has identified there. And, yes, all of the above are included at the moment. So we expect to see a substantial expansion of what we have had in the past, and each of those items is something that we have committed to, and we are working the process at the moment.

Mr. SAXTON. Thank you very much.

Mr. Farr.

Mr. FARR. Thank you very much, Mr. Chairman.

I am excited about where we are going, because I think, sitting here in late July, that when this Committee convened at the beginning of the year, we were starting to speculate, the Year of the Ocean, we are the Committee with the ocean responsibility, perhaps we can make something of the year. And looking back, it is not even over yet, and look at what the Year of the Ocean has done. It has got the best-seller in the New York Times with A Perfect Storm as a book, and the Academy Award went to Titanic, and Dr. Baker produced the El Nińo. So we have been able to accomplish something in this year and at least get our people to think about us.

Monterey was the kind of the bringing together of the clan. Yesterday we passed in this room the Oceans Act, and I think that there is a momentum gained. And then the excitement is to see that momentum gained and a kind of interest in the issue. And I think Admiral Gaffney pointed out how much we have to do by that graph there.

I guess this is where I am concerned as a politician is how you keep that momentum going. The President pledged some new money in Monterey. I would like to talk to Dr. Baker about that. But I think it is more than just the bill has not yet been passed off the floor. It has not gone through the conference committee, and the President has not signed it, and we only have a few days left of really much work to get done here before it all kind of breaks apart to go into elections.

So the concern I have that I want to ask the panel about is really how do we take this momentum and really build it up? Because what we have learned in the process is that we have an awful lot of governments out there, governments and government, trying to do ocean work. There is a need for better coordination. There is scarce dollars when you compare it to even the amount of money that NSF puts into ocean research versus others, it is still a small amount. The Navy, I do not think, has put as much resources where I think Admiral Gaffney says they need to be.

So how are we going to keep this momentum going so that we can start changing our funding priorities in this country to really match the challenge that each of you bring? And the questions I have about it are to want to know how NOAA, with the $224 million that the President pledged, how is that going to be used to revitalize not only the structure within, but to better coordinate visits and buy equipment that is necessary to do the research? Have you focused on that specifically?

Dr. BAKER. Congressman Farr, thank you for that question, and thanks for your leadership in the oceans arena and for the National Oceans Conference. I think it was a pivotal activity for getting commitment from a variety of stakeholders, including the Administration.

The largest amount of money that was identified at the National Ocean Conference was $194 million to build sustainable fisheries, and the largest part of that, about 75 percent, is aimed at providing for us new, very capable fishery vessels that would replace the more than 34-year-old vessels which we currently have in NOAA so that we can improve our stock assessment and fishery research, a key element of building sustainable fisheries. The acoustically quiet ships are going to be a very important part of that.

That was an important new commitment. We have been trying for several years now to get the Administration to commit to new seagoing capabilities for NOAA. This will be the central piece of that. We will be doing this design. We are doing design in conjunction with experts from the Navy, with experts from abroad, so that we have the best possible activity there. The fisheries vessels were the biggest piece of the commitment.

We also have a commitment for new ocean technology to expand our deep sea exploration for ocean monitoring, for navigational charts. As you remember, there were nine specific initiatives that were identified, and I think we got a good start in each of these. But I think also, very importantly, at the conference, the President committed to bringing together all of the Cabinet agencies that are responsible for oceans issues to report back to him in 1 year about how we were cooperating to keep the momentum going. And I think that, together with the passage of the Oceans Act, will provide us the context to work in the Federal Government and the private sector to keep this momentum going on the ocean. So I think we have a very good start here.

Mr. FARR. Dr. Colwell, at NSF, a part of your testimony was sort of all the needs that need to be looked at. Do you see a shifting of priorities to address those needs and the funding at NSF?

Dr. COLWELL. I think there is a need at NSF to be more heavily investing in environmental research overall, and certainly the oceans are a major part of it. But let me point out that I think what is happening in recent years is that there is a clear set of evidence that demonstrates the relationship of human health to the health of the oceans and to ocean events. That is, by being able to measure sea surface temperature, to correlate sea surface height, temperature, nutrients, we are better able to show a relationship, for example, to toxic algal blooms, to microorganisms that may cause human disease.

And so, as we improve our ability to develop predictive capacity for demonstrating this very close linkage to human health, as well as economics, through fisheries and so forth, I think a more dramatic case can be made for increased resources; and NSF certainly supports expanded research.

Mr. FARR. Admiral Gaffney, thank you for your leadership in being able to host this conference at the Naval Postgraduate School at Monterey. I was really proud and pleased that that was the venue.

However, I have to tell you that I am a little concerned because the language was inserted in the bill that we passed yesterday that excludes all military operations, I think it says specifically all Navy military operations and training measures, from consideration by the Ocean Commission. It specifically moves the Navy out. And I am wondering if you think that that is going to hinder the ability for the Commission and the Navy to move toward the things that you said need to be addressed?

Admiral GAFFNEY. No, sir, I do not think it will.

In the research area and in the collection of oceanographic information in an operational sense, we are so tightly coupled, these agencies, the agencies at this table and others, and we will stay coupled just to survive so we can leverage each others' dollars and do what we need to do, that we will by necessity continue to work regardless of what happens. So I think we will do just fine.

We have other mechanisms. The people seated in the back four rows here that actually get their hands dirty with oceanography talk to one another all the time without any help from the people seated at this table, and they will continue to do that by the best people performing and bringing the right critical mass of money together to get things done.

Dr. COLWELL. May I add just a comment to that which you pointed out very succinctly, Mr. Farr; that there is insufficient funding?

Let me note that NSF now provides more than two-thirds of all the Federal resource support for the Nation's universities and ocean research institutions. Clearly, an increase in funding is necessary.

Mr. FARR. I appreciate that. But of your total funding, of your total pie, of outflow, what is the percentage of ocean compared to——

Dr. COLWELL. I will have to get back to you on that, I am not sure.

Mr. FARR. When you compare it to all the ocean funding. Because this is the problem. We have always said we have committed much more. We argued the space station last night. Space station has more funding than all of the program.

Dr. COLWELL. I think as a Nation we need a greater commitment.

Mr. FARR. So what you are talking today is we need a space station for the ocean.

Dr. COLWELL. I would agree, in general.

[Information submitted by Dr. Colwell follows:]

FUNDING FOR OCEAN SCIENCES RESEARCH

The National Science Foundation provides most of its support for ocean sciences research through the Division of Ocean Sciences (OCE) of the Directorate for Geosciences (GEO). In FY 1997, OCE's budges totaled $200 million, approximately 8 percent of the Research and Related Activities (R&RA) Account. Total ocean sciences support for the Foundation, including funding through the Office of Polar Programs and the Directorate for Biological Sciences, equaled approximately 10 percent of the R&RA Account in FY 1997.

Dr. BAKER. Mr. Farr, I am not sure I would agree with that exact statement, that we need a space station for the ocean, although I agree with the amount of funding. Maybe that is the point you are making.

Mr. FARR. Well, the point is exactly, you caught it, the emphasis and the concern and the passion for putting money into research in the ocean. We can do it, I think, more cleverly. I think that the space station has international collaboration, which is something else we support.

My last question, back to Admiral Gaffney, does the Navy support the exemption that was in the oceans bill?

Admiral GAFFNEY. I believe that the Navy does. I am not an expert on that, I will have to admit, sir, but it is my understanding that the Navy does support the exemption that is in the legislation. But I am not sure it is an issue for this particular group of people in this room. We will work together. We will take a leadership role.

If I can go back to your question about funding, I will give you a little personal example. I raised my right hand and went to the Naval Academy in 1964, and basic research, Navy basic research, which started this whole basic research out, by the way, at the end of World War II, was $2.2 billion in today's terms. Basic and applied research, I am sorry. Basic and applied research. Today, it is .8 billion in today's terms.

Now, in the past few years, despite that decline, we have given most favored nation status to the ocean sciences, ocean and related sciences; ocean remote sensing, marine meteorology, that all work together. But if we don't get some growth, if we don't turn up that curve, as has been proposed by Secretary Dalton, to get that turned around the other way, then we are going to be in worse trouble than we are today. And I think that we will also start to disincentivize people from getting into the research sciences as a career in the Nation.

Mr. FARR. One of things I thought was very interesting, in talking to Dr. Ballard about the Jason Project, which the Navy supports, in fact, its largest Federal funding comes from the Navy, but Dr. Ballard said that the majority of the money that Jason raises comes from American corporations. And I asked why would they put so much money, these are millions and millions of dollars that are put into this project, and he said that some of the businesses in this country really understand the need to have ocean research. We need the science, we need the technicians, and they are not being produced because there is not enough ground interest. And the Jason Project certainly has been able to bring that around.

I have been always accused of being a big spender. If I can be a big spender in the ocean, I would love that title, and I would try to support more and more efforts to get money to the entities that are going to do good work. Thank you.

Thank you, Mr. Chairman.

Mr. SAXTON. Mr. Delahunt, do you have some questions?

Mr. DELAHUNT. No, I don't have any questions. I would just make one comment, Mr. Saxton, listening to both you and to Mr. Farr and the testimony.

I think that if the public awareness is such that they can easily and readily understand the potential benefits of ocean research and what is occurring today, that the funding for the technologies for which you have called this hearing—I think there would be great public pressure to secure that funding. And I think that the community at large, the stakeholders in that community, really have an obligation.

You have two tremendous advocates here in Mr. Saxton and Mr. Farr. But if you have a capacity to transmit the potential to the public at large, to the American people, the funding will be there.

Mr. SAXTON. Thank you very much, Mr. Delahunt.

Let me ask one final question for the record. The administration has announced that it intends to build at least three new fisheries research vessels. The assumption seems to be these vessels will be built with government funds and owned and operated by the government.

A recent report prepared by the Office of Management and Budget praises the design of the vessels, but raises significant questions about whether these are the most cost-effective alternatives for providing the necessary fishery data. The report also raises significant questions about whether NOAA will fully use the technological abilities of these ships and whether it generally uses the best available technology when conducting fishery research.

Will the administration look at the build and charter contract operations or contracts for data to meet the fishery research needs? How does NOAA intend to assure the use of best available technologies in fishery research?

Dr. BAKER. Congressman Saxton, we are very concerned about getting at the most cost-effective way of doing business at NOAA. We have not committed to any particular way of getting that capability. The thing we have focused on is the capabilities that are required, the acoustically quiet capabilities.

But at the moment, whether we build and charter, whether private industry offers this, whether it is something that is government owned and operated is something that has to be laid on the table and worked out in terms of cost-effectiveness. All of this is open. We have not made any commitments to the way we would do that.

All we are looking at, at the moment, is the scientific capabilities, and we will make sure we work with you and the private sector to provide the most cost-effective way of getting the capabilities that we need.

Mr. SAXTON. Well, thank you very much.

I would just like to make one final comment. The exemption in the Oceans Act for exemption for operation and training, Admiral Gaffney is the Chief of Naval Research, and we would just like to point out that he did not seek to be exempt. Thank you.

Dr. BAKER. Congressman Saxton, let me answer one question of Dr. Delahunt, who mentioned the public education aspect of oceans. I think it is absolutely critical, and I wanted to say the Woods Hole Oceanographic Institution has done a wonderful job of public outreach, which is done also by the Scripps Institution of Oceanography, and some of the other academic institutions, has been a very important aspect of public outreach.

And we look forward to working on the Federal side with our counterparts in the academic community to get this public outreach and enhance it, as you say. I think it is a critical point.

Mr. SAXTON. One follow-on question. The report that was recently completed for the Office of Management and Budget noted the need to better integrate fisheries and oceanography research. These two areas of research have been conducted largely separately over the last 20 years. To manage fisheries wisely, it is becoming clear that we need to understand the physical systems in which those fish live and the interrelationships between species, particularly the predator and prey relationships. Just counting fish is no longer sufficient.

How can we improve the interaction and our knowledge thereof between fisheries scientists and oceanographers?

Dr. BAKER. Congressman, this is a very important aspect of fisheries, and we have some very nice joint programs with the National Science Foundation and NOAA. There is a program called the GLOBEC, the Global Ecosystem Study, where, in fact, we are looking at how all of these factors interact; and then there is a NOAA-led program called FOCI, Fisheries Oceanography Cooperative Investigation, that is looking at the impact of climate on fisheries.

And, in fact, as we look at salmon migrations right now, they are very much impacted by these long-term changes in the north Pacific Ocean. And through these programs, GLOBEC, FOCI and other related programs, we are starting to get some understanding of how the physical and chemical aspects of the environment affect the ecology. It is an important, complex aspect of fisheries, and I think we have made a good start, and, hopefully, some of this new funding can be applied there.

We are looking forward to the leadership of Dr. Colwell, who is a person who has been a scientific leader in these areas, as she directs the foundation to help us move these programs forward.

Mr. SAXTON. Well, thank you very much. I would like to thank all of you for your testimony this morning and for your statements. We appreciate very much that you are here. Members may have some additional questions for the witnesses, and we ask that you please respond in writing. The hearing record will be held open for that purpose. Thank you very much for being with us.

[The information referred to may be found at end of hearing.]

Mr. SAXTON. Now, let me introduce our second panel. Panel two, we have Dr. Charles Kennel, Director of Scripps Institute of Oceanography; Dr. Gagosian, who opened our hearing this morning, of the Woods Hole Oceanographic Institution; Admiral James Watkins, President of the Consortium for Oceanographic Research and Education; and Dr. Fred Grassle, Director of the Institute of Marine and Coastal Sciences.

And let me remind you of our 5-minute rule, for purposes of moving the hearing forward. I am going to leave the chair for a moment and ask Mr. Farr if he will please take over.

Mr. FARR [presiding.] Dr. Kennel.

STATEMENT OF CHARLES KENNEL, DIRECTOR, SCRIPPS INSTITUTE OF OCEANOGRAPHY

Dr. KENNEL. Mr. Chairman, I want to thank you for the opportunity to testify. I am the new, somewhat wet-behind-the-ears Director of the Scripps Institution of Oceanography in La Jolla, California.

When NOAA makes its weather forecasts that reach almost every home in the United States, they rely on a whole variety of observing techniques, mostly of the atmosphere, including balloons, aircraft, radar, ground measurements, and satellites. They integrate all of these observations, and feed them into the most advanced computer models available.

And when NOAA makes forecasts that extend beyond 2 days, it has been known for the last 30 years that global coverage is needed. So now it is time for the community to move forward, to go from forecasts of 5 days to forecasting next year's weather and, ultimately, the climatic conditions of tens of years from now. As we do that, a broader range of physical effects and scientific issues will need to be included in the observing strategy that started with the weather.

Now, scientists have known for more than a century, that the ocean is the primary driver of climate through its interaction with the atmosphere. Now the public understands that in a way that they never did before.

The 1997–1998 El Niño led to an understanding in the minds of the average person that events in the middle of the tropical ocean actually have an important effect on their day-to-day lives. This is new public understanding. And we believe that this new understanding can be translated into the support needed as we develop an integrated observing strategy to predict climate over a longer period of time.

What we need right now is a strategy to get started. We know some of the things that the strategy would have to achieve. It would have to integrate local measurements in the ocean and of the ocean with space-based measurements. The space-based part of the integration has already begun with an international process through the Committee on Earth Observation Satellites.

If we had the beginnings of our strategy in place, we would also be able to identify those areas of critical technology development that we could focus on to increase the capability of and lower the cost of the integrated system. And we would, at the same time, identify those variables—we can identify some now—which need long-term monitoring.

Finally, we would begin to relate these two developments to the dramatic improvement in climate models and computing power that is needed and possible. There are new initiatives at the National Science Foundation and the Department of Energy being contemplated to address this problem.

I would like to point out from a recent visit to Japan, that they have developed a very impressive Frontiers program that links together their marine agency, their space agency, and their universities to develop and devote major computing power to an integrated observing strategy for the climate.

As has been mentioned earlier many times, it is essential to improve, strengthen, and direct in a more focused way the cooperation and the coordination of the activities amongst government agencies and institutions. I think the beginning of a clear strategy of how to get started at the national level will enable us to show leadership on the international level. So the strategy and getting started is very important.

The first thing we need to do is to integrate the various ocean observing techniques. The first poster shows some of the many different ways of observing the ocean that have been developed, many of them over the last 10 years. We now need to think about how to meld this capability into a system. We will need leadership, cooperation, and coordination.

We need to support research that demonstrates the value of integrating observations from different sources into computer models with the goal of predicting climate. Scripps is involved in three such experiments. One is an experiment on acoustic tomography, in which we relate these results to satellite measurements from TOPEX-Poseidon, and the combination of the two measurements creates an improvement.

You have already heard of the Global Ocean Data Assimilation Experiment, initiated by the international satellite community to relate satellite and in situ data to see the extent to which the combination will improve predictions of ocean state.

And Scripps itself, with the strong support of the National Science Foundation, has been involved in an experiment called the Indian Ocean Experiment. This is a comprehensive experiment involving the efforts of 25 nations, ships, balloons, airplanes, and satellites. Their data will be combined into a single information stream that will be available to all.

Finally, I think we must support the basic technology development of our observing systems, including the NOAA global drifting model initiative, DOE's comprehensive earth modeling efforts, and the Navy's strong support of technology development.

In conclusion, the most important question in environmental science is "What is going to happen to me?" And until we can help you give scientifically reliable answers on that issue to your constituents, they will not know whether to repair their roof because an El Niño is coming or what to believe about scary issues, like the greenhouse effect.

Mr. Chairman, we have many of the tools at hand to start improving our answer to that question. We need leadership, a strategy, and investment in those things that pull the system together. Thank you.

Mr. FARR. Thank you very much, Dr. Kennel. We will be asking questions after the panel finishes.

[The prepared statement of Dr. Kennel may be found at end of hearing.]

Mr. FARR. Dr. Gagosian, welcome back.

STATEMENT OF ROBERT GAGOSIAN, DIRECTOR, WOODS HOLE OCEANOGRAPHIC INSTITUTION

Dr GAGOSIAN. Thank you, sir.

Mr. Chairman, Mr. Farr, Mr. Delahunt, thank you for inviting me here to speak with you about deep sea research. As you could see from the video presentation, I tried to give you some examples of how we get to the deep sea and what we see when we get there. Now I would like to address why it is important to the Nation that we continue to be there and what is needed to continue to improve our research, monitoring and assessment capabilities.

Through our association with, and the long-term investments of, the Office of Naval Research, the National Science Foundation, and the National Atmospheric and Oceanic Administration, we have made significant scientific advances in understanding the ocean's processes and properties. With that investment, we have been able to support an infrastructure for ships, vehicles, instrumentation, education programs and, above all, human talent that is the envy of the world.

But what do we mean by the deep ocean? Why do we want to do research in such a formidable and hostile place? The deep ocean is a world of slopes and canyons, of abyssal plains with depths greater than 9,000 feet, and of midocean ridges rising as much as 12,000 feet. These ridges are linked around the world into a 40,000-mile underwater mountain range, the longest one on earth, 2½ miles beneath the sea. There are approximately 2,000 sea mounts on the sea floor, which rise from 3,000 to 10,000 feet. There are also valleys and trenches that vary to extreme depths. The deepest spot in the ocean is about 7 miles, roughly the distance you see when you look down from an airplane. Yet only a few percent, as Admiral Gaffney pointed out, of the ocean floor has been explored.

Now, there are many reasons why we go and must continue to go to the deep ocean. It is where our planet earth is presently being formed, contorted, stretched and quaked right now. A clear example is the tsunami that recently struck Papua, New Guinea, that was caused by an offshore earthquake.

Samples of ocean sediments, which contain the shells and skeletons of previously living ocean creatures, provide us with a history of previous climates and life forms. The deep ocean is not quiet, nor is it unchanging. Deep ocean currents hold the key to understanding the workings of the global conveyor belt that carries warm surface water to the north polar region in the Atlantic and returns cold water to fill the deep ocean throughout the world. Understanding this circulation is critical to our understanding changes in the earth's climate, which will ultimately lead us to predictions of what environmental changes the ocean can sustain from the atmosphere, such as carbon dioxide input.

A very new and exciting application of deep sea observing is in the forensic study of modern shipwrecks. As noted in the video presentation, our institution has just completed a task for the British Government by mapping the remains of the M/V Derbyshire, which sank in 14,000 feet of water in 1980. The Derbyshire is one of 120 bulk carriers lost at sea since 1980, with the aggregate loss of 1,300 lives. Our equipment and talented oceanographers determined why and how it sank, which led to recommendations on how to prevent future failures on these ships, thus potentially saving many precious lives and millions of dollars. The results of this work were not only the subject of a TV documentary, but were acknowledged by the highest levels of the British Government.

I would be remiss, Mr. Chairman, if I did not speak about one of the most important discoveries of this century, and that is the world of the hydrothermal vents, which you saw on the video I presented. These vents not only churn hot seawater through them and alter its chemistry, but also provide habitats for amazingly abundant exotic life forms, as you saw. Ancient as this life may be, its existence provides a significant leap in our knowledge about life itself. Two-thirds of these life forms have never been observed before. Perhaps more importantly, what this may likely provide is the key to our definition of the origin of life on our planet, and the possibility of life on others. The environment is also where we believe new pharmaceuticals and biotechnological opportunities exist.

I will close with some remarks about the future, particularly with regard to human occupied vehicles. The Navy's deep submersible Sea Cliff has just been transferred to the custody of the National Deep Submergence Facility at Woods Hole Oceanographic Institution. As a matter of fact, it should be crossing the Bourne Bridge right now on a flatbed truck as I am speaking.

It is understood that the Federal agencies intend to underwrite the expense of an engineering study that will analyze the cost, feasibility and technical alterations required to merge the most capable features of Sea Cliff and Alvin. Depending on what the engineering studies produce, and the availability of funds, we hope this will lead to an Alvin upgrade to give it a 7,000-meter depth capability, almost 4½ miles. It has currently a 4,500 meters capability. This would give our human occupied vehicle access to 98 percent of the ocean bottom. It would also give the United States the international leadership role in HOV exploration, something that we lost 10 years ago.

In summary, Mr. Chairman, that is how I see where deep ocean science has been and where it should proceed. We need to capitalize and build on the expertise of today's people and technology to produce a robust capability for tomorrow. There is a tremendous amount we still do not know about our own planet. We have the minds, the questions and the technology at our doorstep.

If the last 30 years is any indication, future discoveries will have great benefit to the Nation and the world. If we want to manage, protect, and use our planet wisely, we need and must understand how it works. We are ready to go, we need a national plan to accomplish this, and we need your support and help. Thank you.

Mr. SAXTON. [presiding.] Dr. Gagosian, thank you so much for your very enlightening testimony.

[The prepared statement of Dr. Gagosian may be found at end of hearing.]

Mr. SAXTON. I would like to skip over Admiral Watkins at this point, if I may, and introduce my friend and one of my heroes, Dr. Fred Grassle, from New Jersey, and let me just say a word to Mr. Farr and to Mr. Delahunt about why Fred Grassle is my hero.

