The Elmer A. Sperry Award 1989

for advancing the art of transportation

The Elmer A Sperry Medal

The Elmer A. Sperry Award

The Elmer A. Sperry Award shall be given in recognition of a distinguished engineering contribution which, through application, proved in actual service, has advanced the art of transportation whether by land, sea or air.

In the words of Edmondo Quattrocchi, the sculptor of the Elmer A. Sperry Medal:

"This Sperry medal symbolizes the struggle of man's mind against the forces of nature. The horse represents the primitive state of uncontrolled power. This, as suggested by the clouds and celestial fragments, is essentially the same in all the elements. The Gyroscope, superimposed on these, represents the bringing of this power under control for man's purposes."

Presentation of

The Elmer A. Sperry Award for 1989

to

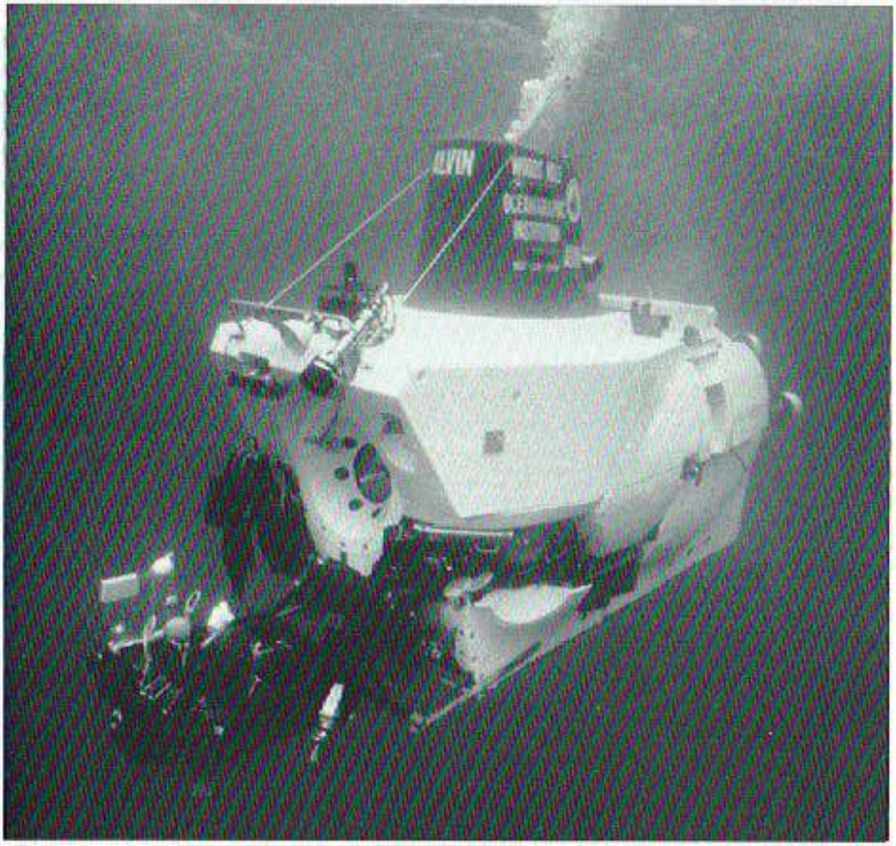
Harold E. Froehlich,
Charles B. Momsen Jr.
and
Allyn C. Vine

by

The Board of Award under the sponsorship of the:

American Society of Mechanical Engineers
Institute of Electrical and Electronics Engineers
Society of Automotive Engineers
Society of Naval Architects and Marine Engineers
American Institute of Aeronautics and Astronautics

At the SNAME Winter Annual Meeting
Friday, November 17, 1989, New York, New York



Alvin

AWARD CITATION

To Harold E. Froehlich, Charles B. Momsen Jr., and Allyn C. Vine for the invention, development and deployment of the deep-diving submarine, *Alvin*.

Alvin at its 1964 christening

Harold E. Froehlich

Harold E. Froehlich was born July 13, 1922 in Minneapolis, Minnesota. He joined the U.S. Navy at age 18 and saw action during World War II in the Atlantic and Pacific theaters.

Mr. Froehlich earned B.S. degrees in Aeronautical Engineering (1946) and Mechanical Engineering (1949) from the University of Washington. In 1951, he earned his M.S. in Aeronautical Engineering from the University of Illinois and went to work at General Mills' Aeronautical Research Lab. He was Project Engineer for balloon rocket flights in the Arctic in 1952 and co-invented a system to collect large volume air samples from the stratosphere for radioactive particulate analysis. He was also Project Director for the Navy's Project Stratolab, which carried men to 76,000 feet.

