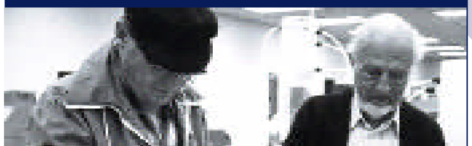
The Link Project

Partnerships to Promote Ocean and Space Research and Exploration through Technology Innovation

Vision

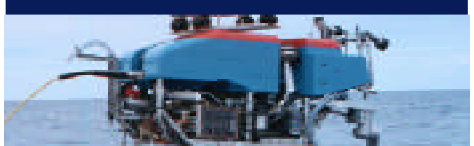
The Vision of this program includes...



Partnerships

Cutting Edge Technology

Discovery



Advancement

Mission

Edwin Link, pioneer inventor and researcher in aeronautics and ocean engineering, invented the first flight simulator, known as the "Link Trainer." His invention allowed pilots, for the first time, to safely train, sense and respond to the dangers of being airbourne. Link did more than invent, however, he used his inventions to explore new frontiers. Together with Jacques Cousteau and George Bond, he also set the stage for living in the sea. He was the first person to breathe a special mix of helium and oxygen that allowed divers to breathe at depths well below those accessible on air tanks. He designed the Johnson-Sea-Link submersibles, the nation's most productive research submersibles in terms of dives performed and innovative scientific applications. He was an engineer, inventor, and explorer who transcended the boundaries between earth and sky.

NASA leads the world in technology innovation, while NOAA is a world leader in ocean research and management. The Link Project attempts to capture the spirit of its namesake and marry the missions and capabilities of these two agencies by crossing boundaries to seek new approaches to ocean research, exploration, and discovery.

Participants in The Link Project will capitalize on the synergy created by combining ocean and space expertise and the potential for funding and in-kind support. Objectives of The Link Project are to:

- *identify priority areas of mutual interest and partnership opportunities for ocean and space scientists and engineers;*
- *promote ocean and space exploration, science and technology development; and*
- *promote the use of cutting-edge technologies for oceanographic research.*

> **"With Edwin Link's long track record of personal involvement in varied aviation and submarine creations, it was natural for him to try submerging himself in a new chamber..."**
>
> S. Earle and A. Giddings, 1980
> *Exploring the Deep Frontier*

The Link Project

Partnerships to Promote Ocean and Space Research and Exploration through Technology Innovation

NOAA/NASA Partnership

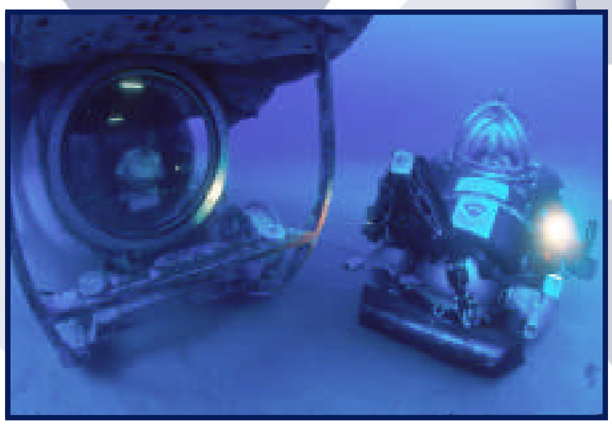
Ocean and space scientists and engineers share many of the same objectives. Especially in the area of remote sensing from satellites, NASA and NOAA work together on many projects. As stated on NASA's Earth Science Enterprise Web site (www.earth.nasa.gov), this NASA program attempts to capture the NASA spirit of exploration and focus it on the Earth. NASA and its interagency partners, including NOAA, "are striving to discover patterns in climate which will allow us to predict and respond to environmental events - such as floods and severe winters - well in advance of their occurrence."

There is, however, another realm of research, in which the partnership between ocean and space is not working as well, and that is *in situ* research—research that involves going into the remote environment, whether it is inner or outer space. Yet, NASA has many of the same technological resources and innovations needed to propel ocean research to new levels, and has its own new and pressing needs to work in systems that are analogs to extraterrestrial oceans, like the deep sea. Recent evidence suggests planets in our own solar system had or still have oceans, which are believed to be a necessary precursor to extraterrestrial life. However, these planets are light-years away and covered in miles of ice. Perfecting required technologies will take decades of preparation and testing on our planet.