Fred is a guy who seems to be able to make things happen that wouldn't normally happen. Fred acquired an old—it was Rutgers University, and through Fred's leadership and a couple of other people, they acquired an old Coast Guard facility at the end of an old road called Seven Bridges Road, on a point of land adjacent to Little Egg Inlet and at the mouth of the Mullica River. They transferred it into a fisheries research facility, transformed the upstairs into a dormitory, and became so busy they subsequently built a dormitory at the other end of Seven Bridges Road to house the multitude of students that became interested in the facility.

They decided they needed to look under the ocean outside of Little Egg Inlet and established the first permanent undersea observatory in the world. They got private industry to help fund it. They got Bill Hughes and I to become involved in the issue, and now we are among the proudest to have in my district, at the end of Seven Bridges Road, this facility known as LEO–15 and the research facility.

And I am very proud to be able to introduce Fred Grassle, one of the people that made it all happen. Fred.

STATEMENT OF J. FREDERICK GRASSLE, DIRECTOR, INSTITUTE OF MARINE AND COASTAL SCIENCE

Mr. GRASSLE. Thank you, Mr. Saxton, for those very kind comments. Members of the Subcommittee, thank you for inviting me to testify on the status of oceanographic monitoring assessment. I particularly want to thank the chairman for his long-standing interest in the subject.

On land we take for granted continuous, real-time, high resolution information provided by our senses; what we see, hear, or smell. Our presence in terrestrial environments provides us with a high proportion of the information needed to assess fundamental environmental and ecosystem processes. We are not so fortunate when we try to predict ocean processes, lacking the common-sense view of our environment that is readily available on the land.

The ocean is a relatively unknown, dangerous and unpredictable place. The livelihood and security of nations has long depended on their seafaring abilities. Efficient, safe sea transportation is a requirement for the economic success of our ports and coastal economies. We need better prediction of coastal hazards, including storms, coastal erosion events, harmful algal blooms, and oil spills, or even when and where to spend a pleasant day fishing or swimming. Naval commanders need to understand as much as they can about their surroundings, as you heard from Admiral Gaffney, at all times, especially in initially unfamiliar environments.

Natural variability is poorly understood so that it is relatively difficult to measure the effects of pollutants or other human-induced change. Ocean ecosystems are said to provide the greater part of the services needed to sustain our society, yet the mechanisms controlling the delivery of these services are poorly known. We have made a commitment to obtain high resolution, long-term measurements from a broad corridor of marine and coastal habitats from the watershed of the Mullica River to the deep sea, as you just heard, using a series of long-term ecosystem observatories or, LEOs, off New Jersey.

Our most intensive study has been at LEO–15, a site at 15 meters depth on the inner part of the continental shelf off Tuckerton and Little Egg Harbor, New Jersey. This has been a joint project with Chris von Alt's group at Woods Hole Oceanographic Institution and industry, as you have heard.

Just as meteorologists monitor present weather conditions and use a combination of observations and computer models to generate weather forecasts, Rutgers oceanographers are using an observation network to monitor the coastal ocean and computer models to forecast its daily changes. The observing system is serviced by an electro-optical cable that runs under the coastal waterway and under the ocean floor to connect two underwater nodes to the Rutgers University Marine Field Station, and from there to the Internet, where it is available to all.

The system transmits video, sound and data on light, temperature, salinity, currents, wave height and period, sediment transport, plankton blooms, and a broad variety of chemical characteristics from numerous sensors that move up and down in the water or are plugged into the nodes at the bottom. Docking stations, developed at Woods Hole, allow autonomous robotic vehicles to sample along transects away from each fixed site and to return to download data and repower batteries.

You saw this vehicle in the video from Woods Hole. Yesterday, the REMUS vehicle did a 60-kilometer run, measuring currents, temperature, salinity and depth over the whole distance of LEO–15. It has repeatedly docked and sent data back to land and over the Internet at LEO–15 during the past 3 weeks.

Boats and divers visit the site on days when the weather is good, and the satellite dish provides broad coverage of sea surface characteristics, temperature, ocean color, and surface roughness. Shore stations, using high-frequency radar, provide patterns of surface currents and provide data on weather in the immediate vicinity of LEO–15.

I have attached a schematic representation of LEO–15 to my testimony, and I hope you all have copies of that.

We expect to add additional observatories at intervals across the continental shelf and into the deep sea. Additional observatories along the coast, such as that proposed off Martha's Vineyard, will add another dimension to what we hope will eventually become a global system.

This work has been supported by the National Science Foundation, NOAA, the National Undersea Research Program, Office of Naval Research, and the last year by three grants from the National Oceanographic Partnership Program. Our most recent grant will transfer the lessons learned from LEO–15 in 1998 and 1999 to a program using a combined observation and modeling system to predict harmful algal blooms in the Gulf of Maine in the year 2000.

We can provide the observations needed to maintain ecosystem services from the ocean, enrich science education in our schools, and bring a greater consciousness of the ocean into our daily lives. I strongly urge you to support, through individual agencies and the National Oceanographic Partnership Program, the further development of a national and global ocean observing system. Thank you.

Mr. SAXTON. Fred, thank you very much.

[The prepared statement of Mr. Grassle may be found at end of hearing.]

Mr. SAXTON. And now we will go to our cleanup man, Admiral James Watkins.

STATEMENT OF JAMES WATKINS, PRESIDENT, CONSORTIUM FOR OCEANOGRAPHIC RESEARCH AND EDUCATION

Admiral WATKINS. Thank you, Mr. Chairman; thank you, members of this Committee, for inviting me here today.

As you know, Mr. Chairman, I am President of the Consortium for Oceanographic Research and Education, the acronym we call CORE, consisting of 52 of the Nation's marine institutions. We represent those institutions here in Washington and have also initiated or undertaken a number of national projects, including the National Ocean Sciences Bowl, and we won the ONR bid for the program office for helping them run the National Oceanographic Partnership Program.

Previous witnesses have described to you several outstanding examples of the kinds of capabilities we have or will soon have and some of our priorities to better understand, monitor and predict the greatest natural force on earth. They have told you what we need to do and why. What I would like to do today is to provide a conceptual road map for how to do what they suggest; that is, how we might transition from the ideas of our researchers, working with the decisionmakers here in Congress and the administration, to an actual system which integrates our national needs and priorities.

We have come to an important juncture in the development of ocean science. More than ever our progress is limited by the lack of important ocean observations. As the Ocean Studies Board of the National Research Council has clearly stated in their new report, "Opportunities in Ocean Sciences: Challenges on the Horizon," the questions of marine resource management, climate prediction and the role of oceans in human health require extensive and long-term observation of the oceans on global, regional and local scales.

Mr. Chairman, I would like to submit a copy of this report for the record.

Mr. SAXTON. Without objection.

[The information referred to may be found at end of hearing.]

Admiral WATKINS. The merits of a variety of independent observing and predictive system proposals, many of which were presented here today, are well understood and accepted. But what we do not currently have is the strategic framework within which we can chart a course to final realization of an integrated ocean observing and predictive system.

We need to couple an analysis of the mission responsibilities of the various Federal agencies with our current and planned observational capabilities to determine the best opportunities for predictive success. From this analysis we can build a plan detailing exact requirements for a comprehensive ocean observing system and address questions on a variety of time and space scales, assimilating, infusing information from these various sources, much like the well-established practices of the defense intelligence community. Analysis and interpretation would then provide the products which we will rely on for better prediction and decisionmaking.

Let me give you an analogy. Early in the cold war, from many prior years of ocean research in deep ocean sound propagation, we developed a highly capable and integrated system called SOSUS, the sound surveillance system. This is a giant series of listening arrays in the Atlantic and Pacific, which eventually contributed significantly to our winning the cold war. Observations from these fixed arrays were highly integrated or fused with multisource observational and predictive data from satellites, ships, aircrafts, human beings and other sensors over a wide geographic area.

Notable is, one, the definition of a national need, with a full understanding of the cost and benefits; two, the commitment to develop a system, not just a collection of parts; and, three, the contribution of all sectors, each bringing their own strength to meeting a complex challenge; and, four, predictions with high probability of success.

The resultant $16 billion investment was repeatedly justified.

I should also note that the first SOSUS array went from the blackboard in 1949 to full-scale operation in 1952, only 3 years later, and at a $1 million initial investment.

Let me now shift to the graphic, which the Committee members have been provided, and the graphic is displayed up there on the first easel. The graphic is an attempt to place into context what I would call a strategic framework for ocean predictions. You will see in the center of that framework what is called the Ocean Observational System. It is a meld of sensors and platforms, including remote sensing, that would be satellites, SOSUS, aircraft; fixed sensors and platforms, that is the TOGA mooring that gave us additional predictive capability for El Ninŏ, the LEO–15 we just heard about, and seismometers. Then there are drifting and unmanned sensors and platforms, including surface drifters, autonomous underwater vehicles, and remote operating vehicles. Then there are ships and submarines, called the UNOLS fleet, which is the academic fleet, University National Oceanographic Laboratory System, the deep submergence vessels, vessels of opportunity, which might include the last of the nuclear submarines that have the capability of going under the ice and can explore areas of surface that no other platform and no other sensor can reach.

Then, inside those, are the information exchanges, with each of those, what I would call subsystems of a larger system, for data access, archival, storage of information, data assimilation and computation. Each of those adds value in itself to our society.

But what we miss, then, is taking that and moving it into a product and benefit, which you see on the right side of my chart, which goes through what I would call a virtual common data center, where all this is brought together in analysis and interpretation and doing the kinds of things that the Congress challenged the National Ocean Research Leadership Council to come up with.

They told us, the Congress told us to address that issue and try to do the analysis and interpretation to give us the products and benefits of climate forecast; sustainable resources which would be the fisheries, as an example; human health, which Dr. Colwell talked about this morning; military readiness, which is an essential part of it.

And by the way, while I have the greatest respect for Admiral Gaffney, I think it is a mistake to leave the Navy out of anything, to exclude them from anything. They are a key part of ocean science and technology. They used to be 40 percent of the entire ocean science investment in the Nation. They have now gone to 20 percent. And to leave them out is absolutely preposterous. What we heard from Admiral Gaffney was a work-around; that despite what exclusion you put in, we are going to work it any way. That is just an aside, Mr. Chairman.

At any rate, what we need now, though, you have seen this graph, and on the left is the mission statement for the Nation, and that doesn't come out of my head. That is what the Congress told us in the National Oceanographic Partnership Program, to horizontally integrate these agencies by national security, economic development, quality of life and education. And that is what we are doing. And those cut across all lines.

And so, therefore, for the first time, we have a thematic approach to horizontally integrate research and development in this Nation in the oceans, and that is a paradigm for any other scientific endeavor, in my opinion. So we have on this chart, then, what I would call the total framework for ocean modeling and predictions that can really give society something new.

Now, what we need from the Congress is your assistance to move aggressively in this framework to an integrated strategic science and technology plan. We in the academic community are asking the Congress to task the administration to work with them to develop such a strategic plan in the form of a comprehensive and integrated ocean observing system that can lead to more useful products and benefits for all, as shown on my chart.

We believe, in addition, that to carry this out the Congress should request the administration to employ the National Ocean Research Leadership Council, consisting of the leaders of each of the nine Federal ocean research agencies, to define components, priorities, research requirements, and some sense of time lines that might be anticipated. This plan should show how an integrated system would optimize the Federal effort to meet specific objectives within those time lines, making clear the products and benefits expected. The plan should address the involvement of other maritime nations with whom we share mutual objectives and can expect some equitable share in the enhanced investments which will be required. This plan should build upon the volumes of well-thought-out agendas developed by the individual agencies, the National Academy of Sciences and other national and international bodies in past years.

Mr. Chairman, this will certainly require both Congress and the administration to come together to make some new resources available. I think so often when we talk about partnerships, we forget the fact that we need a partnership between the Congress and the administration on this issue. We cannot do it alone. There has to be close leadership cooperation here to try to set some new standards here for this kind of integrated science and technology plan.

So often we talk about, well, the Federal Government has to have partnerships with academia and so forth. We need a partnership with the Congress on all this. As you know, we have tried to work that way through the National Oceanographic Partnership Program and its development. We need to continue that, with perhaps joint hearings up here between the Resources Committee, the Science Committee, the National Security Committee, not to talk about budget, not to talk about program, but to talk about strategy. What are we doing? How are we pulling this together? So when the agencies come through with their budgets, you can see them inside a broader strategy. I think that is a worthy objective that the Congress should set.

So on the horizon we can envision greatly enhanced coastal weather and longer-term climate forecasting, more efficient shipping, more informed decisionmaking for difficult environmental and resource management questions, just to name a few benefits.

For the last 50 years of this century we devoted our national attention on outer space, and properly so. We need to focus our attention in the next 50 years, in the next century, to understanding how inner space, the ocean, can assist mankind in meeting its burgeoning challenges.

The Congress has already set in place a perfect mechanism for implementation of this kind of initiative by creating the National Oceanographic Partnership Program. This program provides a platform for collaborative work by the U.S., as well as international ocean research agencies who are looking to the United States for leadership, but they want to know where to plug in. They have a place to plug in now, and we have to engender that to leverage these dollars.

There ought to be a 50–50 share line with the United States and other nations, and we know how to do that. The academic institutions know how to work with them. But we have to have the leadership of the Nation, and that includes the State Department in S&T and foreign policy. You know, I have been clamoring for that, to improve that, and I know the State Department has asked the National Academy to come back and give them a recommendation, but that is a year from now. We need to move it now. We are talking about potentially large investments in an ocean observing system globally, and that means we have to start now with people involved at the front end of the design of such a system.

Anyway, Mr. Chairman, I hope you will consider my recommendations. I look forward to continuing to work with you to ensure we are doing everything we can to make wise use of the greatest natural resource on earth. Thank you.

[The prepared statement of Admiral Watkins may be found at end of hearing.]

Mr. SAXTON. Mr. Delahunt has some time constraints. Would you like to ask a question before you go?

Mr. DELAHUNT. No, I don't need to ask a question, Mr. Chairman, but I do thank you for the invitation, and I hope to participate. It has been very informative, and I particularly appreciate the sense of urgency that Admiral Watkins has brought, and I think that the ideas forthcoming from all the panelists lead me to the same conclusion reached by Mr. Farr; that this really is an exciting time.

And I personally do want to work with Chairman Saxton and Mr. Farr and others in these potential breakthrough initiatives we are talking about. Thank you, Mr. Chairman.

Mr. SAXTON. Thank you, Mr. Delahunt. I look forward to visiting your district this August.

Admiral Watkins, you touched on a subject that is near and dear to the hearts of many of us, in particular Mr. Gilchrest, who talks about the diffusion of responsibilities for ocean issues, and, in particular, not just between the administration and the Congress, but even here in Congress.

I have forgotten the number, but it is unbelievable. It seems to me like there is something like 17 or 18 committees.

Admiral WATKINS. Forty-seven committees, Mr. Chairman; forty-seven committees of authorization, appropriation, in both House and Senate. Yes, sir.

Mr. SAXTON. That even goes beyond what I think we had anticipated. But when we established this Subcommittee, Chairman Young was kind enough to agree to the suggestion that we ought to have a committee that's named as being responsible for the oceans, and finally the title became partly subcommittee on oceans.

So we are hopeful that we will be able to work with the House leadership. And we have, under the leadership of Mr. Gilchrest, begun to talk about how to or whether it is possible, given turf battles, et cetera, to restructure the way we do business in the House to focus more clearly on ocean issues someplace. And, of course, I think it ought to be here, but I am sure everybody has their own idea.

But it relates very much to the objectives of the National Oceanographic Partnership Program. And I guess I would just like to ask you each, have your institutions seen a change in the level of cooperation subsequent to the establishment of the National Oceanographic Partnership Program? Is it working? Does it need any refinement, or is it just fine the way it is and working well?

Dr. Grassle.

Dr. GRASSLE. I would like to comment on that. In building LEO–15, a lot of people were involved. The National Underwater Research Program funded a lot of science out there, which enabled us to begin to understand the environment well enough to really develop the LEO–15 concept. The National Science Foundation actually funded the infrastructure of the system. But more recently we feel that the possibilities for using something like LEO–15 can only be realized through the kind of broad partnership that our funding from the National Ocean Partnership has allowed us to develop.

We have oceanographic equipment companies coming down and finding out things about ocean instrumentation that is off the shelf that we didn't know about, because we are comparing these instruments in the field. Any instrument of any sort can be plugged into LEO–15 and compared with any other instrument. The REMUS underwater vehicle, in its 60-kilometer run yesterday, was running the same route that a towed vehicle from a boat was running with similar instruments. So we have direct comparisons to be made.

We also had Navy SEALS visiting, just because they were curious. They were working with Chris von Alt in another area, and they really wanted to see what was happening at LEO–15 and were very interested.

In the education area, one of our grants is in education, and we are working with school systems in New Jersey. LEO–15 is available on the Web page. That would not have been possible without the kind of broad approach to thinking about observing systems that the National Ocean Partnership has allowed us to develop.

The Office of Naval Research has been supporting the modeling that relates to these coastal systems. And through the National

Ocean Partnership, we have fully integrated the modeling with the observing system so that the models are assimilating data, and we are making actual forecasts of the ocean. And we were pleased last week that the weatherman in our local area, in your district actually, referred to the upwelling and what it was like for the people going to the beach.

So I think that the National Ocean Partnership has really helped us develop the kind of crosscut all of us envisioned. I think I had the opportunity to testify before this Committee once before, in discussing something that I know has been foremost in your mind, as to how to get crosscutting information more available to make decisions about the environment. For the oceans, the National Ocean Partnership has been an important step in that direction.

Mr. SAXTON. Thank you very much. Anybody else want to comment?

Dr. GAGOSIAN. Mr. Chairman, I would like to make a couple of comments with respect to the collaboration. If one looks at the list of principal investigators, and the projects they have been involved with, and the sums of money over the period of time, it is very difficult to do that with just one Federal agency. So there is a tremendous leveraging capability that the partnership program allows for. And in many ways it is an initiation of that collaboration, and I will just give you an example.

The LEO–15 exercises that Fred was talking about has led, as he mentioned, to Chris von Alt's work in wanting to establish another site on Martha's Vineyard, where there is open water all the way to England. The National Science Foundation has funded that. On the other hand, there is a significant amount of cost-sharing that is involved.

Because of the success at Rutgers in New Jersey, we were able to obtain over a third of a million dollars in cost-sharing from someone that actually lives on Martha's Vineyard who is very interested in this kind of facility being on the island. So the collaboration extends beyond the Federal agencies and the principal investigators. It actually extends to some of the private citizenry.

And if everyone participates in contributing to these projects, the Federal agencies, the private sector, and then obviously the scientists and engineers at the different institutions, then you really will have a very successful program.

Mr. SAXTON. Thank you.

Dr. Kennel.

Dr. KENNEL. I have a couple of comments. I am too new to tell you whether there has been a change, but I will say the following: That if you look at Scripps funding in order of importance, our funding comes from the National Science Foundation, the State of California, the Navy, NOAA, NASA, DOE, various other agencies. And the surprising thing to me is how distinct the activities are that are funded by each agency and how critical they are.

This diversity of funding has made Scripps into a diverse institution, and we have been very pleased with it, but I think as we look forward, the community has an important new obligation, which is to think about how to construct these integrated observing systems, both regional and global. And at this point the diversity begins to get in the way—without the further coordination that could be provided by an organization like the Ocean Partnership Program.

The things that need to be done are, first, to be able to develop a plan, a strategy; be able to settle amongst the different kinds of ocean technologies that have been supported by different agencies and institutions, how they ultimately will fit into at least the first steps of a global observing system. How will we reach a decision on how to balance the contributions of each of these very capable technologies? In light of that strategy, where will we put our technology investment funds? Who will be the system integrator? Who will do the basic technological studies that would bring forth an integration at the technical level, the integration that we know that we need?

So I think it is at this level that partnerships, a strong plan and leadership is needed to do those tasks that we cannot do by ourselves in the present configuration.

Mr. SAXTON. Thank you very much.

Mr. Farr.

Mr. FARR. Well, thank you, very much, Mr. Chairman. I wanted to thank both panels. I just got out of a meeting, and I had to tell everybody I had to leave because I had four science directors, an admiral, a secretary and a president waiting for me. So thank you for being who you are.

I look at today as sort of in two categories. One is the existing funding category that comes essentially through the public sector, and Dr. Kennel kind of mentioned the State of California, the NOAA, the Navy, National Science Foundation.

Dr. KENNEL. Department of Energy, NASA.

Mr. FARR. Department of Energy and NASA. All of those are public-funded entities, taxpayer dollars. And it seems to me we ought to be getting—from the importance that the panel has told us, we ought to be getting a better share of the pie.

Then the other side is how do you expand the politics, the lobbying effort, the public's interest in making this a priority? Really, I think we need to focus a little bit more on that.

First of all, on the public side, I believe that each of you have financial officers in your entities. You ought to be taking a look at the requirements of that funding and come back to us as legislators and show us where the bureaucracy just doesn't make any sense, where there is duplication and overlap.

Secondly, I think we need to have some messages that we are not making, and, Admiral Watkins, I was interested in your comment on that. Dr. Gagosian talked about all the things we needed to do and explore and how we sort of lost the lead. I guess it is the Japanese that are really putting the money into equipment. We still have the know-how, as I understand, but they have the better machinery.

If we are so unexplored in the ocean, and there is so much to learn, and it really has to do with, in a sense, national security, knowledge about the planet, why hasn't this moved more into a national security issue, particularly in a post-cold war era, where we are sort of converting to do things we need to do? We have not done very much to put the exploration into a national security issue.

Admiral WATKINS. No, we have not, Mr. Farr.

The United States Navy used to command 7 percent of the national research budget in the old days when it was $8 billion. This is 15 years ago. Today it is 3½ percent of a budget which has almost doubled to $14 billion. I am talking basic research now of the R&D component, the R component that is seldom broken out from D. D disguises the R many times because in D you can have prototype development of a new B–2 aircraft or a nuclear submarine, so it disguises what is in R.

R is the research component. That is what I am talking about. It went from $8 to $14 billion. In oceans it stayed constant in constant dollars, and everybody says, well, that is pretty good, staying constant in constant dollars. Now we are 3½ percent of the investment. That is totally inadequate, and we should be building back over the next 5 to 7 years to something of the order of $800 or $900 million.

So we are not talking about billions of dollars, we are talking about going up at about $15 million a year, And if they have not explained to the Congress how critically important this is right now, then we are not very articulate.

So we have to start growing, and there has to be a deal between the Congress leadership and the White House to say, Mr. President, if you put in another $250 million over the next 5 years as a kick-start for getting this thing really going, get international cooperation through your Secretary of State at the high level, start leveraging these dollars up so we can do the kinds of prediction modeling we desperately need right now, then we in the scientific community come back to Congress with a plan telling you exactly how we are going to spend that money in peer-reviewed research that is integrated. We know how to do that. And so, that deal has to be made, and we ought to do it for the year 2000 budget.