Mr. Froehlich adapted nuclear handling manipulators for undersea use on the bathyscaphe, *Trieste*. This led to his design of *Seapup, Alvin*'s forerunner, at General Mills in 1961. He was responsible for the design and construction of *Alvin* while working for General Mills and Litton Industries.

In 1965, Mr. Froehlich was given underseas remote handling responsibilities at Programmed and Remote Systems Corp. He adapted an extremely lightweight manipulator for the research vehicle *DOWB* and two hydraulic manipulators for Lockheed's *Deepquest*, the forerunner of the Navy's deep sea rescue submarines.

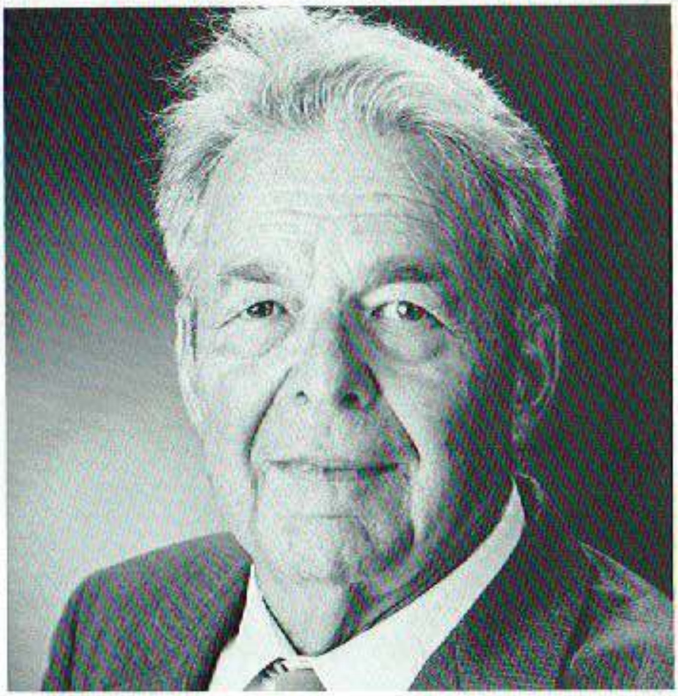
In 1969, Mr. Froehlich joined 3-M, where he developed liquid-fueled burners and wound closure devices until retiring in 1989. He holds over 15 patents.

Charles B. Momsen Jr.

Charles B. Momsen Jr. was born April 19, 1920 in Garrett Park, Maryland. He was graduated from the U.S. Naval Academy in December, 1941 and served in the Navy on continuous active duty until September, 1964, attaining the rank of Captain. Most of his career was devoted to submarines and submarine-related assignments. He was awarded a Bronze Star for actions in *U.S.S. Barbero* in World War II and commanded the Navy's first guided missile submarine, *U.S.S. Cusk*.

From 1958 until 1964, he served as Director, Undersea Programs, in the Office of Naval Research. During this period, he was able to bring to fruition a long-held interest in deep submersibles. The lack of knowledge about the oceans and ocean floor, the straight-forward simplicity of the means, and the general interest of the research community culminated in the Deep Submergence Program, of which *Alvin* was the first result. Mr. Momsen was awarded a Legion of Merit for "his responsibility for the Navy's Deep Research Vehicle program, which led to the construction of *Alvin*."

After retiring from the Navy, Mr. Momsen was the head of the Ocean Engineering Section of the General Motors Research Laboratory in Goleta, California. There, he was responsible for the crew training and operation of the GM Research Submersible *DOWB* (Deep Ocean Work Boat). During this same period, he served as Chairman, Ocean Engineering Division, of the American Society of Mechanical Engineers. Mr. Momsen retired from General Motors in 1982.



Allyn C. Vine

Allyn C. Vine was born June 1, 1914 in Garrettsville, Ohio. He was graduated from Hiram College with a physics major in 1936 and earned an M.S. from Lehigh University in 1940. He joined the research voyages of Woods Hole Oceanographic Institution (WHOI) while still a graduate student and developed an interest in exploring the deep ocean. Vine moved there permanently when a group of researchers from LeHigh University came to WHOI full-time in 1940 for major research projects funded by the Navy.