These discoveries put us at a critical juncture in human history, a time when our understanding of who we are in the universe may completely change. The Link Project will promote this identity quest, as well as provide us new means to study and understand our own planet, and the many critical problems we face as our numbers grow. Ocean science requires new technologies to meet these challenges.

Emerging Needs in Ocean Science

NOAA's mission and ocean research needs are changing in the 21st century. Standard shipboard oceanographic techniques are no longer sufficient to address the range of problems and challenges that face us during the new millennium. The Sustainable Fisheries Act finally mandates a comprehensive approach to fisheries assessment; not just how many fish, but where they live. Fish concentrate in complex areas of the ocean, such as reefs, that cannot be sampled by towed trawls and dredges. Marine Protected Areas are increasingly used to protect dwindling fish stocks and degrading habitats. Wise implementation requires a new level of detailed understanding, and applications of new and advanced technologies. Environmental changes, from coral reef die-offs to coastal erosion, are occurring at unprecedented rates. As a result, faster, broader area surveys must be ground-truthed using *in situ* techniques.



The single-person submersible, DeepWorker 2000 (right) rendezvous with the Atlantis submarine in Hawaii during the Sustainable Seas Expeditions in January 2000. Photo courtesy of Kip F. Evans © National Geographic Society

Many agencies are now grappling with how to implement regional ocean monitoring systems that rival terrestrial and atmospheric systems already in place. These systems will provide constant, high-resolution data streams that must be maintained, calibrated and managed. These ocean research needs span numerous fields and have applications for every person on Earth. Technology development to explore, study and discover new ecosystems and species with commercial and economic potential in the world's oceans is necessary for the survival and health of the human species. These advancements will also guide the decision-making and management processes that will fill the gaps in our understanding of coastal and ocean phenomena.

NOAA is entrusted with the responsibility of managing the National Marine Sanctuary Program. This system of marine sanctuaries is growing, covering not only more, but increasingly larger and deeper areas. Environmental problems are worsening, due, for example, to increasing coastal populations and usage of marine resources and environments. Successful management and outreach activities require new approaches and the development of advanced undersea capabilities.

Several new national programs reflect NOAA's dedication to improving its ability to monitor and explore the oceans using innovative technologies and approaches. For example, NOAA, in partnership with the National Geographic Society, supports the Sustainable Seas Expeditions, which use innovative manned submersibles to showcase the resources and management needs of the national marine sanctuaries. In 2001, NOAA will launch a major Ocean Exploration Initiative to explore the world's oceans for the purpose of discovering, understanding and providing solutions to ocean resource problems.

Coincident to development of the Ocean Exploration Initiative, former President Clinton appointed a national panel of the leading ocean explorers, scientists, educators and industry representatives to prepare a report entitled; "Discovering Earth's Final Frontier: A U.S. Strategy on Ocean Exploration." Regarding technology development, the panel recommends that the nation "undertake development of underwater platforms, communications systems, navigation, and a wide range of sensors, including the capitalization of major new assets for ocean exploration, in order to regain U.S. leadership in marine research technology." This report emphasizes the absolute need to carry out an Ocean Exploration Program through partnerships with emphasis on national commitment and high-level investment. The Link Project offers an opportunity to promote and address the panel's, NOAA's, and NASA's exploration objectives for the 21st century.

Project Implementation

With encouragement and funding from NASA's Office of Earth Science, a steering committee was formed in early 1999 to direct and carry out the project. The funding is to support meetings to: (1) bring together ocean and space scientists and engineers to identify critical needs and potential partnerships; and (2) promote exploration of the world's oceans.

Link Steering Committee and Workshop Participants

Dan Basta, Director*
NOAA/NOS/National Marine Sanctuary Program

Richard Blidberg, Director
Autonomous Undersea Systems Institute

Frank Carsey, Team Leader*
Jet Propulsion Laboratory, Polar Oceanography

Kevin Delin, Team Leader
Jet Propulsion Laboratory, Sensor Webs Project

Ted DeWitt, Ecologist
Environmental Protection Agency

Tommy Dickey, Professor
University of Califonia, Santa Barbara

Paul DiGiacomo, NRC Resident Research Associate
Jet Propulsion Laboratory, Ocean Sciences Element

Diane Evans, Chief Scientist*
Jet Propulsion Laboratory, Earth Science Office

Grant Gilmore, Senior Aquatic Scientist
Dynamac Corporation, Kennedy Space Center

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Jet Propulsion Laboratory, Autonomy and Control Section