And the Feds that the come up here today, they have to stay within the OMB rules. They cannot come up and demand more dollars. So they are going to try to live with what they are given, and I understand that. But you-all have to reach beyond that and have to help get that leveraged dollar up and have us get back to you by the first of next year. So when you open again in the new session of Congress, and ask "where are you going to spend the $250 million," if you put it in there? We will tell you exactly where. It will be valuable all in itself, and we know how to do that. We have to be tasked, though. It will not come out of the nine Federal agencies. They cannot do it.

Mr. FARR. I understand that, and I accept that challenge. I think it is a great challenge. It is one that I accept, and I hope we can commit with the Chairman and our Committee to accept that.

My statement back to you is we also need to move this into a sense of national security priorities, because if we do not—I do not mean this black box security, I mean the fact that the money around here that is being appropriated still is in that, that is where the discretionary dollars are. And we ought to be able to move some of those discretionary dollars and make those a priority.

Admiral WATKINS. I could not agree more. I think this whole issue of national security, unfortunately, has been swept somewhat under the rug in the aftermath of the great win in the cold war. And while that is a big plus, I think what we did at the same time was decide to say deep ocean research is no longer necessary, the Russian submarines are not there. And we did not pick up on the fact that that is not the only reason we do ocean research. It is life. It is full of life, and we need to know more about it.

So the national priority needs to be reestablished. And I think everything you mentioned earlier, what we are doing now to take advantage of the Year of the Ocean and put all these things in place is a critical time to say, wait a minute, we have got a new national mission of some import. Whether you have the equivalent of the old Joint Committee on Atomic Energy up here or whatever you do, you have to do something up here to send that signal to the administration as well. And I believe we are on the verge of setting a new national priority for oceans and how they contribute.

You heard Dr. Colwell talking about the importance of human health and the ocean. We are just beginning to see that El Niño has brought a new dimension. I am not talking about biomedical research. That will take care of itself. That will be the self-interest of pharmaceuticals. I am talking about what is the impact of temperature growth, whether it is anthropogenic or natural, on human health as the population doubles in the world? If we do not start that research now, 50 years from now we are not going to be in a very good position to deal with disease.

So national priority has to be put on this and at the Presidential level and congressional level, both in cooperation with each other.

Mr. FARR. I look forward to working with you and maybe even actually shaping that letter. I am writing it as you talk. We need to tighten that up and get it out and get our Members committed to it now even before the election.

Then the second part of that is how we sort of increase this public buy-in that I think is out there. The excitement is there. I watch the kids who when I grew up, you know, the space area, you had to get space camp started and we got all excited. Now we have the opportunity for sea camps, which I think the demand out there is just really keen. And frankly, there are more places where we can do those than we can do space camps.

But Dr. Kennel talked about it had to become personal. And how can we start personalizing; how can we take the information that you-all are getting and kind of turn that in? I always kidded, we have the fleet numerical, the Navy's center for all the weather data coming to Monterey. The Navy collects all the weather data on the globe, every measurable instrument, and it is all fed into Monterey.

So I said, if you are so damn smart with your big Cray computer, why cannot you tell the farmers what the weather is going to be like in the Salinas Valley, or why cannot you tell the surfers what the weather is going to be like on the coast? I said, there are some real commercial interests with what you do.

Dr. KENNEL. Let me just say that, first of all, the National Oceans Conference did have a personal impact on me. I came back to San Diego, and I wore the cap from the conference the next day to the cleaner, and the gentleman behind the desk said, "Oh, I see were you at Monterey." And I said, "Yeah." He said, "You know. All the fish have gone away. The ocean is responsible for climate. And our coastlines are a mess." And I said—"well, he got the message."

In any case, Scripps has a program with regard to surf. It is an interesting story. Our program takes the Navy's prediction of wave heights on the open ocean and translates it into wave action on a kilometer-by-kilometer basis along the California coast. And there is a big surfing beach just north of Monterey. The Scripps folks came to me one day and said, "You know, we are predicting 25-foot wave heights out there. What should we do?" I said, "Put it on the Internet." It had a very interesting effect. Most of the surfers from that region who were very knowledgeable said, "we are going to stay away from this one, we know what this place is like." But other people from Hawaii and Australia flew in to catch the waves. And as you know, the Coast Guard had to intervene and forbid them from surfing.

In any case, it is not only important for surfers to predict wave heights, but it is those waves that are basically responsible for the transport of sediments down the California coast. Ultimately, we are going to be able to tie a lot of the work together. We are going to be able to take El Niño predictions—we are not ready yet—but we will be able to convert those into the water flow in all the California watersheds, the rivers. We will be able to estimate how much sediment the rivers bring toward the ocean and how much gets into the ocean. We will be able to put it all together.

Mr. FARR. I think the more we do that, the more you will begin buying into this public awareness that we need as politicians to put their limited tax dollars in the right place.

Dr. KENNEL. The scientists can help to a significant extent. For example, just the whole effort to increase the resolution of computer modeling. This effort takes the global information, which we need, and actually brings it down to the local scale and actually improves that. And I believe the whole climate community is certainly focused on that issue. They understand the issue, but the results are not there yet.

Mr. FARR. The next time you bring the group that you talked about in your testimony together, would you include FEMA in it? The coastal States are really concerned about erosion. And FEMA once had a policy where they would provide the FEMA funding for coastal erosion, and they have now backed away from all of that. And they know there is a big cost out there, but it is a big problem. The Florida delegation is very concerned about it, certainly California, other areas where there is large populations.

We have not yet connected the science group and the economics that you have been able to pull out of that with the emergency funding folks, both OMB and FEMA. So you need to get them into your round table.

Dr. GAGOSIAN. Mr. Farr, if I could make just a comment about your thoughts on public outreach. I think we have done a very poor job in the scientific community in articulating the discoveries and the excitement, especially of ocean sciences. I think that is beginning to change now.

I think one of the reasons why we have done a poor job is, one, that things were pretty good in the 1970's and 1980's, and we focused on how to spend the money and how best to spend money. Second, we do not really know how to communicate outside our own community very well, so we stayed within our own community. But I think that is changing.

There are a couple of major programs that are being undertaken now. I think one way to do it is through traveling-museum exhibits, where the substance is put in place by the scientists themselves, but not the way the exhibit is put together. That is put together by professionals who work in concert in a collegial way. And we actually are doing something like that now. Two 7,000-square-foot museum exhibits that will be done, hopefully, by the beginning of 1999, or at least by the middle of 1999, will travel to 15 major museums around the country, museums that have 2 to 4 million a people a year that go through them. So that is one way to do it.

The other is with respect to the K–12 issue. Again, I think it is necessary to have professionals. Most of the time scientists tell people what they need to know. They rarely ask them what they want to know. And I think we have to change that pattern, especially with teachers. And that is beginning to happen as well.

Again, one way do that is with a professional outside company, and we have actually spun off an outside company to start something like that, with people that know this business that are in the publication business, and they themselves are working with, in this particular case, Harcourt General, who has put significant money in, significant being over a million dollars, to start to put together curriculum for fourth- to sixth-graders and seventh- to ninth-graders, a curriculum that will consist of books and workbooks and handbooks, but also obviously a very strong Web interactive service so that the students can see the results as they are happening and actually talk with the people that are being involved.

Video will play a big part in this as well. I see that coming on the horizon. When we took the ship Atlantis that we have to Washington, to Alexandria, last year, it was a real wake-up call for me because every kid wanted to see that, and they were very excited. Ocean sciences is a wonderful way to hook children to get them interested in the basic sciences, because the ocean is not a science, it is a place, and you need physics and chemistry and biology and engineering and geology. And that is the great hook that I think will bring the children into it.

Dr. GRASSLE. I just want to agree with Bob's comment on the importance of getting marine science into the schools. We are involved in about 40 different school districts in New Jersey working with teachers to introduce a marine science curriculum as part of a science program at those schools. And we just 2 weeks ago had a workshop for teachers involved with LEO, and they went out on the boats, they watched the computers, looked at the models and so on. So they got a real, firsthand feel that they could bring back to the classroom.

But I also think that, in trying to get the public involved, we need to better explain that applied problems are also basic problems. I am always surprised when I go to various forums on problems such as beach erosion or problems associated with pollution of our ports that people do not go back to first principles and say, how does this environment work, how does sand move off the coast of New Jersey in our case, or what really is controlling the movement of contaminated sediment at the port?

These are observing system issues, but the observing system is simply the basis for the understanding. And we feel that getting the public involved by putting the information from observing systems relevant to applied problems over the Internet is involving the public. Also, making data available through geographic search engines over the Internet is another useful approach.

Mr. FARR. All the high schools in rural areas teach agriculture because there are jobs after you get out of high school. Every ocean community high school ought to be teaching about the oceans because there are going to be jobs in the oceans. And we have not linked that future employment to our educational training.

Dr. GRASSLE. I know you are familiar with Project MARE developed at Berkeley. That is the curriculum we are using in these 40 school districts.

Mr. FARR. Take a look at the Virtual Canyon, which is one of the exhibits at Expo in Lisbon that was formed from the high school and elementary schools in Monterey on the Monterey Canyon. It is a very exciting curriculum that they are developing right now.

Mr. SAXTON. Let me just expand the conversation if I may for just a moment, and then we are going to have to leave.

Obviously, as was pointed out by the admiral earlier, the ocean covers a great deal more of the earth than we have the capacity to study, particularly as a result of our efforts here in this country. And it seems to me that a cooperative effort internationally would be quite beneficial in light of the fact that these activities are extremely expensive and we are stretching now to expend our efforts.

What is going on internationally? Is there a degree of cooperation, and is there reason for us to be optimistic that ocean research internationally is something that we could look forward to hearing more about?

Dr. GAGOSIAN. Mr. Chairman, there are a couple of examples I would like to give. One is with respect to the ocean observing system in our countries.

The European Union is moving ahead very rapidly. As a matter of fact, they are ahead of us. They are already planning experiments in the northeastern part of the Atlantic Ocean. On the other hand, there are a lot of discussions going on between our scientists and their scientists in planning joint expeditions and joint plans.

There is a lot of cooperation also with the Japanese with respect to the potential for new ocean-drilling program opportunities into the next millennium, and they are actively involved in those discussions, not only with the United States, but with several other countries that are involved in the ocean-drilling program.

And third, the Japanese, also with respect to deep sea observatories, are putting sums of money into this problem that are a bit overwhelming. The Japanese Marine Science and Technology Center had a $100 million plus-up just for deep sea observatories and autonomous vehicles. One hundred million dollars is half of the total NSF ocean sciences budget in one year. So that is just the plus-up.

So clearly there are a lot of opportunities to work with them. But those are just three examples, and I am sure that there are other members of the panel that have others.

Dr. KENNEL. Perhaps my experience at NASA in helping develop an integrated observing strategy from space will be helpful. There is a Committee on Earth Observation Satellites, which consists of 18 spacefaring nations. The program leaders get together once a year, and they have worked to coordinate their activities. At NASA's pushing, we convinced them that the integration of the space observations could only go so far, at which point they had to come to grips with the fact that they also needed complementary ground-based and in-ocean observations. They then stopped and asked themselves the question, OK, that is scientifically correct; Now what do we do? Whom do we talk to?

They have been having difficulty finding an analogous organization to speak to that could pull together the in situ observations. In this particular case, the oceans let us organize our efforts in such a way that we could work on the international scene with the already partially organized space effort.

Mr. SAXTON. Thank you.

Dr. Grassle.

Dr. GRASSLE. There is also interest in having an observing system for biological diversity, and there is an international program called DIVERSITAS, which is kind of an umbrella for most of the international organizations. And although DIVERSITAS has mostly terrestrial members of its executive committee, there is really a strong effort to get something going in the marine environment. Recently the Sloan Foundation became interested in this issue, raising the question as to why we cannot have a clear idea of how many fish are in the ocean, how many fish species.

Now, I see this as a metaphor for understanding about life in general in the oceans. Rita Colwell mentioned that the new technologies in ocean observation give us the background to look in more detail at the processes in the ocean. That is particularly true for organisms such as fish, but also life on the sea floor and the enormous diversity in the deep sea.

All of that depends on designing a global sampling system so that we do not inadvertently lose this important diversity for future generations.

Mr. SAXTON. Thank you very much.

I want to thank each of you for the insights that you have brought to us today. It has been a very interesting and educational 2½ hours or so that we have been able to spend here with you today. We could spend a lot more time; however, we are going to have to bring the Subcommittee hearing to a close at this point. So thank you very much.

The hearing record will be kept open for 30 days for potential responses to questions that Members may have, which they will submit in writing.

[The information referred to may be found at end of hearing.]

Mr. SAXTON. If there is no further business, the Chairman again thanks the members of the Subcommittee, as well as our witnesses, and the Subcommittee stands adjourned.

[Whereupon, at 12:18 p.m., the Subcommittee was adjourned.]

[Additional material submitted for the record follows.]

STATEMENT OF D. JAMES BAKER, UNDER SECRETARY FOR OCEANS AND ATMOSPHERE, U.S. DEPARTMENT OF COMMERCE

INTRODUCTION

Good morning. I am James Baker, Under Secretary of Commerce for Oceans and Atmosphere and Administrator of the National Oceanic and Atmospheric Administration. I thank you, Mr. Chairman, and members of the Subcommittee, for this opportunity to testify on ocean observations and related activities performed by the National Oceanic and Atmospheric Administration (NOAA).

Over ten years ago, NOAA embarked on a mission to observe and record physical oceanographic and surface meteorologic features in the equatorial Pacific Ocean. This mission required the deployment of a new variety of observing instruments, including moored buoys, drifting buoys, atmospheric profilers, tide guages, and sensors released from volunteer ships. These instruments began to record data related to ocean currents, profiles of seawater temperature, salinity, and surface wind and air temperature. For years, these data were collected, transmitted via satellite to NOAA laboratories, and studied by Federal, university, and even international scientists. Over time, the data began to present shapes and patterns of physical oceanic change, and divulge secrets of one of nature's most powerful climatic events, the El Niño. The result of this sustained investment in ocean observation has brought unprecedented economic returns to this country and has introduced ocean and climate science to homes across all regions of the United States. Beyond question, the benefits from this type of long-term, continuous ocean observation are enormous.

NOAA's many activities during the El Niño of 1997/1998 demonstrated the value of long-term ocean observations, and of our efforts to discover the linkages among oceans, the atmosphere, marine ecology, and human society. The ENSO observing system provided the early detection of conditions that might lead to an El Niño, and soon after models developed by NOAA or by its academic partners produced quite accurate forecasts of the timing and relative intensity of the coming El Niño. NOAA worked closely with FEMA, state agencies and the media to ensure that accurate information on El Niño was readily available to decision-makers and the public. Once it was clear that El Niño of historic proportions was underway, NOAA undertook a series of special studies to document impacts along the U.S. Pacific Coast, where large impacts were expected and where a rich base of existing data were available as a background. These efforts made dramatic improvements in the accuracy of 3-5 day weather forecasts, provided vital information for shorter range weather forecasts and flood warnings, and we expect, will provide significant new insights on how anomalous ocean conditions affect plankton, fish, seabirds, and marine mammals in coastal waters.

All seven of NOAA's Strategic Goals rely to some degree on observations of the world's oceans and seas, including their physics, chemistry, and biology. Our understanding of the surface and interior oceans, their variability and interaction with the atmosphere, and of subsurface processes and resources, is far from complete. Despite our recent success in predicting long-range climate events, including the current El Niño event we predicted many months in advance, we still have far to go. Recognizing this fact, President Clinton and Vice President Gore called for an agenda for action regarding the oceans at the recent National Ocean Conference in Monterey, California. There, they highlighted the critical significance of the oceans to our Nation's economic and social well-being, and issued a directive for increased observations of the world's ocean processes and features.

At this conference, the Administration launched nine major initiatives for the exploration, restoration and protection of America's vital ocean resources. These measures will provide new scientific insight into the oceans, promote sustainable use of fisheries and other marine resources, open new opportunities for jobs and economic growth, preserve national security and freedom of the seas, and help preserve our oceans for all time. The President and Vice President are proposing an additional $224 million through 2002 to support these efforts beginning in FY 2000. The initiatives particularly relevant to ocean observations are *Exploring the Last U.S. Frontier* and *Monitoring Climate and Global Warming.* NOAA has a critical role in the development and implementation of these initiatives.

To unravel deep-sea mysteries, discover new opportunities in the ocean, and better understand how to protect marine resources, the Administration is launching a program to map and explore U.S. ocean waters with advanced underwater technology. This initiative, called *"Exploring the Last U.S. Frontier,"* proposes $12 million through 2002 to be used to expand two shallow-water observatories (Aquarius and LEO), build two new deep-sea observatories (Gulf of Mexico and Juan de Fuca Ridge), and develop two high-tech submersibles to explore exotic sea life. A new initiative has been launched in partnership with the National Geographic Society and Goldman Foundation to explore our National Marine Sanctuaries.

To understand better the role of the oceans in shaping our weather and climate, and to help address the threat of global warming, the Administration has announced *"Monitoring Climate and Global Warming,"* an initiative for an expanded ocean monitoring system. We are proposing an additional $12 million through 2002 to place hundreds of monitoring buoys in the North Atlantic and North Pacific to measure critical ocean data, including temperature and salinity at different depths.

To begin today, I would like to explain the scope and nature of NOAA's existing ocean observation systems and present areas where additional work and study are required. Understanding our ocean observation programs will require some discussion of the tools and processes used for observation. These tools—submersibles, automated profiling buoys, state-of-the-art satellites—are in a process of almost constant evolution as our abilities to understand the oceans deepen and our needs for scientific data expand.

Clearly, ocean observation includes the assessment and monitoring of living ocean resources. A major challenge confronting our fisheries managers involves observation of fish stocks using antiquated and unsuitable vessels. NOAA's fleet of eight fisheries research vessels has reached or exceeded their expected service lives. Admiral Craig Dorman recently reviewed NOAA's plan to replace the capacity of these vessels. I will conclude my comments by detailing his report.

EXISTING OCEAN OBSERVATION SYSTEMS

Perhaps the best known of NOAA's ocean observing systems is the El Nińo Southern Oscillation (ENSO) Observing System. This system is comprised of a moored buoy array, drifting buoys, a fleet of volunteer observing ships (VOS), remote sensing satellites and a sea level gauge network. Each component of this network contributes in a different way to our knowledge of ocean processes and to our predictive capability. While the ENSO Observing System is focused on the tropical Pacific Ocean, scientists have recognized that climate variability results from interactions among different oceanic regions, so that improved predictability requires observations of all oceans, which can be combined to create climate information critical to a host of U.S. and foreign users. Thus, in 1998, the International Year of the Ocean, NOAA committed to participating in the building of a Global Ocean Observing System (GOOS) that is essential to improving the basis for our climate forecasting.

The Global Ocean Observing System

Working toward the Global Ocean Observing System, NOAA has adopted a simple strategy: through our climate research program, we support cooperative international observation projects which target modes of climate variability (ENSO, the Pacific Decadal Oscillation (PDO) the North Atlantic Oscillation (LAO), etc.) while at the same time form "building blocks" of GOOS. The building blocks, or networks, on which we are concentrating most of our attention for sustained ocean observations are the following: (1) deep ocean moorings; (2) surface drifting buoys; (3) tide gauges; (4) Volunteer Observing Ships; and (5) autonomous profiling floats. These networks complement each other, and each contributes its unique capabilities to the composite system. In combination with remote sensing from satellites, these five networks provide the backbone of the sustained global ocean observations needed to improve climate forecast skill.

Using the same automated sensing technologies developed for the ENSO observing system, and in cooperation with international partners, a pilot array has been established in the Atlantic in search of modes of Atlantic climate variability that interact with the Pacific variability. Relying on a foundation of cooperation with international partners, NOAA plans additional network expansions in the year 2000, building on the ENSO System and the Atlantic pilot array that will target the North Pacific, the extra-tropical Atlantic, and the eastern Indian Ocean to observe the modes of climate variability beyond ENSO.

The first four of the five networks (building blocks) were developed over the last 15 years as part of the research on El Nińo. The Tropical Atmosphere Ocean (TAO) array of 70 moorings spanning the equatorial Pacific, the VOS fleet of 68 research and volunteer commercial ships covering all oceans, the 63 Indo-Pacific and Atlantic island tide gauge stations, and the global array of 390 drifting buoys, together form the ENSO Observing System. This composite observing system, essential for NOAA's climate forecasting mission, is now maintained on an operational basis. The fifth network, autonomous profiling floats, is a new technology that is not yet part of the "operational" ENSO Observing System, but is proving its value through two research arrays (described below) and is now considered a proven member of the composite, five-network ocean observing system. The Global Ocean Observing System will consist of some combination of these different measurement systems. This innovative technology, specified by the President's proposal in Monterey, will complement other *in situ* and remote satellite observations to refine climate prediction models.

The need for ocean observations to track the Pacific El Niño is well understood. We also know that the Atlantic Ocean generates a significant, but less understood, influence on the climate of North America as well as South America, Europe, and Africa. The influence of the tropical Atlantic competes with, and is modulated by, the Pacific El Niño. These processes can, for example, modulate the frequency and intensity of hurricanes impacting the U.S. eastern seaboard, as dramatically demonstrated by the dearth of hurricanes in the 1997 season—a favorable impact of El Niño. In 1998, NOAA supported implementation of the new Pilot Research Array in the Tropical Atlantic (PIRATA) in cooperation with France and Brazil. This array of 12 moorings is, in effect, an eastward extension of the TAO array; five moorings have been deployed to date, with the additional seven scheduled over the next year.

Other existing NOAA programs for ocean observation include the following:

- A global network of tide gauge stations that has become essential for removal of the inevitable instrument drift in altimeter measurements for accurate climate forecasting.
- A contribution of 19 autonomous profiling floats to National Science Foundation's Atlantic Circulation and Climate Experiment.
- An expansion of the ENSO observing system with 100 additional surface drifters, 75 profiling floats, and four high density VOS lines concentrated in the eastern Pacific to study the North Pacific Decadal Oscillation.
- Satellite systems that provide information globally on winds, the thermal structure of the atmosphere, and sea surface temperatures.
- The National Water Level Observation Network of 189 tide gauges to provide essential data for navigation, tsunami and storm surge warnings, legal determinations of property lines, sea level rise, and other public and commercial applications.
- A network of coastal ocean weather buoys to provide frequent, high-quality marine observations to diagnose conditions to prepare and validate weather forecasts.

Seafloor Observation Systems

While at the National Ocean Conference in Monterey, Vice President Gore noted that submersible and hydroacoustic technologies have brought scientists to a new frontier in fields of undersea research. Recent scientific advances have allowed us access to thousands of square miles of virtually unknown seafloor resources. NOAA has a rich history of support for seafloor observatories and is providing significant new support for various efforts. These include: the "Aquarius" habitat in the Florida Keys, the Long-term Environmental Observatory (LEO) effort off the coast of New Jersey, and the VENTS program in sites along the Pacific Coast.