Vine began working on submarine research and redesigned the bathythermograph (BT), a device for measuring temperature with depth, for use in antisubmarine warfare. He increased the BT's accuracy and reliability and improved its hydrodynamics so it could be deployed from moving ships to locate submarines. He also designed a stationary version for use by submarines to avoid detection.

In 1946, Vine worked on atomic bomb tests in Bikini. From 1947 to 1950, he served at the oceanographic desk of the U.S. Navy Bureau of Ships, Sonar Division, while still on staff at Woods Hole. Vine began working on a proposed small submersible, overcoming the initial concern of oceanographers that it would be too risky and expensive. Vine met with the Office of Naval Research in the late 1950s on the project and persevered until the sub was built. He also helped design *Lulu*, *Alvin*'s mother ship, named for Vine's mother. Vine remains on staff at WHOI.

Origins of *Alvin*

based on an article by Allyn C. Vine

Although oceanographers had been studying the sea for generations using available technologies, the essential nature of the ocean depths eluded them until the echo sounder, undersea camera, and seismic profiling (using sonic echoes to map the sea floor) were developed in the years following World War II. Resulting discoveries inspired a few people to work on obtaining easier access to the ocean floor. One approach was to develop closed-circuit TV systems, carried to the sea floor by largely self-sufficient robots monitored by scientists on board ships. Another was to develop small, deep-diving submersibles that would enable scientists to explore the sea floor themselves. These ideas were sympathetically received by the Office of Naval Research (ONR), especially by those who had worked with submarines during the war. On March 1, 1956, under the auspices of the Navy and the National Academy of Sciences, leading oceanographers strongly endorsed the potential of submersibles as a research tool. Jacques Piccard, son of submersible pioneer Auguste Piccard, was invited to bring the deep-diving bathyscaphe *Trieste* to San Diego to work with Navy and civilian scientists on the biological and acoustical character of deep scattering layers. Eventually, the Navy bought *Trieste*, and on January 23, 1960, Piccard and Navy Lieutenant Don Walsh set a deep-diving record that still stands by taking the bathyscaphe to the bottom of the 37,795-foot Marianas Trench in the Pacific. This demonstrated that scientific submersibles could operate in the deepest areas of the sea.

Another boost for submersibles came from influential reports issued by ONR and the National Academy of Sciences, outlining the need for new and better research vessels, including ones that could go into the ocean depths. Then, on October 4, 1957, the Soviet Union provided an indirect incentive with the successful launch of Sputnik I, the first earth satellite. This display of Soviet technological and scientific prowess sharply increased American interest in, and funding for, all sorts of scientific research, including oceanography. Established oceanographic centers needed the Navy's strong support, both financial and moral, from such enthusiastic Navy officers as Charles Bishop and Charles Momsen Jr. of ONR and Richard Dzikowski of the Bureau of Ships' submarine desk. Scientists and engineers began investigating possibilities. At the Southwest Research Institute in San Antonio, Texas, Edwin Wenk led a team working on deep submersible design. While investigating aluminum as a hull material, he found an enthusiastic supporter in J. Louis Reynolds, vice president of the Reynolds Metals Company, who sponsored the design and construction of a 51-foot submersible, *Aluminaut*. There was a tentative agreement that ONR would support a submersible research program under Paul Fye, Director at WHOI, using *Aluminaut* rented from Reynolds. This plan never came about because of uncertainties in possible divided responsibility regarding changes, safety, etc. *Aluminaut* was completed and independently operated by Reynolds. It was the *Aluminaut* that later helped rescue *Alvin* after it accidentally sank off Cape Cod.

Harold Froehlich, an engineer at the electronics division of General Mills, designed a 15-foot submersible called *Sea Pup*, which would be smaller, simpler, and less expensive than *Trieste* or *Aluminaut*. The idea for *Sea Pup* was strongly emphasized by the *Trieste* office in San Diego in 1961. They wanted a small submarine that could be carried on a modest mother ship, serviced at sea, and capable of multiple dives in a research area. As a result of these and many other discussions, Momsen and Fye agreed to modify the WHOI-ONR contract to procure a somewhat larger and more capable *Sea Pup*. Specifications for such a craft were prepared at Woods Hole with the cooperation of Navy submarine design personnel. These specifications were put out to open bid. General Mills was the lowest bidder and was awarded the contract. Although its electronics division was sold to Litton Industries, Inc., Froehlich was allowed to complete the sub. At Woods Hole, Allyn Vine and many others began preparations for the logistic, instrumentation and operational problems involved.