Todd Jacobs, Project Manager*
NOAA/NOS/Special Projects Office

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Jet Propulsion Laboratory, Breakthrough Instruments and Sensors

Arthur Lane, Thrust Area Manager
Jet Propulsion Laboratory, Observation Systems Division

Eric Lindstrom, Program Manager*
National Aeronautical and Space Administration, Office of Earth Science

Gary McMurtry, Associate Professor
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Steve Rock, Professor of Robotics
Stanford University

Guillermo Rodriguez, Technical Staff
Jet Propulsion Laboratory, Autonomy and Control Section

Robert Schwemmer, Cultural Resource Specialist
Channel Islands National Marine Sanctuary

Andrew Shepard, Associate Director*
National Undersea Research Program, UNCW

Larry Silverberg, Director and Professor of the Mars Mission Research Center
North Carolina State University

Chuck Weisbin, Thrust Area Manager*
Jet Propulsion Laboratory, Surface Systems

David Wettergreen, Research Scientist
The Robotic Institute, Carnegie Mellon University

Junku Yuh, Professor and Director
University of Hawaii, Autonomous Systems Laboratory

**Denotes a member of the Link Steering Committee*

Note that Steering Committee members not present at the first workshop include Sylvia Earle and Loren Lemmerman.

First Workshop

In Situ Intervention Using Unmanned Technologies

Space and the sea are hostile environments to humans. Often, remote sensing and unmanned technologies precede deployment of the most expensive technology—people. Similarly, the first *in situ* technologies The Link Project considered were unmanned. The project may consider a broad range of unmanned technologies; however, in order to focus the first workshop, the following scenarios were prepared for consideration by the Link Steering Committee:

- *Exploring under arctic ice*
- *Life without light: Hydrocarbon seeps in the deep Gulf of Mexico*
- *Impacts of submarine telecommunications cables on national marine sanctuary resources*
- *Do deep shipwrecks threaten national marine sanctuary resources?*

The shipwreck scenario was chosen to focus discussion at the first workshop because it offered a range of technological elements that require development, including undersea robots (ROVs, AUVs), ocean observatories, sensor technologies, and real-time data transmission, all used in remote and harsh conditions. NASA is particularly interested in the challenges of working under ice, and the shipwreck scenario satisfied this need in that surveys and sampling must be precisely oriented to the wreck, as would be necessary for exploring and studying under the ice of Jupiter's moon, Europa.

Shortly afetr this photograph was taken, thePac Baroness laid to rest in her watery grave at 430 meters carrying large quantities of copper concentrate, fuel, and lubricating oils. NOAA would like to know if deep shipwrecks threaten national marine sanctuary resources.
Photo courtesy of Glenn Allen

Objectives

The goals of the first workshop were to identify new technologies to apply to the ocean environment; consider constraints to near-term implementation of the technologies; and recommend opportunities for partnerships.

Lying 430 meters below the surface, 14.5 kilometers west of Point Conception is the wreck of the 162-meter-long bulk carrier, *Pac Baroness*. After colliding with the auto carrier, *Atlantic Wing* in the early morning of September 21, 1987, the *Pac Baroness* went down with her cargo of 21,000 metric tons of finely powdered copper concentrate, and a combined volume of 378,943 gallons of fuel and lubricating oils. Faced with this problem, workshop participants were asked to consider technologies required to address the following specific research objectives:

- *Map and characterize the wreck site and contaminant field*
- *Monitor the transport and ecological impacts of contaminants*
- *Predict the risk of future contamination and ecological impacts.*

Not every possible technology was considered, and specific criteria included:

- *Overlap of NOAA and NASA mission needs*
- *Funding of up to $1 million per year for two years*
- *Interactions of multiple partners (NOAA, NASA, outside scientists and engineers)*
- *Technologies that could be operational within five years*