AQUARIUS

Owned by NOAA and managed by the University of North Carolina at Wilmington (UNCW), *Aquarius* is the world's only underwater laboratory from which diving scientists can live and work beneath the sea during research missions up to 10 days in length. For its current assignment, *Aquarius* operates at a depth of 60 feet at the base of a coral reefwall off Key Largo, Florida. The 81-ton, 43x20x16.5-foot underwater laboratory has many of the comforts of home while also providing scientists with sophisticated laboratory capability.

The special diving capability of *Aquarius,* called saturation diving, allows scientists to work outside the habitat on the reef up to nine hours a day without fear of getting the bends, compared to one hour if they had to work from the surface. Increased research time on-bottom is the key element that enhances scientific productivity beneath the sea. The support personnel of the National Undersea Research Center at UNCW enhance program productivity through diver training, and scientific and operational expertise. Safety is a hallmark of the program.

Aquarius is the centerpiece of a comprehensive environmental research program in the Florida Keys aimed at better understanding and preserving the health of coral reefs and near shore ecosystems.

LEO

September 1996 marked the completion of a seafloor observatory facility providing a real-time Internet link to the undersea environment off the coast of New Jersey. This innovative link provides access to the ocean floor for scientists, engineers, students and educators.

The Long-term Ecosystem Observatory facility, or LEO, was established in 15 meters of water (and named appropriately LEO-15) on the dynamic inner continental shelf off Tuckerton, New Jersey (just north of Atlantic City). The observatory facility, recently renamed the LEO-15 National Littoral Laboratory, consists of two instrumented platforms (termed "nodes"), anchored to the seafloor at distances of 4 and 5.5 km from the entrance to Great Bay. The nodes are connected to a shore-based facility by 9.6 km of electro-optical cable that is buried 2 m meters below the seafloor. LEO-15 provides an excellent site to test and deploy sampling and sensing equipment. Guest ports are available at each node of the observatory facility to supply power, operate instruments, and transmit data.

The LEO-15 observatory was built as a partnership between the Institute of Marine and Coastal Sciences (IMCS) at Rutgers University, and the Ocean Systems Laboratory of the Woods Hole Oceanographic Institution. Support for the development and installation has been provided by the National Science Foundation. Additional support has come from NOAA's National Undersea Research Program (NURP) through the Mid-Atlantic Bight National Undersea Research Center. NURP continues to provide support, both for maintenance and operation of the observatory, and for research at the site. In addition, the Office of Naval Research and the National Oceanographic Partnership Program (NOPP) are supporting modeling efforts, research, and further development of the observatory facility and its sensing capabilities.

One area of rapid advancement has been in the development of an autonomous vehicle, REMUS (Remote Environmental Sampling Units), that will become integrated into the observatory facility. REMUS vehicles will be used widely in the vicinity of LEO-15 this summer as part of a multi-platform adaptive sampling effort focusing on evaluating a relocatable, data assimilative, coastal-ocean forecasting model.

VENTS

Through its VENTS Program, NOAA is conducting ground-breaking research and observations of processes and ecosystems in the interior ocean and sea floor. One recent important finding is the discovery of episodic volcanic/hydrothermal bursts, called megaplumes, which inject massive heat and chemical inputs into the ocean as a consequence of deep-sea volcanic eruptions. Megaplumes persist in the ocean for months, maybe years, and have important ocean environmental consequences because of their heat and chemical content. Now, it is suspected they play an important role in macro- and micro-biological ecosystems.

The VENTS Program obtained access to the U.S. Navy's Sound Surveillance System hydrophore network and has designed and implemented the world's only real-time, Pacific-wide acoustic monitoring capability. This capability enables VENTS to detect and locate deep volcanic eruptions and thus makes it possible for these events to be studied while they are active. While these are the most common volcanic eruptions on Earth, it was not until 1993 when VENTS detected an eruption taking place off the coast of Oregon, along the Juan de Fuca Ridge, that a deep-sea eruption was studied while it was active. These eruptions have profound impacts on the ocean's thermal, chemical, and biological environments.

VENTS scientists are pioneering the study of the sub seafloor microbial biosphere through seafloor and water column sampling projects. These projects, including sampling of the plumes arising from active deep volcanic eruptions, have shown that eruptions are literally windows into the biosphere. Within the last five years, VENTS scientists have discovered that the most unusual of the bacteria which live in extremely hot sub seafloor environments are very common in eruption megaplumes. The monitoring and sampling technologies designed by VENTS have made it possible to recover microbial species with profound potential in industrial, environmental, biotechnical and pharmaceutical applications. For example, an enzyme found only in deep hydrothermal vents is revolutionizing our ability to replicate DNA using the polymerase chain reaction technique. This technique can be used to identify, with a very high probability, disease-causing viruses and/or bacteria, or the DNA of a particular individual.

AREAS THAT NEED ADDITIONAL STUDY

The historic success in forecasting the 1997-98 ENSO event placed an immediate demand on NOAA to improve tropical forecasting and expand our understanding of extra-tropical variability. Conditions in the Pacific in the 1980s were significantly different from those in the 1990s due to decadal-scale shifts in the ENSO cycle. Understanding of other variability modes in the Pacific such as the Pacific Decadal Oscillation and the American Monsoon is a priority for NOAA's climate research program. We must build a sustained observing system in the North Pacific to monitor this region of significant impact on the U.S.

A focused extension of observations into the eastern Indian Ocean is also needed. Many scientists think that westerly wind bursts from the Indian Ocean may somehow trigger the onset of El Nińo. There is considerable evidence that the sea surface temperature variability there influences the Asian/Australian Monsoons, thus affecting their predictability and hence the predictability of El Nińo. In 1998, the Japan Marine Science and Technology Center (JAMSTEC), one of our principal partners in Indo-Pacific observations, began deployment of their TRITON moorings in the western Pacific as the first step in extending the ENSO Observing System westward. As a complement to JAMSTEC's TRITON moorings, NOAA must work with Japan and other Austral/Asian nations to deploy other network platforms to investigate sea surface patterns in this critical monsoon area. The expansion of these types of monitoring platforms is an important component of the initiative "Monitoring Climate and Global Warming" issued in Monterey.

As mentioned above, climate models suggest that the atmosphere and the Atlantic Ocean may be coupled to create a climate influence of great importance to the United States, particularly the easterner U.S. The so-called North Atlantic Oscillation (NAO) and the Tropical Atlantic Variability (TAV) unquestionably affect our climate, but we do not understand how. The first step in understanding these Atlantic regimes is to establish an observing system, similar to the one we have in the Pacific. Over the next two years, data from the Atlantic pilot array will be analyzed to assess long-term observational requirements for the Atlantic.

Assessment and definition of long-term ocean observing strategies is a major task for NOAA and its partners, so that only the best, most cost-effective systems are deployed. Research projects such as CLIVAR and operationally oriented efforts such as GODAE include efforts to develop effective observing strategies. NOAA will be a major participant in these efforts.

Results from the existing undersea research efforts have demonstrated that there are new discoveries with potentially large economic payoff waiting for us beneath the oceans. NOAA intends to increase its efforts in the existing shallow water observatories (Aquarius and LEO) and to participate in the development of two new deep water observatories. Efforts on the Juan de Fuca Ridge and in the Gulf of Mexico will allow intensive study of newly discovered species and estimation of their potential economic value, provide more quantitative data on the impacts of seeps and vents on ocean chemistry and heat balance, and learn of other ocean processes or resources. VENTS and NURP will work with NSF and others to implement an observatory on the Juan de Fuca Ridge. The two NOAA programs will provide the sustained observation effort and dedicated logistics support that will serve as a framework for process research by scientists supported by NSF.

Over the years, NSF and NOAA have had a complementary partnership under which the NSF RIDGE Program has emphasized sub seafloor science, while the VENTS Program has emphasized the area from the seafloor to the ocean surface. Both programs have an interest in the exciting biological discoveries in the venting areas, and are working in close coordination. The NOAA role in the observatory on the Juan de Fuca Ridge will require about 60 days-at-sea of major ship support each year from either NOAA or UNOLS vessels, as well as access to manned and unmanned submersibles from UNOLS, Canada, and elsewhere.

During the height of the 1997/1998 El Nińo, NOAA undertook a special study to determine the impacts of El Nińo on the west coast of the United States, with emphasis on coastal weather and marine ecology. This study clearly demonstrated the strong link between climate variability and weather events. Over the next several months, NOAA will evaluate how increased or redirected ocean and atmospheric observations might improve the predictability of climate variations at regional scales and related weather events.

Finally, our 12 National Marine Sanctuaries remain largely unexplored. In Monterey, the President announced efforts to support the recently announced five-year research expedition within the Sanctuaries that will be led by Dr. Sylvia Earle, the explorer in residence to the National Geographic Society. Dr. Earle's "Sustainable Seas Expeditions" will assist in developing a more comprehensive inventory of the biodiversity within our National Marine Sanctuaries. These efforts will improve science-based recommendations for stronger protections, such as the "no-take" zones in the Florida Keys National Marine Sanctuary.

PARTNERSHIPS FOR OCEAN OBSERVATION

NOAA employs many different types of tools and technologies to undertake ocean observations. A mix of observation platforms (ships, submersibles, moored and drifting buoys, tide gauges, etc.) perform *in situ* measurement, sampling, and/or sensing, while several satellite- and land-based remote sensing systems provide broad-scale surface measurements. The capital and operational costs of collecting ocean observations are very high and NOAA is not able to fully underwrite these costs alone. Thus we are working in cooperation with other nations and collaboratively with other agencies on oceanographic research and *in situ* and satellite observations. Further, we are working with UNOLS to optimize the use of research ship resources. Likewise, it was through a partnership among academia, private industry and a non-profit foundation, that Aquarius, the world's only underwater laboratory, was refurbished and put back into operation as Aquarius 2000.

These extensive partnerships are essential tools for ocean observation, and represent significant enabling capabilities. The two principal types of partnerships we undertake are; (1) those with academic institutions and, (2) those with other Federal agencies. NOAA is very proud of its institutional partnerships with academia, represented by the numerous state Sea Grant programs, the Undersea Research Centers, and the Joint and Cooperative Institutes. Together, these programs conduct at least $80 million of research annually in support of NOAA's missions. Additional tens of millions of dollars flow to academic scientists through other funding pathways. NOAA's Environmental Research Laboratories are Associate Members of the Consortium for Oceanographic Research and Education (CORE), providing an additional communications channel to academic institutions.

Partnerships with private industry, particularly those that involve fishers in data collection, are also important. For example, NOAA's Northwest Fisheries Science Center is developing an Electronic Logbook with Innovative Technology Funds. This prototype project, which is carried out in response to an industry request, will give NOAA the opportunity to mount private-vendor conductivity-temperature-depth meters on as many as 200 West Coast trawl vessels, to supplement data gathered by research surveys on NOAA vessels.

NOAA has joined with other Federal agencies to undertake projects like the South Florida Restoration Program, and has taken the lead on studies in Florida Bay, where NOAA's oceanographic and ecological research capabilities are critical to the project's success. NOAA is very active in the National Oceanographic Partnership Program (NOPP). We support the purpose of NOPP, as stated by the Congress, and are very appreciative of the leadership role played by the Secretary of the Navy and the Office of Naval Research. The NOPP Program Office at CORE is providing excellent support to the NOPP Interagency Working Group.

During the first two years of NOPP, NOAA scientists partnered with various agency, academic, and private sector colleagues to establish systems to make ocean observations, including a pilot North Pacific mooring, development of chemical and big-optical sensors, dual use of the Navy's Over the Horizon Radar, and a coastal forecasting system in the Chesapeake Bay. NOAA and partner agencies utilized the NOPP process this fiscal year to undertake a research program on the Ecology of Harmful Algal Blooms, and NOAA's request for FY 1999 provides funds for NOAA to utilize the capabilities provided by NOPP to investigate the seasonal hypoxia in the northern Gulf of Mexico. NOAA will seek additional opportunities for involvement in NOPP as circumstances permit.

NOAA supports the concept of global-scale observing systems, such as the Global Ocean Observing System (GOOS) and the Global Climate Observing System (GCOS). Internally, NOAA has organized an approach to GOOS and GCOS that combines the capabilities of our research laboratories and our joint institute partners to undertake systematic, sustained *in situ* ocean observations. The overall scientific and engineering expertise available through this joint approach will allow NOAA to obtain the highest quality measurements at the lowest possible cost. For full implementation, we recognize that global-scale observing systems require international participation and financial support. At present, scientist-to-scientist, agency-to agency, or United Nations-based arrangements are being used for international partnerships. Because these global observing systems will be needed over very long periods of time, these arrangements must be made by fiscally and technically capable governments, with binding scientific responsibilities, and a commitment to global application and universal benefit. Consideration of this might become a task for a new Ocean Commission.

NEW OBSERVATIONAL TOOLS NEEDED

As discussed in detail below, additional observations of the oceans are desperately needed. Yet I must add that another critical limiting factor to improved climate and weather predictions is our limitation on computing power. The climate prediction centers in the United States must have access to faster computers and larger data storage capabilities if we are to create higher resolution models and incorporate new types of data into these models. It does little good to increase observations without the simultaneous ability to assimilate and apply these data for improved forecasts. NOAA currently is evaluating the status of its computing infrastructure.

Understanding climate is a global issue. As the climate prediction centers begin installing the next generation forecast models, better data sets will be required covering the global ocean. In addition to targeting the key regions of critical importance outlined above, global measurement of sea surface temperature, upper ocean mass, and surface meteorology will be essential. The international research community is currently at work designing observational strategies for extended climate studies. NOAA is evaluating the ENSO Observing System to make it as efficient as possible. By the year 2000, we will be ready to move forward with the five networks to implement the global observations needed.

Scientists at Woods Hole Oceanographic Institution (WHOI) are developing a plan to deploy moorings at several of the old at-sea weather station sites, where time series data sets from the past can be recovered and continued forward to document climate variability and change. These "ocean observatory" moorings are being designed as a complement to the drifting arrays, VOS, and satellite networks, and are, in effect, an extension of the TAO/TRITON/PIRATA network into the higher latitudes.

Along with the Atlantic pilot arrays, NOAA initiated a "Better VOS" project in 1998 to improve the measurement capabilities of the Volunteer Observing Ship (VOS) fleet world-wide. By the year 2000 the automated observing instruments, being developed at WHOI and integrated through the Small Business Innovation Research Program, will be ready for deployment on the VOS fleet.

One of the advantages of the five-network system is its flexibility in providing various platforms for measuring a host of climate variables—autonomously. For global monitoring of carbon dioxide, measurements in the ocean as well as in the atmosphere must be maintained. The oceans are major "sinks" absorbing carbon dioxide, the principal greenhouse gas contributing to climate change. Presently, ocean carbon measurement campaigns must be supported by research vessels. NOAA scientists, in collaboration with scientists from five other institutions, are working on a NOPP supported project to develop autonomous carbon sampling instruments that can be placed on moorings (and potentially other platforms) to operate independently over the long-term at much lower cost. This project is also developing other autonomous sensors and by the year 2000 will be ready to transition next generation technologies to the oceanographic community for long-term monitoring of biogeochemical and big-optical as well as physical processes.

The two existing arrays of autonomous profiling floats in the Atlantic and east Pacific represent the early phase of a much larger plan under development by a team of researchers from Scripps Institution of Oceanography and Woods Hole Oceanographic Institution to deploy a global network of floats. Floating submerged at various depths to provide circulation information, these 4-foot long tubes automatically ascend to the ocean surface once every two weeks to report ocean temperature and salinity profiles needed to calibrate satellite observations and interpret subsurface ocean characteristics (satellites cannot see below the ocean surface). This project is called Argo and is an essential complement to the satellite altimetry mission, Jason, and successor missions. The project will expand the tropical arrays and help fill the large gaps—data voids of thousands of kilometers—between the moored arrays and the VOS lines.

Another international project that you will undoubtedly hear much more about over the next two years is GODAE—the Global Ocean Data Assimilation Experiment. This project will create a means to provide up-to-the-minute analyses of ocean conditions, the way we now have analyses of atmospheric (weather) conditions for use by the shipping industry, search and rescue, exploration and engineering, fisheries, disaster preparedness and response, and all other ocean users, as well as climate forecasters. GODAE is a huge assimilation and modeling effort that will require the resources of many nations to accomplish. It is being organized under the auspices of the international Ocean Observations Panel for Climate. NOAA is committed to supporting this effort through our ocean observations program—we will help provide the global, real-time, *in situ* ocean measurements necessary for assimilation into the global ocean models.

In order to implement a Global Ocean Observing System, maintenance of an infrastructure for global data set management and international implementation is as essential as maintenance of ocean platforms. It is this infrastructure that will glue the networks together to make a truly global "system." A critical element of NOAA's observational strategy is to work with our global partners to create the infrastructure necessary to ensure the quality and continuity of long-term data sets, facilitate exchange between network operators, and produce and disseminate integrated ocean information that is of maximum benefit to those who need it.

The ocean is generally undersampled. Even in the equatorial Pacific, we know that we must add subsurface salinity measurement capability to the TAO array if we are going to improve predictability of ENSO events. We may need additional measurements of surface winds in the western equatorial Pacific if these winds are determined to be a critical factor in the initiation of El Niño. We recognize that the North Pacific, North Atlantic, equatorial Atlantic and Indian Ocean likely play key roles in short-term climate variability and without additional measurements in these regions, extending climate predictions to include regional- or local-scale predictions may be impossible.

Satellites provide the only true global coverage, but at present are limited to sensing of surface features and properties only. Application of remote sensing technologies from satellites and aircraft are under development to observe the wind field over the ocean (scatterometers, lidars), and it is likely that such measurements will be key for improving ENSO predictability. These remote sensing technologies, coupled with networks of *in situ* measurements from buoys and ships, offer the best opportunity to correct ocean under sampling on a global scale.

More efficient management of our Nation's living marine resources would result from better information about the current status of the various biological components of the marine environment and of the relationships between them. In part, this information must be based on independent surveys using multiple techniques. Some of these techniques, like direct trawls for detailed sampling of a small portion of a habitat, are well developed. Others, like side-scan sonar and airborne lidar, are capable of covering much larger areas, but questions of data processing and instrument calibration remain to be answered. NOAA is working with various other countries and states to answer these questions and develop more accurate surveys.

OBSERVATION OF LIVING OCEAN RESOURCES

A major challenge in providing the required fisheries stock assessment information needed to manage fisheries is that NOAA's fleet of eight fisheries research vessels (FRVs) have reached or exceeded their expected service lives. On average, they are over 34 years old. For several years, options have been studied to replace the capabilities of these vessels. The options have been analyzed by an interdisciplinary team of scientists, acquisition specialists, design engineers and consultants from NOAA, other Federal agencies and the private sector. Admiral Craig Dorman recently reviewed NOAA's plan and generally concluded that the ship design will provide a world class fisheries research vessel, yet is not over specified. The report supports construction of four dedicated FRVs. These ships, supplemented with chartered vessels, represent a good start in maintaining the capabilities to meet our growing stewardship responsibilities.

NOAA Fisheries has reviewed Admiral Dorman's draft report dated 27 April, 1998. The following responds to major elements of the report.

Specification Validation

It is gratifying that both the process which was used to develop ship requirements and the requirements themselves withstood the test of external review. They represent the culmination of a multi-disciplinary collaboration of several government entities and private industry, which spanned nearly a decade. RADM Dorman stated:

> ". . . the FRVs as defined by the requirements statement will be outstanding vessels that should serve NMFS and the nation extremely well as the core of a dedicated fisheries fleet for their full projected lifetime . . . they are not over specified." (pp. 7-8).

He also strongly supports purpose-built ships which agrees with the NOAA approach for meeting its at-sea data requirements; constructing a core fleet of purpose-built, fisheries research vessels, and supplementing it with charters from the private sector and UNOLS.

ICES Noise Standard

Discussed at length was the requirement to meet the ICES noise standard, and ultimately, the report supported both designing the ship to meet the standard and including a centerboard to which acoustic instrumentation could be affixed. These measures will improve the efficiency of hydroacoustics, allow the fleet to accommodate technological advancements, and will minimize survey bias due to behavioral responses to ship noise.

Technology

The report also advocates that NOAA and other sponsors develop a national plan for research dedicated to advancing the state of technology used in fisheries oceanography, and stock assessment, particularly with respect to marine mammals and endangered species. NOAA agrees that a directed, collaborative effort of Federal, and state government, academic and private industry research bodies to focus on tools to better understand and manage the Nation's living marine resources would push the pace of technological advancements. NOAA concurs that a commitment by NOAA, the Department of Commerce, and OMB to request the resources from Congress to implement a national plan aimed at this goal is essential to its success. RADM Dorman, however, agrees that these technologies will not replace the need for dedicated fisheries research vessels, but will be an important tool to improve the quality of resource information and will help in areas where no other technique is more cost effective. These state-of-the-art research vessels give fisheries managers the highly specialized tools they need to make better decisions based on sound science.

In Monterey, the President proposed an additional $194 million over three years to begin construction of these new research vessels and speed implementation of measures to reduce overfishing, protect essential fish habitat, and to restore America's fisheries.

Mr. Chairman and Members of the Subcommittee, that concludes my testimony. I would be happy to answer any questions you may have.

Statement of Dr. Rita Colwell, Director Designate, National Science Foundation

Chairman Saxton and members of the Committee, I appreciate the opportunity to testify today on the important topic of ocean monitoring and assessment. This is my first hearing as Director of the National Science Foundation, and I look forward to many more opportunities to keep Congress apprised of the important research and educational activities that we support.

I am pleased to report to you that the National Science Foundation plays a substantial and critical role in the design and development of the Nation's oceanographic monitoring and assessment capabilities. We can identify a number of areas within which significant progress has been made in recent years, and in the few minutes available I will summarize for you some important successes.

The contribution that NSF-supported researchers make to ocean monitoring is fundamental. Effective and efficient oceanographic observation systems cannot be designed without knowledge of the active processes that they are intended to monitor. One exciting theme emerging from the past decade of ocean sciences research is the degree of **complexity and variability** of the oceans physical, chemical and biological processes, frequently on spatial scales of as little as half a mile. It is clearly impossible to monitor anything other than the surface of the global ocean (or even coastal waters) with such minute spatial resolution. Therefore, it is essential to understand the underlying processes sufficiently well so a small number of key observations can be identified that reliably tell us how the system changes overtime. Only with an understanding of the **process** can we make good decisions about what measurements will best characterize changes in the ocean, and, most importantly, how many measurements are required, and where they should be located.