Alvin was christened at Woods Hole on June 5, 1964. Its name was an acronym for Allyn Vine, the driving force behind the work at Woods Hole. Though they still faced such problems as training pilots and crew, debugging, obtaining certification from the Bureau of Ships, and installing scientific apparatus, the oceanographic scientists and engineers at Woods Hole now had a viable deep submersible program in operation.

Alvin's Design and Construction

based on the memoirs of Harold E. Froehlich

While providing a manipulator for the bathyscaphe *Trieste*, the need for a smaller, more maneuverable and more easily handled submersible became known. With inputs from A. Rechnitzer, L. Schumaker, and Don Walsh at the *Trieste* office in San Diego, I began to sketch vehicle concepts, calculate performance possibilities, and collect data on components that could be employed. My experience with several recent projects brought a degree of practicality to this effort. Adapting manipulators for undersea use had proven the engineering concept of using a fluid inside a compartment to balance sea pressure and in which to run equipment. Batteries, motors, pumps, controls, etc. could all operate satisfactorily in oil and high ambient pressure. This concept avoids the severe weight and volume penalty inherent in providing buoyant support for heavy enclosures for these components. Only the personnel sphere and the buoyancy systems would require air. My experience with life support systems in closed personnel spheres provided the knowledge necessary to supply oxygen, absorb exhaled carbon dioxide, and control humidity. Managing balloon buoyancy, weight and balance proved to be valuable experience. Designing and constructing tough flexible bags was helpful in designing *Alvin*'s variable ballast system, believed to be a first for submarine use. Also, I had completed a study for the Office of Naval Research on powering plastic streamlined hulls.

In 1961, I presented ideas for a stern drive assembly for deep-diving submersibles at the Pacific Science Congress in Honolulu. The assembly included a drive motor mounted totally within the hub of a relatively large diameter propeller surrounded by an airfoil-shaped shroud to provide yaw stability. The entire motor, assembly and shroud were pivotally mounted on a vertical axis to provide maneuverability similar to a small boat with an outboard motor. In addition, the dynamic pressure fields of the shroud and propeller would favorably interact to augment thrust and reduce drag. The short body could accommodate a forward-mounted pressure hull to house personnel. A front-mounted mechanical arm would permit operators to manipulate interactively objects discovered through forward viewing ports. Skids could be added to sit on the ocean floor, or the vehicle could be made neutrally buoyant and hover.

These ideas were well received by oceanographers, including Allyn Vine. General Mills, Inc. management invested funds for a preliminary design, and specifications for several vehicles (called "Seapup") were generated. In 1962, Dr. Earl Hays and Bill Rainnie from Woods Hole visited GMI to discuss specifications for a similar submersible with some special requirements regarding size, number and location of viewing ports, and power supply capacity dedicated to operating scientific apparatus. Woods Hole solicited competitive bids from industry, the Bureau of Ships issued safety specifications, and a contract to design, construct and test the new submersible, *Alvin*, was signed. I became the project engineer, reporting to Murray Harpole, Manager of Development Operations, and mechanical engineers Forrest Grimm, Ray Meinhardt, and Darrel Nelson were assigned to the team.

Engineering Challenges

In designing the pressure hull assembly, a problem arose due to BuShip's inclusion of an ASME boiler code rule of thumb which required the addition of reinforcement steel on the top hatch, high on the vehicle. This would have caused *Alvin* to be stable in an upside down position! Our design called for carrying the stress through the closed hatch. Over 50 models of the thickened hull areas were studied on an analogue computer, and a scale model was made and tested at Southwest Research Institute to prove its adequacy. Although the Bureau of Ships was reluctant to change its standards, alternate designs were flawed, and the GMI hatch design was eventually accepted by WHOI. When the three pressure hulls originally built were tested, collapse depths were estimated to be 15,800 feet, 16,100 feet, and 15,100 feet, well beyond the 10,800 foot requirement.

Studies of surface friction using data from airships, blimps, free balloons, bathyscaphes, airplanes, helicopters, submarines, torpedoes and surface vessels were used to design *Alvin*'s body shape and the placement of its components so their influence on one another would be beneficial, allowing the sub to use a minimum of power for propulsion. *Alvin*'s fineness ratio (length/diameter) is less than half that of a conventional submarine. Hydrodynamically, this is a first for a submarine. It was accomplished by controlling the boundary layer by mounting a large propeller inside a stabilizing ring shroud at the stern of a stubby, streamlined body. The interacting pressure fields of the shroud, propeller and body complimented each other to reduce drag by preventing flow separation. The main propulsion, at the stern, recovers energy from the boundary layer created by friction on the body.