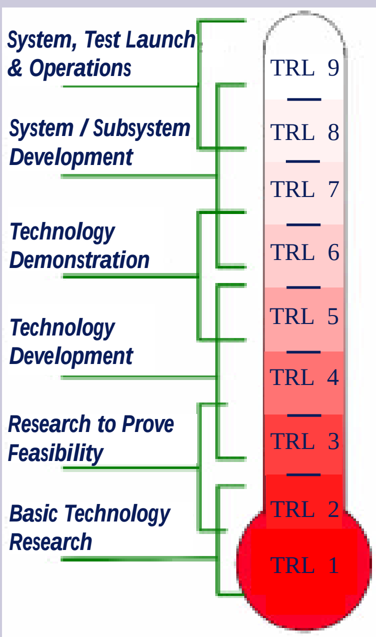
Process

From August 29-31, 2000, 24 scientists and engineers representing 14 agencies and institutions participated in the first Link workshop held in Santa Barbara, California. The diverse group included people who are developing new technologies that may be employed in ocean science and exploration, and representatives from the ocean science and management communities that may benefit from access to these emerging technologies. What the participants had in common was their interest in sensing and sampling in extreme, remote, aqueous environments. What they often lacked was much information on each other's needs and methods.

The first task was to clarify terminology and perspectives. Communication was often a barrier between the disciplines of engineering and science, ocean and space, as well as NOAA and NASA. Early discussions often served to explain concepts and terminology. This matter is fundamental to the success of The Link Project and has become a new

NASA Technology Development

Technology development is a driving force for many NASA programs. At any time, thousands of new technologies are in various stages of development. In order to summarize development status, NASA uses the concept of Technology Readiness Levels (TRLs). TRLs are systematic metric measurement systems that support assessments of the maturity of a particular technology and the consistent comparison of maturity between different types of technology (Mankins, J. 1995). The figure below summarizes levels 1 through 9, essentially from basic idea to successful deployment in space. The Link Project is focused on the later stages (7-9) of development in the hopes of applying NASA technologies to ocean problems in the next few years.



objective for future efforts. The workshop agenda included background presentations, discussion of the shipwreck scenario, breakout groups to identify promising areas for collaboration, and prioritization and characterization of the most promising technologies.

Results

Eric Lindstrom, Program Manager of NASA's Office of Earth Science, began the workshop by reinforcing his desire to "open the vault" of NASA technologies and expertise to the ocean research community through improved communication and partnerships. The workshop accomplished these tasks. In the words of Dan Basta, Director of NOAA's National Marine Sanctuary Program, "we expanded the circle of influence and expertise that may shape the coming decade of exploration." Partnerships evolved during and following the workshop (see "Success Story"). Other specific workshop recommendations included:

- *Continue working with The Link Steering Committee to define and support future workshops;*
- *Establish mechanisms (e.g., Link Web site expansion and integration with other relevant sites) to promote future collaborative efforts, improved communication, and access to NASA funding programs for ocean scientists; and*
- *Encourage site visits between ocean and space experts, e.g., NOAA research staff visits to the Jet Propulsion Laboratory to develop greater understanding of potential new sensor technologies; NASA staff visits to NOAA ships and labs to determine whether NOAA resources can be used to help NASA testing or mission planning; and NASA visits to National Undersea Research Centers to discuss methods for deploying ROVs and AUVs through ice.*

Success Story

Collaborating with Innovative Technology

Several workshop participants remarked that they gained useful professional connections through the first Link workshop. Kevin Delin of the NASA's JPL gave a presentation on his work in the development and applications of Sensor Webs. "The Sensor Web is an independent network of wireless, intra-communicating sensor pods, deployed to monitor and explore a limitless range of environments. This adaptable instrument can be tailored to whatever conditions it is sent to observe" he said. (For more details about Sensor Webs see page 5 "Technology Showcase"). Delin currently has a functioning field demonstration in the Huntington Botanical Garden in San Marino, CA, where simple Sensor Webs are monitoring microclimates. At the workshop, he expressed a desire to develop an aqueous experiment by deploying Sensor Webs into the marine environment. There was much interest following his presentation.

Ted DeWitt of the United States Environmental Protection Agency (USEPA) is interested in working with Sensor Webs to monitor physical, chemical, and biological processes in estuarine and near-shore environments. A proposal is currently in development to fund a workshop during the next year that would focus on the potential development and siting of Sensor Webs in Pacific Northwest estuaries, such as Yaquina estuary (Newport, Oregon) and/or the South Slough estuary, site of the South Slough National Estuarine Research Reserve (Charleston, Oregon).

Grant Gilmore of the NASA Kennedy Space Center (KSC) and Kevin Delin are also discussing the possibility of using the Cape Canaveral lagoons at KSC as a demonstration site for an aqueous application of Sensor Webs.