The NSF-funded Tropical Ocean Global Atmosphere (TOGA) program focused on the physical processes occurring in the tropical ocean and atmosphere. The result was a recognition of the forces underlying the El Niño phenomenon, which in turn led to the design and deployment of the existing El Niño-Southern Oscillation (ENSO) observing system. The classic example is the array of buoys maintained by NOAA in the equatorial Pacific. This array is proving to be a powerful predictor of El Niño events. A small number of buoys, only 70 in total, in conjunction with satellite remote sensing methods is sufficient to monitor a vast area of the tropical Pacific Ocean. This capability was made possible by the basic research carried out by NSF-supported investigators cooperating with NOAA, NASA and international scientists in the early 1980's on the Tropical Ocean Global Atmosphere (TOGA) program.

In addition to complexity and variability characteristics of the oceans, important is designing a monitoring strategy to recognize the intimate links that exist between the chemical, physical and biological changes that we are witnessing. Today we know that it is impossible to understand the dramatic fluctuations in fish populations on the Georges Bank, for example, without understanding subsurface current systems that control dispersal of fish larvae. We cannot understand the development and distribution of plankton in the ocean (a primary food source) without understanding the chemistry of the ocean. The "blooms" of plankton in the ocean depend on availability of nutrients, including micronutrients such as inorganic elements and vitamins.

Clearly, monitoring the ocean must be a multidisciplinary activity because the of the interconnected physical, chemical and biological processes that control the health of the oceans. Support of those activities require inter-agency cooperation and partnerships.

One helpful way of categorizing the measurements that need to be made to monitor the oceans is to consider the following three overlapping classes:

- First, we need sustained time-series monitoring that provides data useful perhaps decades from now to **detect** subtle changes in the chemical, biological and physical characteristics of our oceans. These measurements provide the early-warning of changes in our earth system.
- Second, we need selected long-term observations that allow us to **predict** changes in our oceans and weather systems and thereby alleviate negative impacts—unquestionably this year's El Nińo activity is a clear example of this. The real time experiments and the predictive capacity they provided gave us some extraordinary new insights on climate and health.
- Lastly we need measurements, observations and experiments to help us understand the dynamic **processes**—physical, chemical and biological—that are *responsible* for the changes, that are the root cause of all the changes that occur—the understanding of which is essential to any capability for skilled prediction. It is the interactions of these processes that provide the elegant complexity that sustains both human and environmental health.

There is an intriguing shift that is slowly occurring in the emphasis of oceanographic research. Two decades ago the most exciting and unexpected discoveries occurred because researchers traveled to new locations in the oceans—this is the traditional mode of "exploring." However, today many of the biggest surprises are coming from measurements made at the same location but over long periods of time. It is the dynamics of the earth that is opening up many of the most intriguing secrets. Today oceanographers are becoming more explorers **in time,** as well as explorers **in space,** an important phenomenon of the science in this area of study.

It is in the **process-oriented** category of monitoring and observation that NSF is vitally active, and I am pleased to report that we are involved in a remarkably diverse and exciting set of projects. I have sufficient time here to describe only a few representative examples.

- The ocean moderates how rapidly the carbon dioxide content of the atmosphere is increasing. We are just finishing the fourth regional experiment of the Joint Global Ocean Flux Study (JGOFS) to trace the ganic and inorganic pathways of carbon through the ocean. The goal is to learn how carbon dioxide cycles through the Earth system. The Southern Ocean experiment followed those in the North Atlantic, the Equatorial Pacific and Arabian Sea. The processes of these unique regions will be combined into a global model that will allow us to better predict, for example, future climate change.
- This past winter, a team of researchers has lived on an icebreaker that is frozen into the pack ice in the Arctic Ocean, drifting with the ice floes as a floating science station. The project is part of a set of activities, taking place under the U.S. Global Change Research program, known as SHEBA (Surface Heat Budget of the Arctic Ocean), which pulls together data and information on how the sun, clouds, air, ice, and ocean interact and affect the annual melting and refreezing of the Arctic ice cap. This has long been a major uncertainty in climate models, and the SHEBA project has already helped to improve our understanding of climate change.
- Although the unique biological communities associated with ocean floor hydrothermal sites have been known for more than two decades, new organisms are still being discovered and the evolution-with-time of these sites is being explored—they are severely affected by volcanic eruptions on the ocean floor but re-establish themselves with remarkable rapidity. NSF-funded repeat visits by both manned submersibles and remotely operated vehicles to ocean depths of 12,000 feet and more are providing these remarkable observations.
- We recognize the need for long term continuous observations on the ocean floor (not just repeat visits once every few months), and it is indeed a challenge to devise approaches to this that are reliable, flexible and affordable. We are heavily involved in three particularly exciting pilot projects: two that use fiber optic cables (a volcano observatory off the island of Hawaii, and a coastal monitoring site off New Jersey) and a third located in mid-Pacific between Hawaii and California that will use an abandoned ocean floor telephone cable thousands of miles long to provide real-time access to an earthquake monitoring station and other sensors.

This scientific research can help us learn how to monitor changes on the ocean floor, and satellite remote sensing is a uniquely powerful approach to global observations of the sea surface. But how can we keep track of what is going on in the miles of ocean that exists in between? This is a realm in which we have seen some of the most remarkable innovation over the past five years fueled primarily by the needs of the World Ocean Circulation Experiment (WOCE).

As I present this to you this morning there are approximately 500 robotic vehicles distributed over the thousands of square miles of the north Atlantic oceans, drifting along with the ocean currents over half a mile beneath the surface. Approximately every two weeks each of these small instruments rises to the surface collecting data (temperature and salinity) as it moves to the sea surface, and then via satellite, telemeters these data as well as its position to investigators on shore. After being on the surface for about a day, they sink back down to their profiling depth of about half a mile and then repeat the cycle month after month after month. These robot floats, called PALACE (Profiling Autonomous Lagrangian Circulation Explorer) floats, are for the first time providing physical oceanographers with a real time synoptic view of ocean dynamics.

Technological innovation is changing the way we do oceanography—permanent seafloor observatories, new optical and acoustic imaging methods, long-term moorings, deep-diving manned submersibles, satellite communications, robotic vehicles—all are mechanisms for discovery that NSF supports as part of the revolution in the way we observe our planet's oceans.

We are in a time of rich opportunity for research in oceanography. As new observation systems are implemented we will learn ever more about the changes that are occurring on our planet on time scales of days, years decades and centuries. Hurricanes, droughts, floods, destruction of coral reefs, coastal erosion, climate change, El Niños, fisheries, human health—all are phenomena that are affected by, and in some cases, controlled by the oceans.

U.S. investigators in our nation's universities and oceanographic institutions are the world leaders. We do not lack for talent, or ideas or plans. If NSF can provide its community of researchers with adequate resources, as requested by the President in his 1999 budget, then a spectacular future of continuing new discovery and understanding is assured, that will build the intellectual foundation, and provide the knowledge of the ongoing processes, that is essential to the design of an effective ocean monitoring system.

Thank you again, Mr. Chairman, for the opportunity to share with you and the members of your Committee the exciting research being supported by NSF. I would be pleased to respond to any questions that you might have.

STATEMENT OF REAR ADMIRAL PAUL G. GAFFNEY. II, U.S. NAVY

Mr. Chairman, distinguished members of the Subcommittee, thank you for this opportunity to appear before you to discuss ocean exploration, monitoring and assessment.

This year—the International Year of the Ocean—has heightened public interest in our planet's most important features—the oceans. It has also elevated ocean science, research and education much higher on the national agenda, as was demonstrated by the prestigious participation at the National Ocean Conference held last month at the Naval Postgraduate School in Monterey, California. Enormous momentum was created by the Administration, Congress, academia and industry at that meeting; perhaps we can use the remainder of this year to raise and meet national oceanographic goals that have been neglected of late.

The Department of the Navy has long considered the study and exploration of the oceans to be a required competency—we must do it. We do it, not because we love it, or because it's interesting, or because we are chartered to do it—we do it because it is the foundation that provides the information required for every Naval operation. In fact, the root discriminator that separates Naval Forces from Army and Air Forces is the maritime environment in which the Navy and Marine Corps must work. That point is punctuated when you consider we are a Naval Force which is continually and agilely deployed globally; and, that is why the Navy must take a leading role in national oceanographic matters. (Admiral Boorda and I testified before this Committee and others in 1996 on this point.)

Over the last 50 years, we have invested billions of dollars in research, global ocean survey, data archives and predictive capabilities. Take for example these ocean monitoring tools and platforms that came out of our naval science and technology investment:

—SWATH Bathymetric Sonar

—Laser Line Scan Optical Sensor
—Global Positioning Satellite (location)
—PALACE Float (profiling capability)
—Current meters (conventional and acoustic doppler)
—Bioluminescence sensors, and
—Moorings . . . just to name a few.

We made the investment in these capabilities because we must be experts about our working environment. We must know ocean processes so we can understand how energy is transferred throughout the marine environment—a Naval need with an incredible civilian spin-off.

Despite our past efforts, and those of others, it is surprising to learn that only about five to seven percent of the ocean floor has been mapped to anywhere near the resolution that 100 percent of the moon has been mapped.

Why is that? Somehow it seems unlikely that it's more important or less expensive to map the moon. I, too, get excited about space exploration, but I get *really* excited about exploring and understanding our oceans for many of the same reasons. Future capabilities that will help us in our ocean quest include affordable arrays of drifting buoys that can profile the water column and report home their observations. These exist in quantities of hundreds measuring some variables; we need thousands measuring all important variables. Coastal systems that can profile the water column while moored to the bottom are also needed.

As a science and technology funding agency—the first in America—the Office of Naval Research develops many new technologies for ocean exploration and understanding. The major tools used today are based on a legacy of shipboard sampling, but the future belongs to autonomous systems that complement the shipboard survey we will continue to need for decades. These new systems can be either moored, or drifting, or independently moving small, unmanned systems. ONR is currently working on networks of inexpensive autonomous underwater vehicles. Also on the horizon are new remote sensing instruments such as the Naval EarthMap Observer satellite, or NEMO, which will provide hyperspectral images when it is launched in 2002. It is a DOD/Navy/Industry partnership.

NEMO, like so many other programs, reiterates the fact that no one group or agency can support all of the costs for oceanographic research, ship operations, surveying and modeling that need to be done on a global scale. The Department of the Navy depends on partnerships with other Federal agencies—NSF, NOAA, NASA, DOE, DOI—as well as academia and industry to develop new capabilities and leverage our decreasing budget dollars.

Another key opportunity for partnering is offered through the National Oceanographic Partnership Program (NOPP). Now in its third year, this program was initiated, and is fully supported by Congress. The Secretary of the Navy provided Department money and took the lead in getting the program started. Other agencies are now joining in with funding and strong participation. It is a terrific partnership with real give-and-take, great understanding, new leveraging, and program focus. Because the several agencies that are working together can actually create critical mass to address the neglected ocean, the NOPP is the right body to address a national ocean exploration, observation, and assessment agenda.

I believe that the Nation should discuss the need for 100 percent survey and understanding of the world's oceans during the next millennium. This, of course, can only be accomplished if all cognizant agencies cooperate and participate. For example, we might consider starting such a survey, and beginning the millennium, with a single exploration and mapping effort—100 percent coverage of one important area. According to NOAA, thirty-six U.S. states and territories have a total of more than 95,000 miles of coastline, so there are many suitable places to begin a major effort. As I will discuss later, the NOPP presents a forum for discussion of a suitable and plausible project. We owe it to ourselves and our descendants to know at least as much about our oceans as we know about the moon . . . or other planets.

I've been calling this notion "GISMOE" for the Great Intra-American Seas Millennium Ocean Expedition . . . it could also be called "GABE"—Great American Bays/Bights Expedition. Perhaps I should leave the acronyms to others, but what is important is that we start the process, and there are two reasons I think this is worthwhile:

1. The crosscutting theme of the recently released Ocean Studies Board report "Opportunities in Ocean Sciences: Challenges on the Horizon," is that we need to observe our the water planet. The report concludes that ocean sciences are at a critical point—a point where, given a commitment, "substantial progress can be made on a number of societally important issues." Such an effort needs to be a national imperative and involve the resources of many Federal and State agencies. So starting to understand the global ocean at one coastline

makes sense, certainly for the civil agencies, but also because a global Navy needs to understand the very complex littoral environment processes. Understanding those processes in our own "Exclusive Economic Zone" and littorals is more affordable and can serve as a surrogate for similar littoral areas in remote parts of the world where we may not have access.

2. There is a great unity in the ocean community for continued and comprehensive observation for a myriad of reasons. I agree with that; a proper start is to determine a full and complete baseline. A survey of a body or basin of water, its water column, bathymetry and bottom composition is "Step One." Then continual monitoring of that area over time long time is next. That's what we do with weather today and what we should be doing with the oceans.

These are some thoughts from a Navy oceanographer and Chief of Naval Research. I recognize they are hollow unless embraced by "100 percent partners"—full participation of all cognizant agencies. In that regard, this issue of global ocean monitoring, and where and how to start is appropriate for discussion within the NOPP's Leadership Council and Advisory Panel. I intend to propose such dialogue be initiated so that we join the next millennium with an acceptable plan. We are doing our part by funding many projects to understand ocean dynamics, including investigating new approaches to mapping and understanding ocean bottoms and littoral areas.

It will take decades to understand the submerged planet as well as we understand the moon, but we need to begin somewhere. Your support for our requested program is important.

Thank you for the opportunity to be here today. I would be happy to respond to any questions you might have.

STATEMENT OF CHARLES F. KENNEL, DIRECTOR, SCRIPPS INSTITUTION OF OCEANOGRAPHY, UNIVERSITY OF CALIFORNIA, SAN DIEGO

Mr. Chairman and Members of the Committee, thank you for inviting me to testify today on the status of ocean monitoring and assessment. I am Dr. Charlie Kennel, Director of U.C. San Diego's Scripps Institution of Oceanography (SIO).

Overview Of Scripps Institution Of Oceanography

From our campus overlooking the Pacific Ocean, Scripps Institution of Oceanography (SIO) continues a 95-year tradition of scientific leadership. SIO is one of the world's oldest, largest, and most important centers for marine science research, graduate training and public service. Part of the University of California at San Diego, SIO's preeminence in biological, physical, chemical, climatological, geological, and geophysical studies reflects its continuing commitment to excellence in research, modern facilities, distinguished faculty, outstanding students, and public service. Acknowledging our rich tradition, the National Research Council recently ranked SIO first in faculty quality among oceanography programs nationwide.

With annual expenditures of more than $100 million and a staff of 1,200 scientists, technicians and support personnel, including nearly 200 graduate students, SIO is involved in more than 300 major research programs.

SIO also maintains one of the largest and most capable fleets of academic research vessels in the country with 4 sea-going vessels and one research platform. SIO has operated large and small world-ranging ocean science research ships continuously since 1908. Ships were among the first technologies used by scientists to make ocean observations. In a 1953 proposal to the Rockefeller Foundation, a Scripps scientist stated: "The long arm of the oceanographer is his ships and his groping fingers, the cable. Without ships to test and to explore, the hypotheses and laboratory discoveries of the marine researcher become dry and insubstantial and the researcher blind and isolated."

Scientists depend on ships to make many critical ocean observations (see Appendix 1). New technology has expanded the spatial and temporal sampling capability of ships. Devices such as drifting and moored buoys, sea floor observatories, subsurface profiling floats, satellites, acoustic instruments, remotely operated vehicles and autonomous underwater vehicles, enable scientists to make continuous observations of time dependent, large-scale phenomena (e.g. El Nińos), abrupt events (e.g. earthquakes, tsunamis), and provide the essential, complementary ingredients of an effective global observing strategy.

At Scripps, we believe an integrated approach to observations—which includes climate, weather, global change, natural hazards, and solid earth phenomena such as undersea volcanoes and earthquakes—is fundamental to sound science. This approach enhances the productivity of our research infrastructure while generating coherent data sets required in interdisciplinary ocean studies. Although continuing technology development is critical, we already have at our disposal the basic elements of an integrated global observing strategy.

The Value of Integrated Observations

Predicting changes in the ocean is critical for the accurate forecast of the global climate on time scales of months to years. Variations in the ocean structure and circulation patterns dramatically affect heat and moisture input to the atmosphere. The oceans also play a key role in regulating greenhouse gases in the atmosphere. Ocean observations are required to capture events, initialize numerical models for climate and weather prediction, calibrate remote sensing observations of the ocean, and provide real-time data for marine commerce, ecosystem monitoring, and fisheries. In short, any global climate prediction system depends on an integrated global observing strategy for the ocean.

An integrated observing strategy is important to how we monitor and manage local as well as global climate events. The devastation caused by this year's El Niño demonstrates the significant social and economic value of new capabilities to forecast climate conditions up to a year in advance. Economic studies suggest that enhanced climate prediction capabilities, if used appropriately, could reduce extreme seasonal climate damage costs in the U.S. by 25 percent or $2.7 billion annually in the agricultural sector alone. Water, energy, and transportation managers, as well as farmers, could plan and avoid or mitigate losses with more accurate and timely predictions. The agricultural futures market would also become more efficient.

In an effort to reach out to vulnerable communities, Scripps, the California Department of Boating and Waterways, and the California Coastal Commission hosted a workshop in La Jolla August 19, 1997, to describe and discuss possible coastal impacts of severe storms associated with El Niño. As a follow up to that meeting, Scripps researchers worked closely with potentially affected cities throughout the region. We encouraged them to prepare risk assessments and a list of possible mitigation measures. That information provided decisionmakers with science based, cost/benefit analyses to determine the appropriate level of mitigation. In this way, an integrated observing strategy, informed by public and private sector needs, transformed scientific data into knowledge that saved lives and property.

The media coverage of the 1997-98 El Niño led to a public understanding that events in the middle of the tropical Pacific ocean have a profound impact on day-to-day lives. Scientist have long appreciated the need to understand and observe the ocean, now the public does as well. We believe that this public understanding can be transformed into support for the implementation of a global ocean observing strategy.

Elements of a Strategy

Prediction of the 1997-98 El Niño was made possible by the El Niño Southern Oscillation (ENSO) observing system, the Topex-Poseidon satellite radar altimeter, and improvements in coupled ocean-atmospheric models. The remarkable performance of these research tools offers a glimpse of what a more comprehensive, integrated observing system and continued improvements in coupled ocean-atmospheric models will provide. These advances will improve prediction of short-term climate events, such as El Niños and La Niñas (the opposite phase of the El Niño oscillation), elucidate the impacts of such events on regional weather and ocean biology, and are necessary before we can deepen understanding of long-term climate events like Pacific Decadal Oscillation, North Atlantic Oscillation, and Tropical Atlantic Variability. Only by understanding these natural events will scientists be able to distinguish "global warming" from natural climate variability.

Responding to policymakers' needs for definitive assessment of global warming and the range of its possible regional impacts requires a global observing strategy. I believe such a strategy must contain at least five elements. First and foremost, it requires integrating "in situ" with space-based systems. No one technology is adequate to provide the answers needed, as each technology has its benefits and drawbacks (see Appendix 2). Space observation provides global coverage. "In situ" observations provide "sea truth" by making measurements in the water, of the water, and under the water. The key to implementing a successful observational strategies lies in adopting a problem-driven approach where the system is designed to meet measurement needs specific to given problems. Both the data needs for numerical models and a clear definition of new scientific questions will determine the appropriate array of observational technologies to be used.

The second component of the strategy involves improving climate models, data assimilation techniques, and computing power. The combination of these tools will enable us to reconcile disparate observations and fill gaps where data are not available. In addition, these models make possible predictions ranging from global scale to highly localized phenomena. Scripps scientists are currently developing a system of "nested" models that will transform predictions of seasonal climate events into rainfall predictions for individual California watersheds. This climate initiative builds on established practices of weather services which assimilate vast arrays of disparate data into complex models for forecasting.

Third, despite the array of technologies currently available, new instruments are needed. Therefore, a technology development program that is science-based, through the active engagement of the university community (see Appendix 3), must be formally integrated into Federal agency research programs. Technology development should focus on increasing capabilities and lowering costs strategically to enable the deployment of a global system. One advance of particular value would be the development of an underwater Global Positioning System (GPS). Underwater GPS would be a tremendous advance for underwater gliders and other observational technologies, and enable profiling floats to begin to measure ocean velocity. Another area of focus should be on the many chemical and biological properties of the ocean which cannot yet be measured by any remote or unmanned technology with the necessary precision or on the same scales as can physical and geophysical properties.

The fourth component of this strategy ensures the continuity of physical, chemical and biological measurements. By this I mean supporting long-term time series observations and data validation. These measures are especially important when scientists make predictions about long-term phenomena like Pacific Decadal Oscillation and global warming. As we deploy "better, faster, and cheaper" observational tools, such as new satellites and ocean observatories, we must take care to maintain established records and data in standard formats and on modern media, and implement a program to calibrate and validate new data sets. Furthermore, even areas where technology development is still necessary, climatically important measurements of chemical and biological properties by conventional means must be sustained until they can be enhanced. For example, efforts to study changes in ocean chemistry and biology must continue, especially as they bear on the prediction of the effects of atmospheric carbon dioxide on climate change, questions of profound importance to predicting global warming.

The fifth element of a global observing strategy involves cooperation and coordination of research activities. Federal agencies must work to integrate existing programs, leverage scarce resources, and promote new initiatives. I am pleased to see the Navy, NOAA and NSF here today. Coordination and commitment of these agencies, along with NASA and DOE, is critical to the success of this strategy.

Increased cooperation and collaboration is also required among universities, Federal agencies, other countries and the private sector. As we move from exploratory research to routine monitoring for many global-scale problems, we will enter into new partnerships, and use non-traditional institutional arrangements. Scripps is at the forefront of creating such partnerships across institutional and national boundaries. In 1999, SIO will lead an international experiment in the Indian ocean (INDOEX) to study the impact of aerosols on regional and global climate, a major global change issue. INDOEX, involves ships, aircraft, surface stations and satellites, from several nations, including U.S.A., Germany, France, England, India, Netherlands and others.

International cooperation is also moving forward on a broader scale. International space agencies, through the Committee on Earth Observation Satellites (CEOS), are working with other partners to develop an Integrated Global Observing Strategy (IGOS). IGOS is a process to help ensure that resources are addressing the highest priority observational needs, while taking into account the missions and plans of space agencies, and the up-to-date requirements of major international user programs. This involves assessing gaps and unnecessary overlaps in observing systems, as well as cross-cutting issues such as data calibration, validation, management, and policy. Initial IGOS focus has been on the space component. Now is the time to provide the "in situ" strategy to complement the progress made by CEOS.

Specific Recommendations

Given our present observational capabilities and the demonstrated value of ocean observations in seasonal climate prediction, fisheries, commerce, coastal and military applications, it is imperative that we advance an integrated global observational strategy. This is the only way to provide the data needed by scientists to make believable and useful predictions about natural and anthropogenic climate change.