Power is supplied from conventional lead acid batteries stacked in three battery racks. Special bottles to equalize pressure and permit battery venting were developed. The battery packs are droppable for safety reasons.

Safety was paramount in our thinking, and a new material called "Syntactic Foam" was employed wherever space was available. It consisted of small glass spheres secured in an epoxy resin. It required special machinery to mix and apply and many molds to provide the necessary shapes. Being solid, it could not leak out like gasoline, as used in the *Trieste*.

Major design effort went into providing safety features. In addition to making many items droppable, the forebody containing the personnel sphere was made buoyant and releasable from the rest of the vehicle.

Originally, we had planned to use hard spheres, sea water, and steel shot for changing vehicle weight when submerged and for freeboard control when on the surface. However, since performance of a sea water pump was uncertain, a closed oil system was developed using flexible bags which displace sea water and increase buoyancy when filled. Allowing sea pressure to push the oil from the bags into hard spheres reduces buoyancy. Buoyancy was provided using aluminum spheres and syntactic foam, which filled all the interior flooded spaces.

Alvin's outer skin was conventional fiberglass secured in an epoxy resin. Sea water is free to flood into all the non-sealed cavities inside *Alvin*, so that the skin does not need to resist sea pressure.

Alvin's assembly began early in 1964. Maintaining weight, displacement and buoyancy was a constant challenge, as each piece of equipment's weight and location affected *Alvin*'s balance. Computations and estimates constantly had to be updated, and accounting forms were used to tally every item's air weight, water weight and location. When *Alvin* was first submerged, in June 1964, I was pleased to see positive stability, with the conning tower up!

ALVIN

Recollections of Charles B. Momsen, Jr.

The Office of Naval Research is responsible for maintaining the Navy in the forefront of research related to its mission. A deep-diving submarine was one of the tools necessary for conducting that research. We had already sponsored and supported the acquisition of a number of research vessels, and others were under construction. These ships represented a major expenditure in support of ocean research: ocean engineering, acoustics, marine biology, geophysics and marine physics.

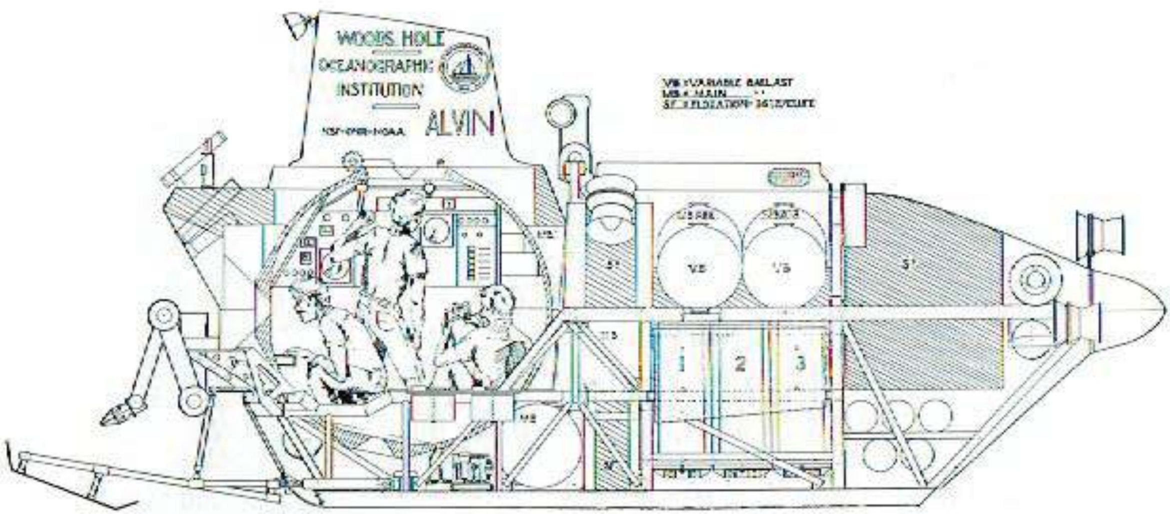
Missing from this "tool bag" was a means for getting the interested scientists into the deep ocean. They had long coped with the limitations of using instruments lowered from the ocean surface in their search for knowledge. What was needed was a vessel capable of getting to at least 6000 feet and having the maneuverability and versatility necessary for scientific explorations. It needed to be simple, safe and easily moved about. Since handling problems are amplified as size increases, room for a pilot and one scientist were minimum criteria. *Alvin* evolved from these needs and the consideration of all feasible submarine designs.