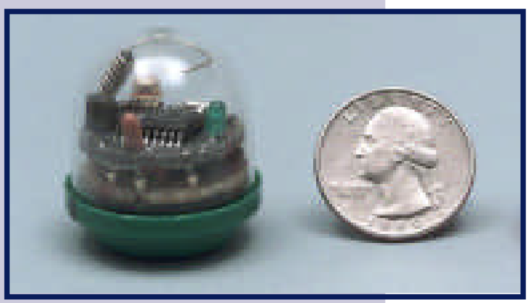
Technology Showcase

Priority in-situ technologies and development efforts were identified by the working groups. The Link Project Web site, which is currently being revised, will include more detailed descriptions of these and other technologies.

Sensor Webs

A Sensor Web consists of networked, wireless, spatially distributed sensor pods that are deployed to monitor and explore remote environments. While an ordinary sensor network passively gathers data, a Sensor Web can modify its behavior based on the data it collects. The pods share data with each other, so, the Sensor Web can react and adapt to its environment as a whole. The system is reactive, adaptive, and includes self-healing and self-modifying capabilities.

The Sensor Web is an emerging technology that will be ideal for a number of scientific studies within the marine environment, such as mapping and monitoring the biological, physical, and chemical environment (e.g., pollutant plumes, algal blooms, suspended sediments, dissolved oxygen). Real-time, virtual presence across air-land-sea boundaries is applicable to both local (event-triggered) and regional (baseline) conditions.



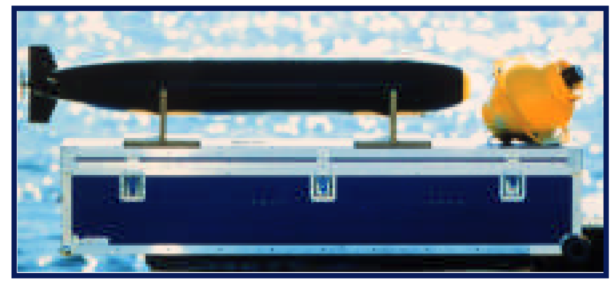
A single sensor pod, the size of a quarter, gathers data and communicates wirelessly with numerous other pods to form a Sensor Web. Photo courtesy of K. Delin, NASA/JPL

More information on Sensor Webs is available at: http://sensorwebs.jpl.nasa.gov.

Semi-autonomous Navigation, Control, and Manipulation

Tethered Remotely Operated Vehicles (ROVs) are commonly used for ocean research, especially for deep-sea applications. However, tethers pose significant barriers to payload and manueverability. Semi-autonomous vehicles with lighter or detachable tethers may offer ideal solutions. The vehicle must have enough on-board intelligence, power and capabilities to respond to high-level task directives from the remote user. Also, control of some functions may be better accomplished under computer control than via tele-operation, such as precision, high band-width manipulator control. Operational manipulator systems on ocean vehicles are now tele-operated. Research demonstrations of task-level commanded underwater manipulators have been done, but none of these are ready for deployment without further development efforts. Required features to enable semi-autonomous manipulator control include precise arm-tip placement control with the sample site, coordinated arm-vehicle control, and sensor-based control (e.g., control from a camera mounted on the arm).

There are promising areas for the development of navigation and guidance systems that are needed to repeatedly locate an exact site. First, sensor-based guidance systems allow "sniffing" down gradients. Assuming that the appropriate chemical sensor exists, there is also the challenge of developing an intelligent search strategy that will guide the vehicle autonomously to the site. Second, precise relative navigation around a site can be done using "bottom" reference navigation; examples include long baseline, short baseline, ultra-short baseline, and sonar-based maps. Ideally, the vehicle will create its own world model for real-time navigation with no external systems required.



REMUS (Remote Environmental Monitoring UnitS) are low cost AUVs designed for coastal monitoring and multiple vehicle survey operations. Photo courtesy of Woods Hole Oceanographic Institution

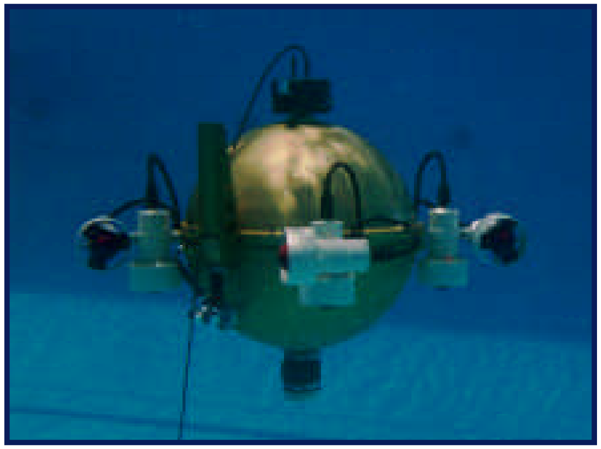
Autonomous Benthic Explorer known as ABE. Photo courtesy of Woods Hole Oceanographic Institution