Having described the key components of the envisioned observing strategy we must now take the necessary steps to implement it. First, research institutions and Federal agencies must begin the analysis necessary to determine the best combination of “in situ” observing platforms. Satellite integration has begun under the auspices of CEOS. We must support a similar effort for “in situ” sensors. Federal agencies should then support the technology development and research needed to optimize the integration strategy.

Second, it is critical to support NOAA’s efforts in climate monitoring, particularly the President’s initiative for a $12 million, global array of subsurface profiling floats. The array will complement the contributions of climate-related satellites. Another technology which has already demonstrated its value in conjunction with satellite altimetry data is Ocean Acoustic Tomography (see end of Appendix 2). Ocean Acoustic Tomography measures temperature averages over thousands of miles, thus permitting the detection of small climatic changes. Deploying both types of technology and supporting research on improving the use of integrated data will accelerate efforts to improve seasonal-to-interannual and climate prediction, detect global warming, and attribute these changes to natural and/or anthropogenic causes.

NASA’s GODAE (Global Ocean Data Assimilation Experiment) initiative, a pilot project of the CEOS/IGOS process, should be supported. GODAE will be the first operational demonstration of our ability to estimate the physical state of the global ocean and its evolution. With many potential benefits, including improved climate prediction and understanding, GODAE will turn powerful data assimilation techniques to merging data streams from satellites and “in situ” sensors.

Finally, I encourage Federal agencies to develop modeling and data analysis programs that provide up-to-date descriptions of the evolving ocean. This effort should encompass physical fields that affect weather and climate, as well as chemical and biological processes. The National Science Foundation and the Department of Energy are considering important initiatives in this area. NSF is considering an ocean data assimilation and modeling center to support climate dynamics and other branches of ocean sciences such as biological modeling and assessment and pollution prediction. DOE is contemplating anew to increase dramatically the rate of climate simulation model development and application to produce decade-to-century-scale forecasts of climate change with regional resolution.

Again, I thank you for this opportunity to testify and would be happy to answer any questions.

Appendix 1—Ships

Scientific observation of the ocean has always required the use of dedicated, effective research vessels. Today, research ships are an even more critical component of ocean observations than has been the case in the past for a number of reasons. First, there is simply no way that many important observations can be made in unattended or remote fashion. Ships can manage observations of deep ocean chemical properties needed to diagnose the ocean’s role in the global carbon cycle and to track them in various locations, tasks unattended devices cannot perform. Arguably the most important observing network in today’s ocean, in terms of practical impact on forecasts of real economic and social importance, is the tropical Pacific buoy array (ENSO) maintained by NOAA. Its reliability depends on regular network maintenance using ships. Ships will be needed in increasing numbers and capabilities to establish, maintain and support the integrated global observational strategy.

Second, as new technologies emerge, they generally must be calibrated with existing methods to preserve the integrity of the data. Calibration or “sea truth” must be both extensive and ongoing, and it typically involves the use of ships. Finally, global-scale measurements are increasingly amenable to remote or unattended observation. This refines our large-scale views of oceanic variability and focuses investigations into the fundamental oceanic processes that shape large-scale fields and their evolutions. One can see the beginnings of this in programs that have carried out shipborne investigations of upwelling regions guided by near-real time satellite imagery to disclose patterns of upwelling activity. As the mapping and monitoring power of unattended sensors grows, so will opportunities for shipborne process studies which will allow monitoring at all the scales needed to understand oceanographic phenomena.

Appendix 2—Ocean Observing Technologies

No one technology is adequate to provide the answers needed to understand and predict natural and anthropogenic climate change. Each technology has its benefits and drawbacks. For example, the forte of satellite data is the regularly repeating, synoptic nature of the data. Its limitation is that satellites observe only the sea surface, hence requiring subsurface data for interpretation and understanding. Principal satellites of interest in climate are altimeters (e.g. Jason-1, TOPEX-Poseidon, Geosat Follow-On) for measuring sea surface height; scatterometers (e.g. NSCAT, ERS-2) for measuring surface winds; and AVHRR (Advanced Very High Resolution

Radiometer) for measuring sea surface temperature and microwave rainfall measurements. Scripps is now experimenting with the measurement of tropospheric moisture at sea using the Global Positioning System (GPS).

"In situ" data are required to interpret subsurface structure corresponding to satellite surface observations. For example, measurements of upper ocean heat content are crucial in interpreting altimetric height. In situ measurements are also needed to measure the deep ocean, calibrate satellite data, and measure parameters for which there is no satellite capability. As an indication of the number of tools which already are available, a brief list of "in situ sensors" is as follows:

- surface drifters which measure surface current, sea surface temperature (SST), barometric pressure and surface salinity;
- profiling floats which measure temperature and salinity profiles, presently to about 15;
- moorings or fixed platforms which deploy a wide variety of instruments to measure temperature, salinity, velocity, and meteorological parameters;
- volunteer observing ships which measure temperature, salinity to 800 meters, meteorological parameters, and atmospheric trace gases;
- acoustic thermometry which measures sound speed, providing temperature averages along paths between source-receiver pairs; and
- research vessels, which are required to deploy and monitor some of the above systems, conduct hydrographic surveys (that include biological and/or geochemical measurements in addition to temperature, salinity, velocity), and meet specialized needs autonomous instruments cannot.

Integration of "in situ" and satellite data has begun to show great promise. A joint analysis of Satellite Altimetry, Acoustic Tomography and computer modeling found that changes in sea level as measured by satellite altimetry are not by themselves a representative proxy for the variable ocean heat storage (an essential climate parameter). But when combined with the acoustic measurements they yield a meaningful measure of the basin heat storage.

Appendix 3—History of Ocean Climate Observations and Technology Development at Scripps Institution of Oceanography

Throughout the 20th century, university researchers have advanced the design and testing of new instruments and observing technologies. Scripps has played a leadership role in pilot experiments for new in situ observing technologies (ocean profiles and surface observations from volunteer commercial ships, profiling floats, acoustic thermometry, and surface drifting buoys) that make large-scale observations economically feasible for some climatically important ocean properties.

Scripps scientists were responsible for the following breakthroughs in ocean climate monitoring and technology development:

- establishing the California Current monitoring system in 1937—the longest, continuing ocean monitoring program in the U.S.;
- inventing and establishing the Volunteer Observing Ship Expendable Bathy Thermograph (VOS-XBT), or temperature probes network, in the early 1970s;
- inventing and deploying the global drifting buoy network in late 1980s;
- inventing and deploying the network of real-time, profiling floats in north Atlantic and tropical Pacific;
- developing the most accurate techniques for measuring the amount of carbon in seawater;
- and inventing the acoustic thermometer.

Clearly, continuing support for university collaboration with the private sector technology development is important to sustaining innovation in the global observational strategy.

CHARLES F. KENNEL, DIRECTOR OF SCRIPPS INSTITUTION OF OCEANOGRAPHY, VICE CHANCELLOR OF MARINE SCIENCES, UCSD, DEAN OF THE GRADUATE SCHOOL OF MARINE SCIENCES

Charles F. Kennel is the ninth director of Scripps Institution of Oceanography at the University of California, San Diego (UCSD). Kennel also serves as UCSD Vice Chancellor of Marine Sciences, Dean of the Graduate School of Marine Sciences, and a professor in the Scripps graduate department.

Born in Cambridge, Mass., Kennel received a bachelor's degree in astronomy from Harvard College in 1959 and a doctoral degree in astrophysical sciences from Princeton University in 1964. He was appointed an associate professor of physics at UCLA in 1967 and a professor in 1971. Kennel became UCLA's executive vice chancellor in 1996.

Kennel's research at UCLA focused on fundamental plasma physics combined with space and astrophysics. His work centered on basic plasma turbulence theory and collisionless shocks, the physics of the solar wind and planetary magnetospheres, and the physics of pulsar magnetospheres and active galactic nuclei.

From 1994-1996, Kennel served as associate administrator for NASA, directing Mission to Planet Earth, the world's largest environmental science program.

Kennel was elected to the National Academy of Sciences in 1991 and was named a Fellow of the American Association for the Advancement of Science in 1992. He also is a Fellow of the American Geophysical Union and the American Physical Society. He won the NASA Distinguished Service Medal and the Aurelio Peccei Prize from the Italian Academy of Sciences in 1996. He received the 1997 James Clerk Maxwell Prize from the American Physical Society and the 1998 Hannes Alfven Medal of the European Geophysical Society.

Kennel has been a Harvard National Scholar, a Woodrow Wilson Fellow, a National Science Foundation Postdoctoral Fellow, a Guggenheim Foundation Fellow, a Fulbright Senior Lecturer in Brazil, a Fairchild Professor at the California Institute of Technology, and an Alfred P. Sloan Foundation Fellow.

Outline Dr. Charles F. Kennel's Testimony

I. Introduction

II. Overview of Scripps Institution of Oceanography
History
Budget
Research fleet

III. Ships and other technologies used in ocean observations

IV. Ocean's role in climate

V. El Nino as example of value of climate prediction

VI. Need for ocean observing strategy to understand and predict climate

V Elements of an Ocean Observing Strategy
I ntegration of space-based and " in situ" sensors
Improved climate models, data assimilation and computing power
Technology development program
Continuity of measurements--long time series & data validation
National and international cooperation and coordination (INDOEX)

VI. Recommendations
Begin integration of " in situ" sensors
Support NOAA $12 million observing initiative
Support other observing technologies--acoustic tomography
Support NASA GODAE program
Support modeling and data assimilation programs--NSF &DOE

VII. Appendix I--Continuing importance of ships in ocean observations

VIII. Appendix II--Description of ocean observing technologies

IX. Appendix III--SIO's history of ocean observations and technology development

STATEMENT OF ADMIRAL JAMES D. WATKINS, U.S. NAVY (RETIRED), PRESIDENT, CONSORTIUM FOR OCEANOGRAPHIC RESEARCH AND EDUCATION

Mr. Chairman, members of the Subcommittee, I would like to thank you for calling this hearing today to discuss this very important subject. The previous witnesses have described to you several outstanding examples of the kinds of capabilities we have, or will soon have, and some of our priorities to better understand, monitor and predict the greatest natural force on Earth. What I would like to do is provide a conceptual road map for how we might transition from the ideas of our researchers, working with decision makers in the Congress and the Administration, to an actual system which integrates our national needs and priorities.

The breadth of our national need for knowledge of the ocean system is daunting. Research providing the foundation for missions to advance economic development, protect quality of life, ensure national security and improve science education is a complex weave of multiple disciplines and specialized technologies, addressing questions from the most basic mechanics of the Earth system to very applied engineering solutions. Federal responsibility for the wide scope of ocean science is split among nine Federal research agencies, each with specific mission parameters, but often working in unison to address common research requirements.

We have come to an important juncture in the development of ocean science. More than ever, our progress is limited by the lack of important ocean observations. As the Ocean Science Board of the National Research Council has clearly stated in their new report "Opportunities in Ocean Sciences: Challenges on the Horizon," questions of marine resource management, climate prediction and the role of the oceans in human health require extensive and long-term observation of the oceans on global, regional and local scales. Mr. Chairman, I would like to submit a copy of that report for the record.

For example, if we are to monitor and respond to harmful algal blooms, we must be able to "see" their early indications in individual estuaries and near shore environments. If we are to understand the dynamics of commercial fish species, we will require in-depth knowledge of the regional ecosystem and how it is affected by physical and chemical variability. If we are to provide better regional climate forecasts, we must first obtain and integrate oceanic data on a basin and global scale. The applications are many, and the potential payoffs are tremendous.

So, what is needed to meet our objectives?

You have heard from previous witnesses that there has been a lot of thought given to this question and that we have a lot of answers. The merits of a variety of independent observing system proposals are well understood and accepted. What we do not currently have is a definitive strategic plan to chart our course to an integrated ocean observing system. We need to couple an analysis of the mission responsibilities of the various Federal agencies with our current and planned observational capabilities to determine the best opportunities for success. From this analysis, we can build a plan detailing exact requirements for a comprehensive ocean observation system. The system would then include integrated modules to gather data and address questions on a variety of time and space scales, assimilating and fusing information from these various sources, much like the well established practices of the defense intelligence community. Analysis and interpretation would then provide the products we will rely upon for better decision-making.

We have undertaken a similar task in the past, which is worth commenting on. After World War II, anti-submarine warfare was determined to be a national priority. The oceanographic community, including Federal agencies, academia and industry, was tasked with developing a system to detect and track Soviet submarines, utilizing significant developments in acoustics research and related technologies. What resulted was the development of the Integrated Underwater Surveillance System (IUSS), the fixed portion of which was called SOSUS, the giant series of listening arrays in the Atlantic and Pacific. Observations from these fixed and mobile arrays were highly integrated or fused with multi-source observational and intelligence data from satellites, ships, aircraft, humans, and other sensors over a wide geographic area. This highly capable and integrated system eventually contributed significantly to our winning the Cold War. Notable is (1) the definition of national need, with a full understanding of the costs and benefits, (2) the commitment to development of a system, not just a collection of parts, and (3) the contribution of all sectors, each bringing their own strengths to meeting a complex challenge. The resultant sixteen billion dollar investment was clearly justified. In the interest of demonstrating the effectiveness of our national will, I should also note that the SOSUS arrays went from the blackboard in 1949 to full scale operation in 1952 . . . only three years!

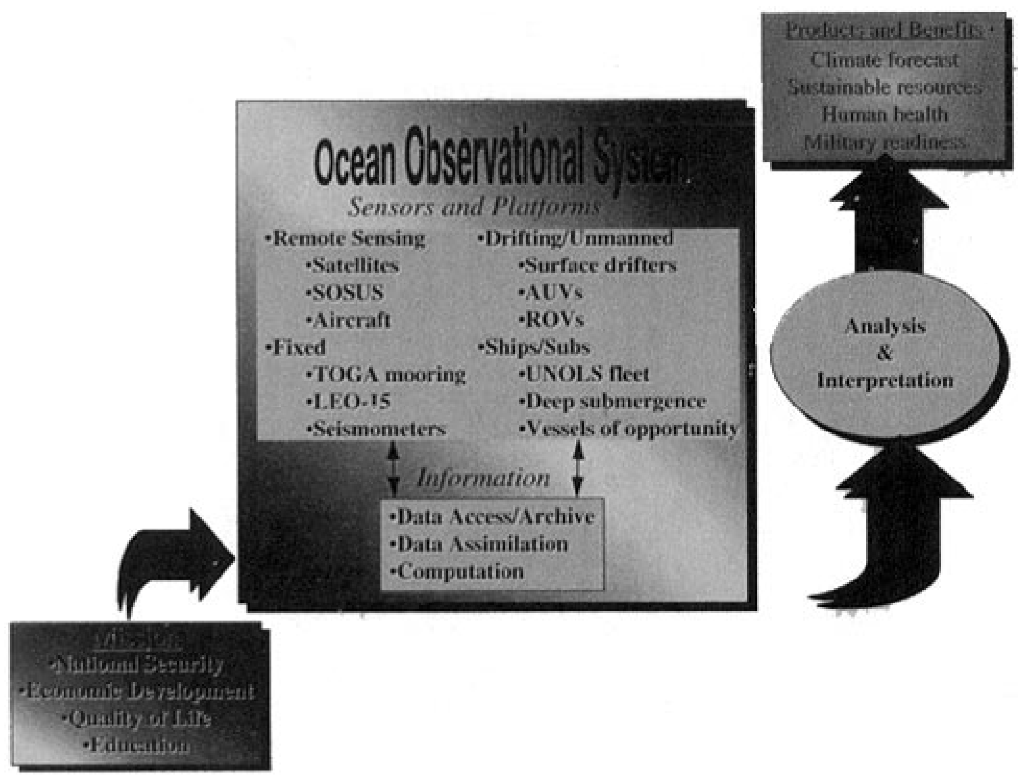
I believe we are poised to undertake a similarly important, if not more complex, task today, but we need your assistance. We need the Congress to demand a strategic plan for a comprehensive ocean observing *system.* The Congress should request that the National Ocean Research Leadership Council, consisting of the leaders of each of the nine Federal ocean research agencies, develop such a plan, defining components, priorities and resource requirements. This plan should show how an integrated system would optimize the Federal effort to meet specific objectives on a specific timeline, making clear the products and benefits expected. The plan should also address the involvement of other maritime nations, where we have mutual objectives and can share equitably in the investment. And this plan should build upon the volumes of well thought-out agendas developed by the individual agencies, National Academy of Sciences and nations in years past. Mr. Chairman, this will certainly require coordination of the Congress and Administration to make the proper resources available.

From such a plan, we can finally begin to realize the many benefits of ocean science that we just talked about today. On the horizon, we can envision greatly enhanced coastal weather forecasting and longer term climate forecasting, more efficient shipping, and more informed decision-making for difficult environmental and resource management questions, just to name a few benefits.

The timing for such an initiative will never be better. Because of the recent El Nińo event and the oncoming La Nińa, the U.S. public sees daily the value of our current ocean observational capabilities. But those who rely on the products of ocean science—State governments, many industries, the educational community to name a few—are clamoring for more comprehensive data and more advanced products. For the last 50 years of this century, we devoted our national attention on space, and properly so. We need to focus our attention in the first 50 years of the next century to understanding how the oceans can assist mankind in meeting its burgeoning challenges.

The Congress has already set in place a perfect mechanism for implementation of this kind of initiative by creating the National Oceanographic Partnership Program. This program provides a platform for collaborative work by the ocean research agencies, bringing together the best minds in academia, industry and the Federal laboratories.

In closing, I want to thank you again for holding this hearing. Your continued leadership, Mr. Chairman, and the interest of this Subcommittee is sincerely appreciated by the oceanographic research community. I hope that you will consider my recommendations and I look forward to continuing to work with you to ensure we are doing everything we can to make wise use of our greatest natural resource.


Mission
•National Security
•Economic Development
•Quality of Life
•Education
Ocean Observational System
Sensors and Platforms
•Remote Sensing
•Satellites
•SOSUS
•Aircraft
•Fixed
•TOGA mooring
•LEO-15
•Seismometers
•Drifting/Unmanned
•Surface drifters
•AUVs
•ROVs
•Ships/Subs
•UNOLS fleet
•Deep submergence
•Vessels of opportunity
Information
•Data Access/Archive
•Data Assimilation
•Computation
Analysis
&
Interpretation
Products and Benefits
Climate forecast
Sustainable resources
Human health
Military readiness

Testimony
of
Dr. Robert B. Gagosian

Director
Woods Hole Oceanographic Institution

before the
Subcommittee on Fisheries Conservation, Wildlife and Oceans
Committee on Resources
U.S. House of Representatives

July 30, 1998

INTRODUCTION

Mr. Chairman, members of the Subcommittee, thank you for inviting me here today to speak with you about deep-sea research, how we get to the deep-sea, what we see there, and why it is important to the Nation that we continue to be there. I will also outline the present status of our deep-sea technology and what is needed to continue to improve our research, monitoring and assessment capabilities.

First, as an introduction, let me remind you that the importance of deep-sea submergence to the Nation is rooted in history. In 1940, deep-submergence, as well as the activities of the Institution which I represent, the Woods Hole Oceanographic Institution, changed dramatically with the support of the war effort. Research concerning the prevention of marine fouling, the effects of salinity and temperature on underwater sound, and the dynamics of underwater explosions all had great pay off for our forces. In the post-war period, with the advent of nuclear propulsion and nuclear submarines operating for long periods of time in the deep "blue water," the Nation's military strategy needed knowledge of the world's deep oceans, not just our own coastal zone, and it needed undersea predictive capability. This need was highlighted during the Cold War, for example, by events such as the loss of nuclear weapons off Spain and by the loss of two U.S. nuclear submarines in the deep Atlantic Ocean. Such losses emphasized our need for technology and operational know-how for locating, surveying or salvaging items on the ocean floor, including military hardware. At that time, the Office of Naval Research (ONR) and the National Science Foundation (NSF) made significant, long-term research investments in the studies of ocean thermal, chemical and acoustical properties, as well as bottom topography. This research, ultimately, helped submariners process and assess the many noise sources in the sea, and enabled them to discriminate undersea threats. We now know that those long-term investments paid off not only for the military but for the academic, ocean-science community as well. This research investment led to a significant improvement in our understanding of ocean dynamics and the processes which control how the ocean responds to the atmospheric forcing and internal changes in ocean structure.

Clearly the government long-term investment in the early days of oceanography provided the model for the continued funding we have today, which comes not only from the Navy and the NSF, but also NOAA. With that investment, we, the oceanographic community, have been able to support an oceanographic infrastructure of ships, vehicles, instrumentation, educational curricula and above all – human talent - that is the envy of the world. As Director of the Woods Hole Oceanographic Institution (WHOI), I am proud today to represent an institution which not only has its grand share of that talent, but which also operates the United States National Deep Submergence Facility. With the financial support of the NSF, the Navy, and NOAA, this facility is comprised of world class vehicles – human occupied (HOVs, like *Alvin*) and it's support ship. The R/V *Atlantis*, remotely operated (ROVs, like *Jason*), and autonomous vehicles (AUVs, like *Remus*). Together with deep mooring systems, these vehicles are the workhorses for operating scientists and technicians and provide the backbone of deep-sea data collection and observing capability for the Nation's science community.

WHAT IS THE DEEP OCEAN?

Observing the deep ocean is as much a formidable engineering challenge as it is scientific. With its own special set of problems, such as changing temperatures, densities, and particularly the darkness and extreme pressures, attempts to measure and characterize these vast inner-space environments rival our attempts to do the same in outer space.

The deep ocean is a world of slopes and canyons, of abyssal plains with depths greater than 9000 feet, and of mid-ocean ridges rising to as much as 12,000 feet. These ridges are linked around the world into a 40,000-mile underwater mountain range, the longest one on earth, 2 1/2 miles beneath the sea. There are approximately two thousand sea-mounts on the sea floor, believed to be of volcanic origin, which rise from 3000 to 10,000 feet. There are also valleys and trenches that vary to extreme depths. The deepest spot in the ocean is about 7 miles – roughly the distance you will see when you look down from an airplane. Yet only a few percent of the ocean floor has been explored.

We are clearly heavily dependent on progress in technology to broaden our measurement view in the deep ocean. New advances in upper and deep-sea technology, as well as satellite and computer information technology enable us to ask questions today which we could not have addressed (or, perhaps, even thought of) just a decade ago. As we enter the next millennium, we are poised on the doorstep of an incredible, unprecedented opportunity to learn about the oceans and the earth, *our* planet. As you will hear today, we know what we need to learn, why, and how. We just need to do it.

WHY IS IT IMPORTANT THAT WE GO TO THE DEEP OCEAN?