I had been in contact with and had had conversations with many, if not all, of the people interested in solving this problem. Allyn Vine and Paul Fye at Woods Hole were prominent among those consulted.

Money for the project came with the establishment of the Deep Research Program, under the sponsorship of the Office of Naval Research, Underseas Program Division. Most of the obstacles we faced were related to lack of interest and conflicting priorities. The relatively short tour of duty of Naval officers in ONR was also a handicap. To steer the project through these barriers over the four year period necessary to establish the program and marshal Navy support, an individual thoroughly familiar with the program and dedicated to its success was vital. Since I had an extended tour of six years, I was fortunate enough to be in a position to provide that continuity and, at the same time, provide technical guidance to the project.

A number of project officers supported the effort during *Alvin*'s developmental years. Many people in the Bureau of Ships, at David Taylor Model Basin, and elsewhere in the Navy also contributed. Many segments of industry and the research community aided and supported the project.

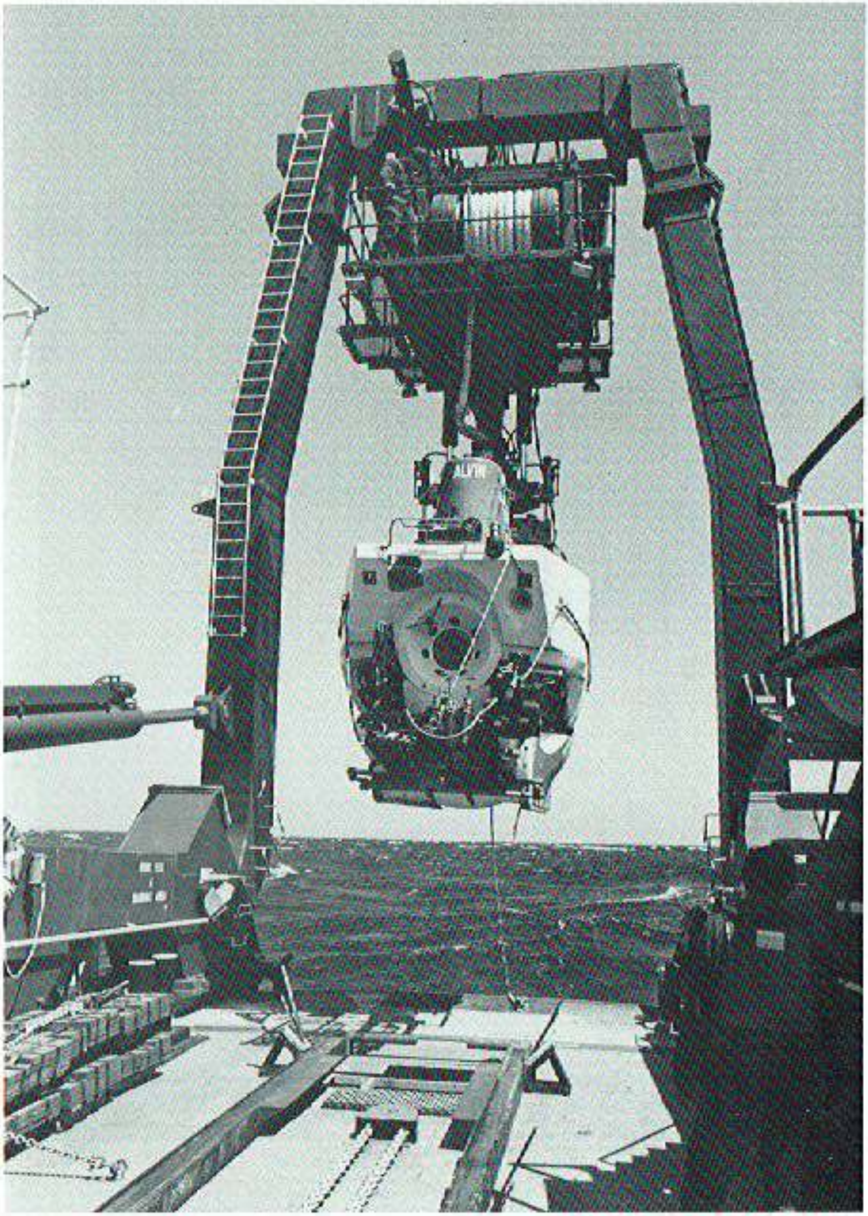
Needless to say, by attracting the help of our supporters and avoiding the efforts of our detractors, we were able to prevail, and *Alvin* became a reality. The objectives of simplicity, small size, and safety were firmly held.