Most of the technology required to complete an integrated proof-of-concept demonstration of these technologies exists, at least in the laboratory. An integrated demonstration could be accomplished within three years and would require multiple laboratories to merge their technologies into one demonstration platform. This integration would serve to (1) demonstrate the feasibility of the mission and (2) identify those technologies requiring further development to enable the deployment of a final system.

Multiple, Cooperating Autonomous Underwater Vehicles (AUVs)

Significant benefit can accrue if multiple AUVs are able to coordinate their activities to accomplish a defined task. Multiple systems offer a number of specific benefits, such as the ability to obtain higher-resolution temporal and spatial sampling. Under-sampling in the ocean is recognized as being a critical deficiency in our ability to understand global ocean processes. Other benefits are the ability to implement adaptive control, leading to more efficient sampling, as well as the ability to implement complex sampling strategies that would not be possible utilizing a single vehicle. Inherent in a multiple-vehicle system is the robustness offered, since a single failure is not a catastrophic failure (i.e. the remaining vehicles can adapt to accomplish the defined task).

A substantial amount of effort has gone into developing intelligent control architectures for individual autonomous agents. In parallel with these activities are investigations centered on the control of remote systems through some level of remote presence. The vehicles' status could be displayed and updated on a regular basis over a distributed user interface, wherein geographically dispersed users could monitor and assess the progress of operations and generate appropriate commands to modify the onboard sampling strategy. It would be possible to leverage existing vehicles and ongoing research investigations at various academic and research organizations to undertake a three-year program leading to such a demonstration project.



ODIN (Omni-Directional Intelligent Navigator)is a sphere-shaped, eight-thrustered URV with specifications capable of instantaneous movement in all 6 degree-of-freedom motions from both tethered and autonomous modes. Photo courtesy of the Autonomous Systems Laboratory

The Solar Powered AUV (SAUV) being retrieved after sea test off Vladivostok. This extremely long endurance AUV is part of a joint development effort between the Institute for Marine Technology Problems (IMTP) in Vladivostok, Russia, and the Autonomous Undesea Systems Institute in Lee, New Hampshire. Photo courtesy of the Autonomous Undersea Systems Institute

In situ Sensors: Sampling, Calibration, and Verification

Multiple sensors, sensor arrays, sampling methods, and control hardware need to be integrated into instruments that perform specific tasks in a diverse set of environments (e.g., deep ocean, hot water vents, coastal shallows). They may experience pressures from one to greater than 600 atmospheres, and temperatures from minus 4° to over 500°C. Sensors may be deployed for days or years, collecting data continuously. Dynamics of the local environment dictate the required frequency of measurements and the rapidity with which each measurement is accomplished. Most measurements will vary between 10 seconds at the fastest (dynamic hydrothermal vents) to daily or even weekly sampling, depending on research objectives. Measurements may be event driven, and thus, the sensor package may be quiescent for weeks or months, then required to run at seconds to minutes. Sensitivities required vary between part per thousand to less than parts per billion, depending upon the species in question and the nature of the problem. Accuracy also depends on the specific problem being addressed, from a factor of 2 or 3 to less than 10%. Deployment platforms may be fixed or mobile, including observatories, Remotely Operated Vehicles (ROVs), Autonomous Underwater Vehicles (AUVs) and human occupied submersibles.

Key challenges facing long-term ocean sensor deployments include the need for routine calibration and data validity checks, which are difficult without instrument recovery. Natural sample characteristics must be preserved prior to and throughout analysis. Due to the broad range of sensor requirements and capabilities, many agencies and industrial partners are possible. The development of each sensor, as well as the specific sampling and inlet system required, have the potential for a different sponsor/partner arrangement.