There are many reasons why we go, and must continue to go, to the deep-oceans. It is where our planet earth is presently being formed, contorted, stretched and quaked - right now. It is likely where life may have first begun on this planet – and where we can still witness it beginning. Samples of its sediments, which contain the shells and skeletons of previously living ocean creatures, provide us with a history of previous climates and life forms. The deep ocean is not quiet, nor is it unchanging. There are strong currents which connect together all of the ocean basins. Deep ocean currents hold the key to understanding the workings of the global conveyor belt that carries warm surface water to the North polar region in the Atlantic, and returns cold water to fill the deep ocean throughout the world. Understanding this circulation is critical to our understanding of possible changes in the earth's climate. Knowledge of the physics and the chemistry of the oceans is also essential to understanding ocean circulation, which in turn can have important effects upon global weather systems. Observations from the deep-ocean will also provide us with many answers about the changing chemistry of seawater, which ultimately will lead us to understand what environmental changes the ocean can sustain from the atmosphere, such as CO_2. The deep-ocean is also where we are turning for new pharmaceuticals and biotechnology innovations. It is also where we may need to turn for energy and minerals. The deep-oceans also provide the excitement of exploration and of the unknown, which together with all the physical disciplines, form the perfect classroom for our children and science.

Let me now elaborate on some of the important reasons to be in the deep-oceans as well as some of the scientific discoveries that deep-sea research has brought to us and deep-sea technology has enabled.

Along with the deep valleys and high mountains of the deep-sea lies the phenomena of plate tectonics. As you know, the earth is a collection of plates that piece together the unsettled mantle. Determining plate stability through measurement of plate stresses, and determining predictive behavior through sophisticated models may one day lead to forecasting earthquakes, landslides and seafloor spreading. These seafloor instabilities are the origins of tidal waves or tsunamis, just like the one that recently struck Papua, New Guinea. Seafloor sensors and satellite systems could offer early warning of an impending disaster by detecting seismic activity, large wave pressures, and sea level changes. Local warning systems could be an adjunct to such a global ocean observing system.

These deep-sea mountain ranges are also the sites of constant volcanic activity. Nine tenths of all of Earth's volcanic activity takes place on the sea floor, forming new bottom material, rich in deep earth minerals and toxic gasses. It is a wonder any life could exist there. However, through the curiosity of our scientists and their dedication to deep-ocean exploration, one of the most important discoveries of this century was made just 20 years ago. This was the discovery of the hydrothermal vents, which not only churn hot sea-water through them and alter its chemistry, but also provide habitats for amazingly abundant, exotic life forms. Ancient as this life may be, its existence provides a quantum leap in our knowledge about life itself. Two-thirds of these life forms have never before been observed. Perhaps more importantly, what this may likely provide is the key to our definition of "the origin of life" on *our* planet and the possibility of it on others.

Hydrothermal vent systems also have particular potential for Biotechnology applications. In June, I was honored to be a participant at the Monterey National Ocean Conference, and had the pleasure of being on a panel with Thomas Mitchell, the CEO of Genencor International, Inc., one of the world's leading industrial biotechnology companies. He described that one of the major goals for biotechnology is the identification and development of enzymes with special functional characteristics. In particular, because extreme conditions are the rule in many industrial settings, significant commercial value is derived from enzymes that can flourish in those environments - like those from the deep-ocean. The microorganisms of the vent sites could yield enzymes, he said, that have significant commercial value to industrial applications.

Going deeper still, into the sea floor with the coring capability of the international Ocean Drilling Program (ODP), we find and assess the nature and origin of sub-bottom fossils and ancient sediments. We are able to obtain a biological and environmental record extending back almost 200 million years. Studies of the deep ocean bottom reveal extraordinary levels of biodiversity. Deep-ocean drilling has shown that microorganisms exist at great depths below the seafloor. This is a very important discovery. This scientific knowledge alone has lead us to double the estimates of the global biomass. Like the vent communities, the concept of "life" as we knew it two decades ago is changed forever. The fossil record in sediments also shows us that the deep ocean is not constant in time; major events such as past ice ages reflect the climatic consequences of the altered "conveyor belt."

Science and technology have also advanced deep-ocean salvage and archeology. This committee knows about the discovery of RMS *Titanic*. Perhaps less well known, but arguably more important for its societal and economical relevance, was the recent forensic survey of M/V *Derbyshire*. This ship, a 964-foot British bulk carrier, sank in over 14,000 feet of water off Okinawa in a 1980 typhoon. All 44 people on board perished. The *Derbyshire* was one of more than 120 bulk carriers lost at sea since 1980 with the loss of more than 1300 lives. The Woods Hole Oceanographic Institution was requested by the United Kingdom and European Commission through UK's Memorandum of Understanding with the U.S. National Science Foundation to help them determine the cause of this tragedy. The final report offers 11 strong and wide-ranging recommendations for improving bulk carrier safety, which the managing director of Lloyd's Register's marine division said would have important implications for all other ship types and encouraged prompt action on its recommendations. There are several reasons why I draw the committee's attention to this topic. The *Derbyshire* survey illustrates the value that comes from long-term investment in basic research. Here are tools developed with basic research funding that have enabled important scientific discoveries, while they also have been used to find the *Titanic* and to solve an international mystery of a bulk carrier sinking. The result of the survey will be used to improve ship construction standards with attendant improvements to safety of life at sea and environmental quality. In the process, WHOI's deep-sea ability to service U.S. scientists' needs, our primary customers, has been enhanced with technical upgrades funded by the United Kingdom.

Clearly, our deep ocean discoveries and research of the past continue to be evaluated for their potential to generate new and improved industries for our Nation's economic engines. An additional one involves helping to quench the world thirst for oil.

Increasing population and the large number of developing nations demanding higher levels of energy is pressuring the current world oil reserves. Estimates claim that it will threaten the availability of oil-derived energy within the next 50 years. Energy companies will have to increase exploration to meet the increased demand. More research on the geology and physics of the Earth's crust may offer some solutions.

However, there is one new source of carbon based energy that has been receiving renewed attention by industry, the Department of Energy, and the Congress. That source is the phenomenon of Methane gas hydrates. They exist in vast deposits in the sea floor in many regions of the world. Early estimates for the United States EEZ alone point to many trillions of cubic feet of gas, locked below the sea floor in its natural state of a water molecule cage. These deposits, if confirmed, have the potential to provide years of energy independence.

The potential for mineral production from the sea floor has held the imagination of industrial entrepreneurs for years. Manganese nodules were the target of early mineral extraction from the ocean floor 30 years ago, but failed to be economically viable. It is likely the interest could be rejuvenated in the future once new technology and market demands make production profitable. As you can imagine, there are many other opportunities for mineral production development. The periodical "The Economist" (May 23, 1998), reported in an article on the sea that, "Exploitation of the deep seems only a matter of time."

This short deep-ocean tour would not be complete without some note of the impact on education. From earliest childhood we introduce our youngsters to the wonders of the ocean planet through the color and biodiversity of the denizens of the deep. From the killer whale Willy, to the countless personalized sea creatures of children's books, we capture the imagination of our young people and instill in them the first elements of science literacy, and a respect and caring attitude for nature and for themselves in the family of Earth inhabitants. Since the study of the oceans necessarily involves all the physical disciplines, it is ideally suited to pull that child into the wonder of science *and* keep her there. We all know that our science and math literacy in this county could use a little help. If that help can be provided by studying the deep-oceans, while also imparting an understanding of how interdependent we humans are on the oceans, our grandchildren will live in a better, safer, cleaner world.

It may go without saying, but let me urgently emphasize that we will also need consistently strong Congressional support for our science *graduate* programs so that those children being drawn into the science classroom can become the leaders we want them all to be tomorrow. We need that kind of leadership and science strength in our Nation to truly harness the Earth in a sustainable way for future generations.

DEEP-SEA TOOLS: PAST, PRESENT AND FUTURE

Before I begin a discussion of the essential tools needed for deep-sea exploration, let me preface that discussion with the fact that even the world's best tools are not useful without the best minds asking the best questions. We are incredibly fortunate in our country to have many of the best minds in ocean sciences right here in the United States. These scientists are asking the toughest questions, and not settling for quick answers. They need your continued support and your long-term investment, as answers do not come quickly, or, unfortunately, cheaply. This talent comprises one of our Nation's biggest treasures. I believe this very strongly, Mr. Chairman, and want to make sure this goes on the record.

With the financial support of the Navy and the National Science Foundation (NSF), WHOI led the development of the HOVs, with the design and construction of DSV *Alvin*, and the ROVs, with design and construction of the *Jason/Medea* family. In the meantime, the Navy's deep submersibles, *Sea Cliff* and *Turtle*, became adaptations of *Alvin*. Mr. Chairman and members of the committee, it is with great pride that we can say that virtually all of the world's deep-submersible handling systems are adaptations of the system pioneered to handle *Alvin*. In addition, our tethered vehicle technology has been cloned and implemented in Navy deep survey systems, and ancillary and mission equipment, particularly camera systems, have been spun off to military applications.

However, Mr. Chairman, we dare not sit on past successes. Despite their capabilities, our vehicles do have shortcomings relative to available technology and relative to the needs of science. The following tables show where we now stand. I should add here that Japan has allocated this year an additional $100 million for the development of undersea vehicles and seafloor observatories. This is in addition to the already double-digit percent increases in their budget for ocean sciences over the last several years. We have work to do.

<u>Current Statistics</u>

Human Occupied Vehicles (HOVs):

	U.S.	Japan	Russia	France
Name	*Alvin*	*Shinkai-6500*	(2) *MIRS*	*Nautile*
Depth Rating	4,500 m	6,500 m	6,000 m	6,000 m

Remotely Operated Vehicles (ROVs):

	U.S.	Japan	Russia	France
Name	*Jason*	*Kaiko*	(unknown)	*Victor*
Depth Rating	6,000 m	11,000 m		6,000 m

I would now like to address plans for the future of the U.S. Deep Submergence Facility, with your help and support.

<u>Human Occupied Vehicles: HOVs</u>

The U. S. research community has repeatedly reaffirmed the need for human occupied vehicles (The Global Abyss: An Assessment of Deep Submergence Science in the United States UNOLS Report 1994: Sea Cliff Working Group Report July 1997 UNOLS [University-National Oceanographic Laboratory System] DESSC [Deep Submergence Science Committee]; "Undersea Vehicles and National Needs", National Research Council, National Academy Press, Wash. DC 1996). To quote The Global Abyss report: "The submersible is a valuable and necessary element of a versatile deep submergence investigative capability. The submersible couples the cognitive and stereoscopic capabilities of the human mind with a system . . . permitting complex and interactive manipulations (and) . . . large payloads."

The limitations of *Alvin* are: depth (4,500 meters), endurance and power for propulsion or sampling.

The Future of HOVs
The Navy's deep submersible *Sea Cliff* has just been transferred to the custody of the National Deep Submergence Facility (NDSF). It is understood that the federal agencies intend, through FOFCC (Federal Oceanographic Fleet Coordination Council), to underwrite the expense of an engineering study which would analyze the costs, feasibility, and technical alterations required to merge the most capable features of *Sea Cliff* and *Alvin*.

Depending upon what the engineering study produces, and the availability of funds, we hope this will lead to an *Alvin* upgrade to give it the following characteristics:

Depth	7,000 meters
Time of Bottom	4.5 hours
Total Submerged Time	Up to 12 hours (normally 8 hours)

This would give HOV access to 98% of the ocean bottom; it would give the United States the leadership role in HOV exploration.

<u>Remotely Occupied Vehicles (ROVs)</u>
After gaining acceptance in the development mode in the early 90's, this type of vehicle is rapidly becoming the workhorse of deep-ocean science.

Although the WHOI NDSF *Jason/Medea* is a good science tool having successfully completed many complex multi-scale operations, it lacks capacity according to the user-community in the following areas: depth; propulsion power; payload power for hydraulics, lights, cameras, manipulators; tether management to enhance on-bottom dexterity; and data transmission, a product of the increasingly sophisticated sensor packages demanded by the task.

Future of ROVs
WHOI has plans to significantly upgrade the *Jason/Medea* ROV while taking advantage of the national investment in tether cable systems in the U. S. oceanographic fleet. These fiber optic, steel armored cables and their associated winch handling systems represent a huge investment and have significant untapped capacity. The characteristics of an upgraded *Jason/Medea* system will be:

Depth	Greater than 7,000 meters
Time on Bottom	Greater than four days
Payload Power	5 kW
Propulsion Power	21 hp
Manipulator(s)	Heavy lift / user-friendly

We believe these upgrades should begin immediately and they will take about two years to complete at a cost of about $2.5 – 3.0 million.

Autonomous Underwater Vehicles: (AUVs)

This is an age in which small underwater robots, so-called AUVs, will be available to compliment and supplement other tools and vehicles. HOVs and ROVs are superb tools, but they have in common one major drawback – they must have on-scene support ships available.

The AUV offers the ability to stay behind after the support vessel has departed. Equipped with a wide variety of sensor systems from magnetometers to cameras, sonars and chemical/temperature sensors, these vehicles can run a wide variety of mission profiles ranging from planned surveys to "event responses". Examples of the later might include conducting temperature and chemical sampling after an underwater volcanic or seismic event or sampling a sewage outfall pipe after a large rainstorm. Of note, AUVs also have numerous military applications such as mine hunting and special warfare.

AUVs will be an essential part of future ocean observatories. They are oceanography's equivalent of a Mars Rover, only the tasks are harder, the operating environment is more hostile and available development funding is much less.

SUMMARY

In summary, Mr. Chairman, that is how I see where deep ocean science has been and to where it should proceed. We need to capitalize and build on the expertise of today's people and technology to produce a robust capability for tomorrow. There is a tremendous amount we still don't know about our *own* planet, so we have a lot of work to accomplish. We have the minds, the questions and the technology at our doorstep. Who knows where our exploration will lead? What new discoveries lie ahead? If the last thirty years is any indication, the discoveries will have great benefit to the Nation and the world. If we want to manage, protect and use our planet wisely, we need to understand how it works. To accomplish this,we need your support and help.

Thank you.

Testimony
of
Dr. J. Frederick Grassle

Director
Institute of Marine and Coastal Sciences, Rutgers University

before the

Subcommittee on Fisheries Conservation, Wildlife and Oceans
Committee on Resources
U.S. House of Representatives

Mr. Chairman, members of the Subcommittee, thank you for inviting me to testify on the status of oceanographic monitoring and assessment. I particularly thank the Chairman for his long-standing interest in this subject.

On land we take for granted continuous, real-time, high resolution information provided by our senses; what we see, hear, or smell. Our presence in terrestrial environments provides us with a high proportion of the information needed to assess fundamental environmental and ecosystem processes. This information is placed in a spatial and temporal context by modern satellite technology and weather stations, and steadily improving maps of changes in weather, topography, land use, and habitat characteristics. We have increasingly accurate forecasts of weekly, interannual, and even decadal variation. We are not so fortunate when we try to predict ocean processes, lacking the common-sense view of our environment that is readily available on land.

The ocean is a relatively unknown, dangerous, unpredictable, and unmanageable place. Despite this, the livelihood and security of nations has long depended on their sea-faring abilities. Efficient, safe, sea transportation is a requirement for the economic success of our ports and coastal economies. We need better prediction of coastal hazards including storms, coastal erosion events, harmful algal blooms, and oil spills, or even when and where to spend a pleasant day fishing or swimming. Naval commanders need to understand as much as they can about their surroundings at all times, especially in initially unfamiliar environments. Natural variability is poorly understood so that it is relatively difficult to measure the effects of pollutants or other human-induced change. Ocean ecosystems are said to provide the greater part of the services needed to sustain our society, yet the mechanisms controlling the delivery of these services are poorly known.

We need better-informed management of all of our activities with respect to the marine environment. For example, we have inadvertently allowed our fisheries resources to decline and cannot adequately predict rates of recovery. We have some general knowledge of the habitats of some species, but, it is difficult to imagine the daily experience of individual fish especially at the various stages of their growth to adulthood. It is hard to imagine being a fish buffeted by strong waves and currents, let alone a hurricane. For those species making a home in bottom sediments, how do they respond when the surrounding sediment is swept away? How do individuals use their senses to interact with one another, sense predators and prey, or navigate to new habitats?

Whenever we have had a more continuous presence in the marine environment, we have made significant leaps in understanding. Field experiments on rocky shores have shown that interactions among individuals are as important as physical measures in determining where plants and animals live. Coral reef scientists began to better understand the reef environment and the serious changes that are occurring on reefs when they started to make observations underwater on a daily basis. I have personally been involved in the revolution in understanding life in the deep-sea from use of manned submersibles, such as ALVIN, and the long-term bottom stations it allows us to visit. Since it was established in 1989, the Institute of Marine and Coastal Sciences at Rutgers University has made a commitment to obtain high resolution, long-term measurements from a broad corridor of marine and coastal habitats, from the watershed of the Mullica River to the deep sea, using a series of Long-term Ecosystem Observatories, or LEOs.

Our most intensive studies have been at LEO-15 (15m depth), an area on the inner part of the continental shelf off Tuckerton and Little Egg Harbor, New Jersey. Just as meteorologists monitor present weather conditions and use a combination of observations and computer models to generate weather forecasts, Rutgers oceanographers are using an observation network to monitor the coastal ocean and computer models to forecast its daily changes. The observing system is serviced by an electro-optical cable that runs under the coastal waterway and under the ocean floor to connect two underwater nodes to the Rutgers University Marine Field Station, and from there to the Internet. The system transmits video, sound, and data on light, temperature, salinity, currents, wave height and period, sediment transport, plankton blooms, and a broad variety of chemical characteristics from numerous sensors that move up and down in the water, or are plugged into the nodes on the bottom. Docking stations allow autonomous robotic vehicles to sample along transects away from each fixed site, and to return to download data and repower batteries. Boats and divers visit the site on days when the weather is good, and a satellite dish provides broad-coverage of sea surface characteristics (temperature, ocean color when it is not cloudy, and surface roughness). Shore stations using high-frequency radar provide patterns of surface currents, and provide data on weather in the immediate vicinity of LEO-15. (Figure attached)

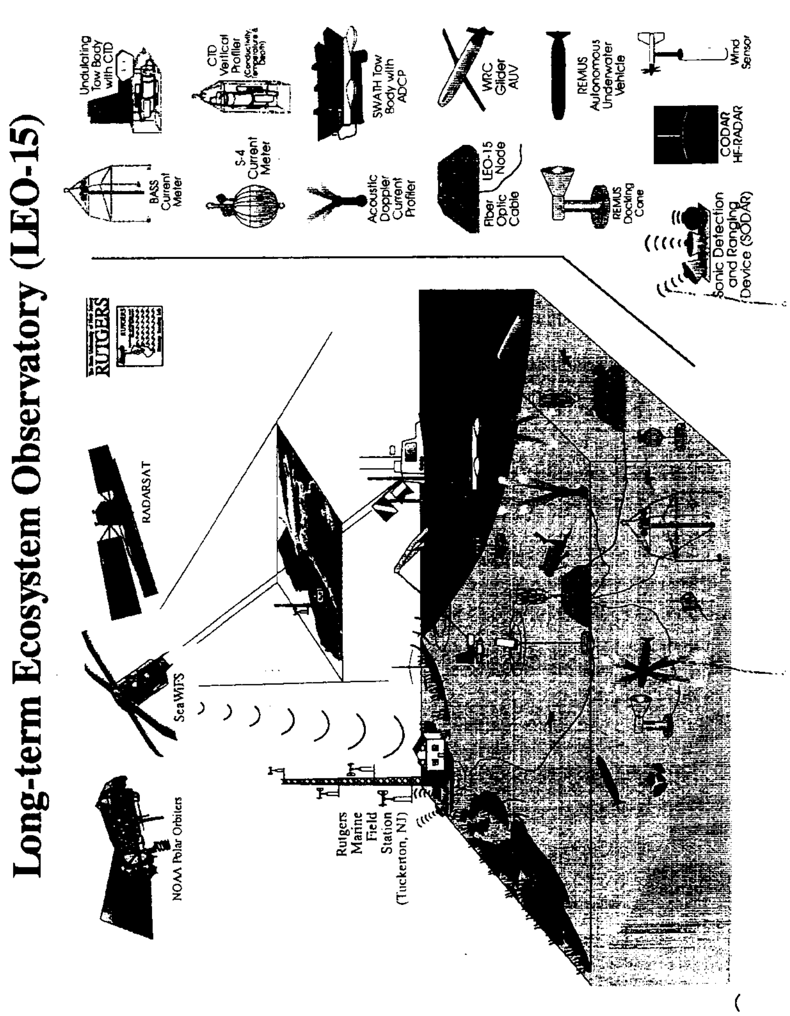
Our requirements for the observatory were ambitious: 1) continuous observations at frequencies from seconds to decades, under all conditions, 2) spatial scales of measurement from millimeters to kilometers, 3) practically unlimited power and broad bandwidth two-way transmission of data and commands, 4) an ability to operate in storms, 5) an ability to plug in any type of new sensor, including cameras, acoustic imaging systems, and chemical sensors and operate them over the Internet, 6) bottom-mounted winches that cycle instruments up and down in the water, either autonomously or on command, 7) docking stations for a new generation of autonomous robotic vehicles to download data and repower batteries, 8) an ability to assimilate data into models and make three-dimensional forecasts of the environment, 9) means for making the data available in real time to schools and the public over the Internet, and 10) relatively low cost relative to the cost of building and maintaining manned above- and below-water systems. All of these objectives have been achieved during the last few weeks of intensive operations at LEO-15 (see news articles in U.S.A. Today (7/21/98) and the Philadelphia Inquirer (7/22/98) attached).

We expect to add additional observatories at intervals across the continental shelf and into the deep sea. Additional observatories along the coast, such as that proposed by Woods Hole Oceanographic Institution off Martha's Vineyard, will add another dimension to what we hope will eventually become a global system. This work has been supported by the National Science Foundation, NOAA National Undersea Research Program, Office of Naval Research, and, in the last year, by three grants from the National Ocean Partnership Program. Our most recent grant will transfer the lessons learned from LEO-15 in 1998 and 1999 to a program using a combined observation and modeling system to predict harmful algal blooms in the Gulf of Maine in 2000.

The components of a national ocean observing system will vary depending on location. In Japan, underwater observing systems similar to LEO-15 have been used for ocean bottom seismographs to predict earthquakes. Recently, they have been adapted to provide a broader array of environmental measurements. For some time, deep-sea geologists and biologists have planned to make the self-contained ecosystem of a hydrothermal vent into an observatory, and this goal may now be achieved with support from the National Ocean Partnership. In our ports, environmental monitoring systems could yield real-time useful information to harbor pilots and sewage treatment plant operators, early warning of harmful algal blooms, and alarms if fuel or other chemicals are spilled. These systems would monitor the natural environment and make us aware that these ecosystems, despite their heavy use, are worth protecting. By making the data available on the Internet and storing data in geographically-referenced systems, local watershed associations and the public can better appreciate their local marine environment and be alerted to the problems caused by out-of-site, out-of-mind approaches to management. At our beaches, observing systems will continuously monitor wave patterns and characteristics, alert us to waste disposal failures, predict storm effects, and measure sand movements so that we may better understand the causes and potential means for controlling beach erosion.

Intensive, long-term biological monitoring requires an improved global context for designing sampling programs. From satellite ocean color data, it has been possible to map estimates of phytoplankton productivity over the entire ocean. From sea surface temperature, sea surface height, and arrays of current meter moorings, better maps of global ocean circulation have been made available. High resolution maps of the sea floor, such as those used to find the first hydrothermal vents, are being produced. For the first time, we have continuous maps that can be used as a reference for sampling the distribution of plant and animal species, as well as measuring global change. The rich biota on the ocean floor are almost entirely unknown and, with support from the Sloan Foundation, scientists are asking what sort of observing system would be required to produce a global census of the fishes in the ocean.

At only a fraction of the costs of investigating space, or the terrestrial environment, we can provide the observations needed to maintain ecosystem services from the ocean, enrich science education in our schools, and bring a greater consciousness of the ocean into our daily lives. I strongly urge you to support, through individual agencies and the National Ocean Partnership Program, the further development of a national and global ocean observing system.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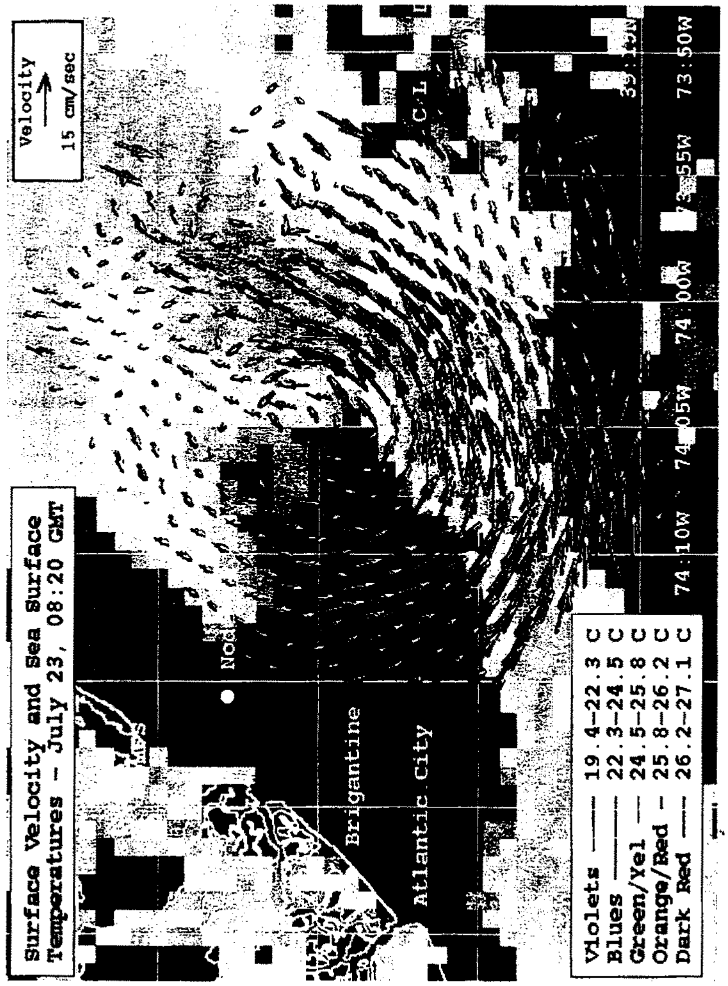
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73:50W

Lab takes big plun

N.J. station delivers constant data

By Paul Hoversten
USA TODAY

Six miles off the coast of New Jersey in ocean 50 feet deep, an odd assortment of robotic sensors bobs and weaves like a curious sightseer among the fish and seagrass.

Some of the devices poke periscopelike through the depths on tethers tied to stainless-steel shells on the sea floor. Others swim freely like battery-powered minisubs with headlights to pierce the darkness. Still others are towed through the brine by boat, rising and falling in the current.

It may seem like an aquatic ballet in search of a choreographer, but this frenzied dance is part of the largest and most sophisticated unmanned underwater laboratory in the world.

Every second, via 6-mile cable, the robotic sentinels send data including water temperature, surf conditions, fish populations and wave size to Rutgers University's Marine Field Station in Tuckerton, N.J. There, scientists pore over the data to develop better scientific models of how vital coastal areas change over time.

"We want to do with the ocean what you see people do with weather forecasting," says Fred Grassle, director of Rutgers' Institute of Marine and Coastal Sciences and co-founder of the lab.

A substantial payoff is expected. Two-thirds of the U.S. population lives near coastal areas, making it increasingly important for scientists to better understand the forces that shape the oceans and marine life and to learn the roles that human activities play in the mysteries of the sea.

What, for instance, causes great blooms of plankton to suddenly thrive in the ocean and consume oxygen that's essential for marine species? Why is the water warmer at one beach and colder at another on the same day? Why do water quality, clarity and color vary greatly at different depths within the same column of sea water, and what do those differences mean for humans? Where do fish go when hurricanes bear down?

Scientists hope to learn the answers to these and other questions through a sustained, systematic study of a single underwater site. Until now, they've had to rely on ships, satellites and a few buoys.

"To really understand the ocean, you need to go in there and stay for a long time," Grassle says. "If you're on land and walking into a forest, you have some of the same senses, sights and smells as the animals there. You can hear what they're hearing and see what they're seeing.

"In the ocean, you're in a strange environment, and it's hard to get a good context of what's happening in the system. We're as ignorant about what happens on the continental shelf as we are the deep sea."

The "laboratory" where Grassle and others have set up their instruments is a sandy underwater ridge about 2½ miles long and half a mile wide in Atlantic Ocean waters 6 miles east of Little Egg Inlet.

Photos by Tim McCarthy for USA TODAY

Key link: Engineers Thomas Austin, left, and Robert Goldsborough assemble the REMUS probes that visit the LEO-15 nodes.

Co-founder: Fred Grassle says LEO-15 is a step toward forecasting oceanic activity.

Wired underwater

First considered, then rejected for a floating nuclear power plant in the 1970s, the ridge today is home to LEO-15, short for Long-Term Ecosystem Observatory-15 meters deep.

With LEO-15, scientists literally have wired the ocean for sight and sound. For the first time, they have 24-hour access to a wide swath of sea in virtually every weather condition imaginable, even during a raging hurricane. All the data are real-time and available on the Internet at marine.rutgers.edu.

Grassle and Chris von Alt of the Woods Hole Oceanographic Institution in Woods Hole, Mass., first dreamed up LEO-15 in 1986 during a conversation about how to mine the ocean for more data.

But it wasn't until 1994, when a $1 million grant came through from the National Science Foundation, that the plan took root. Today, LEO-15 is a $4 million project with 40 to 50 researchers, including dive teams to clean and maintain LEO-15. Annual operating costs are $1.5 million, funded mostly by the National Science Foundation, Office of Naval Research, National Oceanic and Atmospheric Administration, and Department of the Interior.

LEO-15 began operating on a modest scale in August 1996 with two instruments called "nodes" that sit a mile apart on the sea floor and are connected by cable to shore.

In each stainless-steel node is a buoyant device operated by an electric winch that is controlled via the Internet. The device rises like a periscope to gauge the temperature, salinity and chlorophyll count at different depths.

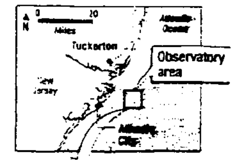
This summer, LEO-15 has grown to include a small robotic submarine developed by von Alt. It can dock, recharge its batteries and transmit data, all while underwater. The submersible, called REMUS, for Remote Environmental Monitoring Units, made its first successful docking last week at one of the LEO-15 nodes 50 feet below the surface.

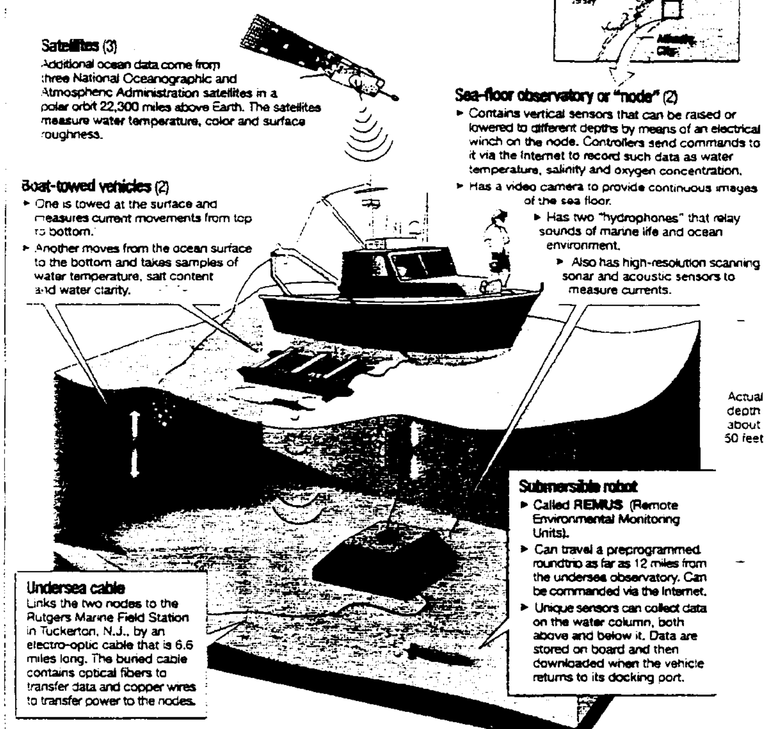
"That's the first time there's ever been a successful docking in the open ocean" by such a

ge as part of aquatic life

All about LEO

Rutgers University's LEO-15 stands for Long-Term Ecosystem Observatory, 15 meters deep. It uses sea-floor stations and submersible robots to provide the world's first continuous study of changes in ocean conditions — in real time over the Internet.





Sources: Rutgers University Institute of Marine and Coastal Science, Woods Hole Oceanographic Institution

By Grant Jerding, USA TODAY

craft, von Alt says. His team has had to struggle with hauling the submersible out to LEO-15 by boat, dropping it in the water, retrieving it at day's end and returning it to shore.

Now that the submersible can dock and undock from its underwater mooring, "it's sort of like giving the keys to the car to one of your kids," von Alt says. "You're saying, 'OK, you're on your own.'"

Eventually, the laboratory may have five or more submersibles, each of which could roam up to 6 miles from base and back on a single battery charge.

Also this year, scientists began towing two kinds of instrumented platforms through the water to measure currents and water quality. The towed vehicles make the rounds from May to August, when the water is warm and rich in nutrients.

A sea of knowledge

Other undersea observatories exist around the world, including those in California's Monterey Bay and off the coast of Japan. But none has the range of capabilities that LEO-15 has. An observatory is planned to be built off the Big Island of Hawaii this summer and another, a smaller sister of LEO-15, is to be installed in 2000 in Katama Bay, off Martha's Vineyard, Mass.

LEO-15 already is paying scientific dividends. Researchers are learning more, for example, about the summertime flood of nutrients off New Jersey that can scare off marine life by robbing the water of air.

Data from LEO-15 indicate the nutrient boost occurs naturally, regardless of what humans do on land. Research by others had suggested that sewage drains and fertilizer runoff from farms were at fault.

The nutrient phenomenon is similar to what happens in the Gulf of Mexico when plankton blooms pouring in from the Mississippi River create a seasonal "dead zone" that kills bottom-dwelling organisms.

"We're finding out about the processes that are controlling this upwelling of nutrients," Grassle says. "That is the basis for most of the coastal fisheries, and we've gotten a more detailed picture of it this year than ever before."

The lab also is studying the health of surf clams, the biggest fishery in New Jersey's seafood industry and source of most of the nation's clam chowder.

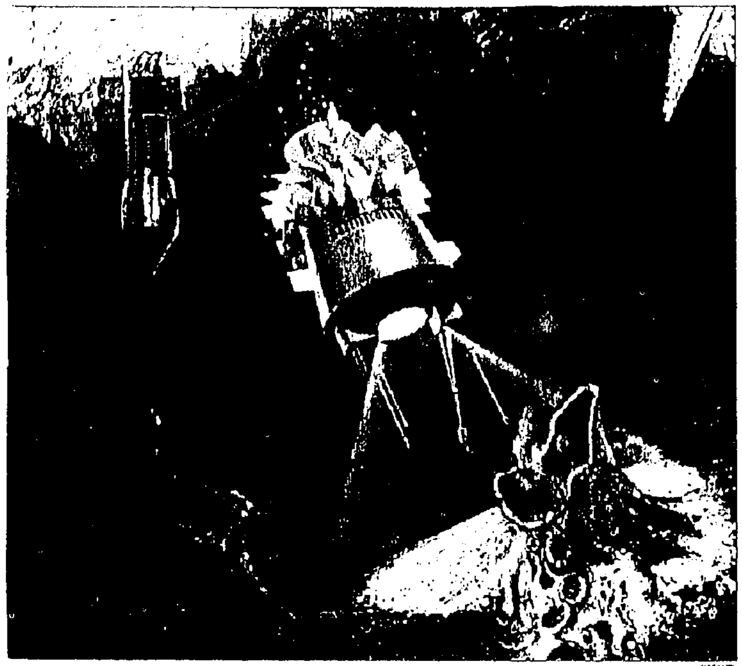
Scientists are beginning to understand conditions in which surf clams cluster in a "settlement," as well as which conditions are favored by predators like snails and starfish.

"If you stay at a place long enough, you begin to peel away the onion," von Alt says.

To expand farther out to sea, researchers say, requires only the deployment of more nodes and cable. The cable could be hooked up to LEO-15 like a long extension cord.

"We see this as an observatory that will be here indefinitely," Grassle says. "We've made a commitment to it, and people want to know what's happening in the ocean. All of our oceans have to be managed, and we have to be much smarter about how we do it."

Minisub could land a rendezvous inside Jupiter's moon



NASA/JPL

...ter exploration: In this artist's conception, a robotic submarine ...lores an underwater vent in Jupiter's icy moon Europa, which scientists say could harbor life. The National Aeronautics and Space Administration plans to launch such a mission after 2005.

Some of the same technology used in oceans on Earth could wind up someday on the other side of the solar system.

Europa, one of Jupiter's moons, appears to have an ocean beneath its icy crust. That ocean might contain plankton or other life that could be found only with a robotic submarine of the sort now off New Jersey's coast.

That remote submersible is investigating Atlantic waters east of Little Egg Inlet as part of Rutgers University's Long-Term Ecosystem Observatory-15.

The sub, called REMUS, for Remote Environmental Monitoring Units, is equipped with lights, a camera and other sensors that would be needed to explore Europa's murky depths.

NASA now has the Galileo spacecraft in orbit around Europa and Jupiter's other major moons. Sometime after 2005, NASA hopes to launch an orbiting probe to map the surface of Europa, followed by another spacecraft to land there.

A third mission would feature a special bullet-shaped lander called a "cryo-bot," with a small radioactive heater to melt through Europa's thick ice crust. Upon reaching water, the cryo-bot would dispatch a mini-sub called a "hydro-bot" to search for any signs of life.

Chris von Alt, a robotics engineer with Woods Hole Oceanographic Institution in Woods Hole, Mass., built REMUS and other underwater vehicles that discovered the wreck of the Titanic in the north Atlantic. Since March, von Alt has been consulting with engineers at NASA's Jet Propulsion Laboratory in Pasadena, Calif., who are designing the Europa missions.

> "The Titanic's just a rusting hulk. Europa would be far more interesting. . . . Can you imagine flying into a world where we've never been?"
>
> — Chris von Alt, robotics engineer

Submersibles like REMUS, some say, could pave the way for a generation of small, intelligent, autonomous subs.

"The challenge is to take a vessel like REMUS and see how small we can make it and still survive the hazards on Europa," says Linda Herrell, a Jet Propulsion Lab systems engineer.

Von Alt and his colleagues at Woods Hole, Herrell says, "are world experts at deep-water and high-pressure vehicles."

For von Alt, a space mission would make the Titanic's discovery trivial by comparison.

"The Titanic's just a rusting hulk," he says. "Europa would be far more interesting from my perspective. Can you imagine flying into a world where we've never been?"

Europa is so far from Earth — about 407 million miles — that it takes 35 to 50 minutes for signals traveling from Earth at the speed of light to reach a spacecraft there. It takes just as long for confirmation signals to be sent to Earth from the spacecraft.

So a submersible plying Europa's ocean could not be steered from Earth because of the transmission time delay. It would have to be almost completely independent.

Designers might have to give it some kind of artificial intelligence or problem-solving abilities to navigate such hurdles as icebergs or underwater caves.

Engineers also must address how the hydro-bot gets its power, how it communicates and whether it needs an umbilical with the mother probe.

It also would have to be small. The Jet Propulsion Laboratory estimates a payload sent to Europa probably could be no longer than 3 feet and weigh no more than about 65 pounds.

However it ends up, the cryo-bot and hydro-bot first will be tested in a remote icy area like a Greenland coastal shelf.

NASA also is studying an international ice-drilling operation in Antarctica, where a body of water the size of Lake Ontario lies beneath 4 miles of ice.

The lake is estimated to be 500,000 to 1 million years old and, like the ocean on Europa, has never been seen or sampled. The deepest ice sample from Lake Vostok is from 328 feet above the underground water. NASA and others are studying bacteria and microorganisms trapped in the ice.

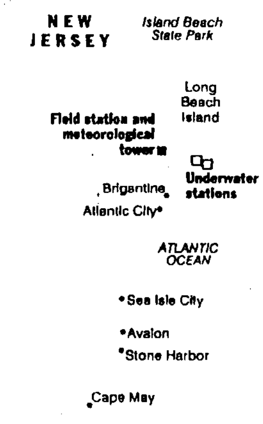
The knowledge gained could be significant. Says Herrell: "We'll be able to understand what the difficulties are in drilling. We have a technology path that has to be developed, and we're just starting it now."

By Paul Hoversten

See ART CAREY on F4

Off the Shore, turning robots into Flipper to gather ocean data

Scientists will have a fish-eye view of underwater conditions and can monitor environmental changes.



The Philadelphia Inquirer / SALEEMA N SYED

By Faye Flam
INQUIRER STAFF WRITER

A school of robots about the size of small dolphins is learning to swim off the New Jersey Shore this summer.

Their eventual mission: to monitor the conditions 50 feet below the surface of the Atlantic, detecting environmental changes and acting as underwater weather forecasters, predicting temperatures, currents, and variations in marine chemistry.

These robots, which look like 4-to-6-foot-long torpedoes, are among the first ever designed to swim "autonomously," completing pre-programmed routes without the help of human controllers.

"We'll be able to see the ocean the way a fish sees it," said Rutgers University oceanographer Fred Grassle, one of the founders of the project, called LEO-15 for Long Term Environmental Observatory at 15 meters depth. For the first time, Grassle said, scientists will get continuous data under all kinds of conditions, including ones hostile to human explorers.

"We still don't know what happens underwater during a hurricane," he said. "Do all the fish hide in trenches?"

Grassle came up with the idea for LEO-15 in 1986, along with Christopher von Alt, an engineer from Woods Hole Oceanographic Institute in Massachusetts.

They eventually received $1.7 million from the National Science Foundation and other agencies to carry out their plan, which would combine stationary monitoring equipment with a set of little robots, dubbed REMUS, for Remote Environmental Monitoring UnitS. Two years ago, Grassle, von Alt and their colleagues deployed the stationary part of the project — two Volkswagen-size "nodes" that can be attached to a variety of data-taking instruments.

The nodes sit on the sea floor, three and four miles off the coast, about eight miles north of Atlantic City. A long cable connects them to computers and power sources at the researchers' field station, which perches on the edge of a wetlands preserve

See ROBOTS on F3

For The Inquirer / NANCY ACGANO

Engineers Tom Austin *(left) and Mike Purcell are trying to get the torpedo-shaped robots (rear of boat) to dock at underwater units.*

Little Flipper robots to study ocean

ROBOTS from F1

near Tuckerton.

Meanwhile, von Alt and a team of five other Woods Hole engineers built the fleet of robots. The team brought them to the Jersey Shore two weeks ago and began training them to obey their commands.

The big goal last week was to get them to dock into a port, or "garage" as Grassle calls it, which the researchers attached to one of the stationary nodes.

Eventually, if all goes as planned, the robots will swim courses of up to 13 miles. When done, they will automatically dock in the garage, release their data, and recharge their batteries.

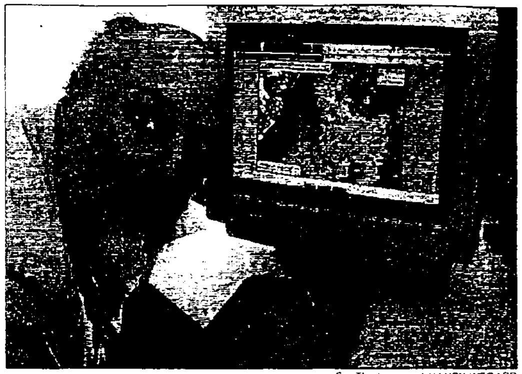
They can't quite do that yet.

Last week, engineers Tom Austin and Mike Purcell were spending their days in a small rubber-sided boat—throwing the robots overboard and trying repeatedly to get them to dock. A few times, they lost track of the robots and had to search for them for an hour or so.

At first the robots missed the garage at least four out of every five tries. Eventually, their success rate improved as the engineers tuned up the robots' electronic circuits.

"We're not quite ready to let the kids go out with the car keys," von Alt said. He and his colleagues are taking the robots back to Woods Hole in a month for more work before they are established as permanent parts of the project.

In the meantime, Grassle said the stationary parts of the LEO-15 project would allow them to begin making predictions of underwater "weather," which can be as tempestuous as it is above the surface. Masses of warm and cool water roll through like fronts, and occasional "upwellings" of cold deep water can kill thousands of creatures.



For The Inquirer / NANCY WEGARD

Fred Grassle clicks *on the Rutgers University Marine Field Station Web site at http://marine.rutgers.edu for data.*

The robots also will be able to keep tabs on changes that might be caused by pollution. A better understanding of the sea might have prevented the planned dumping of 40 million tons of sewage sludge into the deep sea off the New Jersey coast during the late 1980s and early 1990s.

Some scientists had argued that by using the deep part of the ocean more than 100 miles from the coast, the wastes would quickly disperse to harmlessly small concentrations. But further sampling done by Grassle and others showed that toxins in the sludge fell to the bottom, home to hundreds of species of plants and animals.

That dumping has since stopped.

Increasingly, robots are working as proxies for human scientists and explorers — a tactic that may save money and spare lives. Under the current plan, before any astronauts ever reach Mars, scores of robots such as the small "Sojourner" will roll over its rocky surface.

Ocean explorers sometimes complain that their field lacks the big money and glamour of space travel, but the two areas may soon merge when NASA begins to explore Europa, a moon of Jupiter that just might harbor an ocean beneath an icy crust. Woods Hole's von Alt has been consulting with NASA on designs for robots that could plunge beneath the ice and perhaps search for signs of alien marine life.