Underwater Imaging for Characterization, Mapping and Positioning

The ocean environment is dynamic and inherently three-dimensional. Several current problems highlight the increasing need for more detailed, wide-area three-dimensional seafloor maps. For example:

- *rapid assessment of fish stocks and habitat*
- *accelerating degradation of marine ecosystems due to natural and anthropogenic factors*
- *increasing realization of the role of the seafloor in generating materials that affect Earth's climate and environment*
- *discovery of new life forms and potential biotechnology products at deep-sea vents and seeps.*

Imagery produced by a range of new acoustic and optical technologies may aid the improved characterization of seafloor habitat, physical processes and biota. A composite of these images may, for example, be used to construct the geophysical structure of a fish habitat and simultaneously record the number, type, and location of fish present.

Many of the challenges facing ocean and space scientists will require the use of robotic vehicles that must be able to navigate in unknown, previously unmapped regions. Frequently, there is no opportunity to add infrastructure, such as beacons with known geographic positions, to provide required mapping data. Positioning must be determined relative to the available sensor measurements. The objective of simultaneous mapping and positioning is to enable a mobile robot to build a map of an unknown environment, while simultaneously using that map to navigate. This problem is especially challenging for AUVs.

Specific technologies with promise for meeting these challenges include:

- *Passive sonar arrays (two-dimensional)* — receive ambient sound from the water and produce an image that can be used to identify the location and source over ranges of hundreds of miles.
- *Active sonar* – these systems (e.g., seismic profilers, side-scan sonar) provide high-resolution (meter) sensing of surface morphology, identify macro-organisms, and characterize surficial and sub-surface, substrate characteristics
- *Passive optics (e.g., photography)* — produce very high-resolution images; key technology to be developed for ocean science is the processing of images, collected either in pairs or sequences, to determine scene geometry.
- *Active optics* – for example, LIDAR and Laser Line Scanners, can "see" better (through more turbid water) than passive systems; provide extra high-resolution (centimeter) data on surface morphology, and, when equipped with proper filters and light sources, may be used to detect biota.
- *Data assimilation* — data must be pre- and post-processed, interpreted, and combined into geo-rectified maps useful for positioning and navigation; key challenges are in the development of the numerical methods that are required when the geometric relationship between images is not known a priori.
- *Image integration* – for many problems, the best solutions involve the integration of multiple techniques; fusing images from different modalities, such as a passive acoustic image with an optical image (e.g., seeing the fish that is making a particular sound), results in more accurate and more detailed characterizations.

Exploration 2002

An International Symposium for Ocean and Space Technology Innovation

Exploration 2002 will be an international symposium to promote the benefits to humankind of ocean and space exploration, research, and related technology development. The three-day meeting will:

- Highlight recent and future advancements in technology that may benefit ocean and space exploration and research
- Feature explorers who have been to the frontiers and their stories of discovery
- Describe a future in which deep-sea and inter-planetary exploration, and the existence of previously undiscovered life, are not science fiction

Symposium Highlights

NASA already has a healthy program to integrate its satellite programs with other earth science efforts. Thus, Exploration 2002 will feature technologies that take humans to new frontiers, either directly or indirectly using telepresence. Proposed features of the symposium include:

- Plenary session featuring leading technologists and explorers as keynote speakers
- Thematic sessions led by chairs of distinction, based on technologies for *in situ* exploration, including human occupied vehicles, space stations, robotic vehicles (tethered and autonomous), unmanned observatories and sensor technologies
- A closing session featuring invited presentations on visionary futuristic ideas, e.g., How does NASA envision searching for life in Europa's ocean, and what does the agency need to get there? What will a fully instrumented Earth ocean mission accomplish and how will we get there?
- Technology showcase for exhibits, posters and product displays
- Open to the public and media for a registration fee, with invitees to include international representatives from ocean and space scientists and engineers from academia, government an industry, and private exploration and technology companies (e.g., oil, telecommunications)

The Kennedy Space Center (KSC) in Cape Canaveral, Florida, is promoting aquatic research programs and has expressed keen interest in hosting the event. Dr. Grant Gilmore of the Dynamac Corporation, currently serves as meeting coordinator and liaison to the KSC. The meeting will include special events, such as a tour of the shuttle launch facilities.

Contact The Link Project leads for more information on Exploration 2002.

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Symposium

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Edwin A. Link, visonary, pioneer inventor, and researcher in aviation and ocean engineering. Photo courtesy of Bates Littlehales © National Geographic Society

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Edwin Link and Seward Johnson, Sr.
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Sensor Pod the size of a quarter
© Kevin Delin, NASA/JPL

Deep sea organism
© I. MacDonald, Texas A&M University

Launching of the Jason ROV
© Woods Hole Oceanographic Institution

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