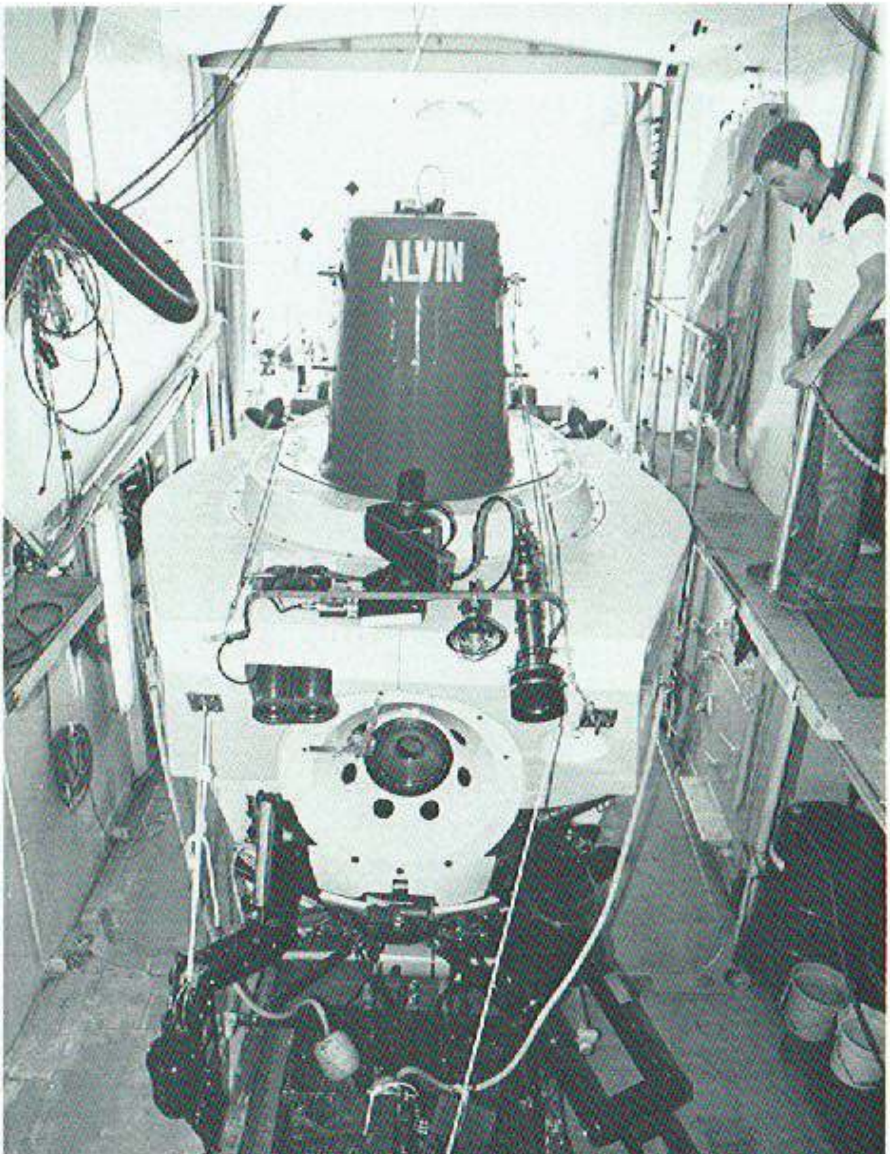
Interior structure of *Alvin*, 1964


1983 overhaul of *Alvin*'s sphere


Alvin in hydraulic A-frame, 1986



Alvin ready for launch from R/V *Atlantis II*



Alvin preparing for launch in its hangar on board R/V *Atlantis II*

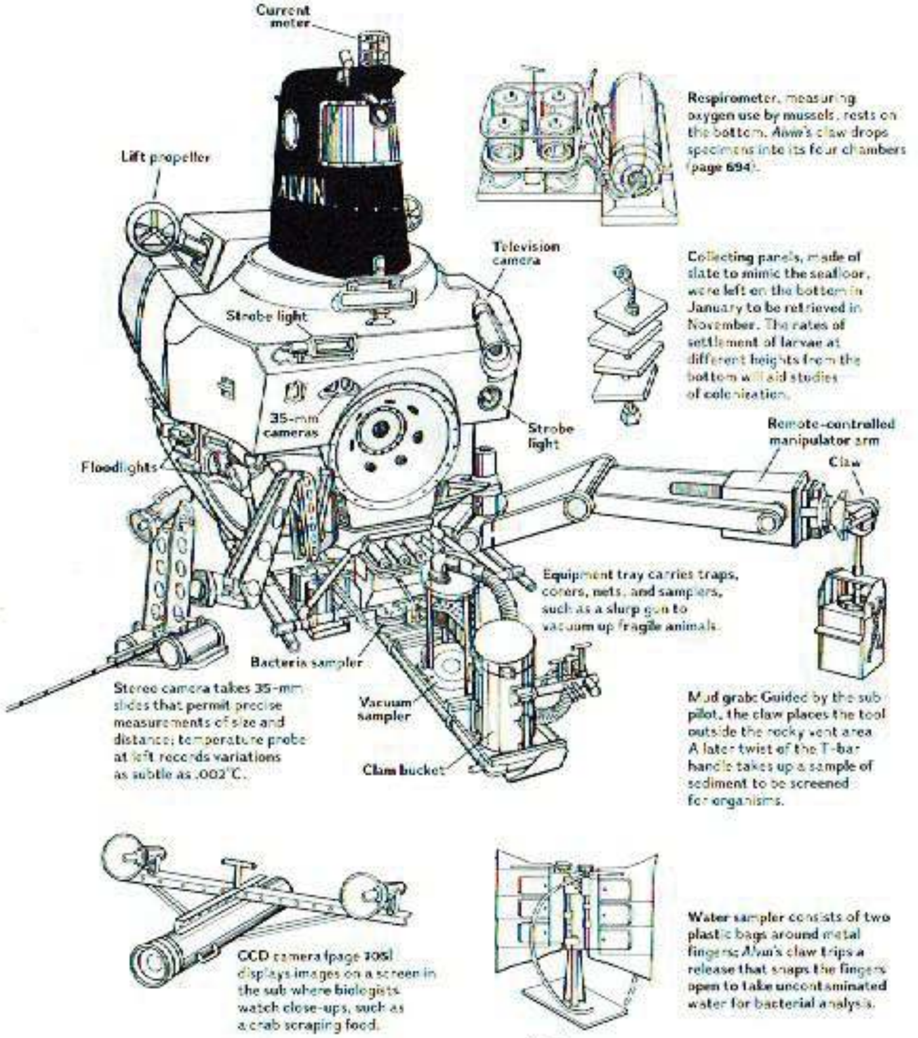
Alvin's Adventures

compiled from WHOI publications

Alvin's early test dives were limited to shallow dives (12-70 feet) in regions local to its home base, Woods Hole Oceanographic Institution. But as engineering changes increased its depth capacity and its exploits began to attract scientific interest, the little sub went farther afield and deeper into the ocean environment.

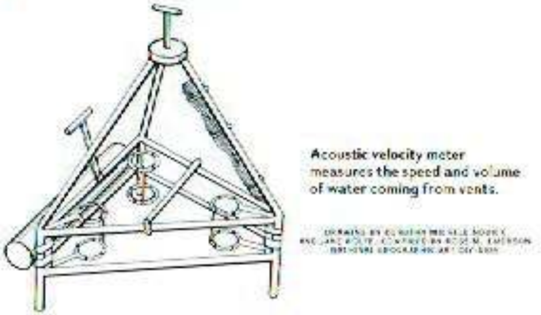
The mission that first demonstrated *Alvin*'s usefulness was the case of the missing hydrogen bomb. Dropped in the Mediterranean off Spain in a 1966 plane collision, the bomb threatened human life and public confidence. *Alvin* was called to the rescue, along with *Aluminaut* and the Perry *Cubmarine*. The search was initially slowed by the Navy's security precautions, which prevented *Alvin*'s crew from seeing detailed photos of the bomb or searching the area where a Spanish fisherman had seen it fall. After two weeks, *Alvin*'s pilot, Marvin J. McCamis, spotted skid marks on the ocean floor, and expedition leader Earl Hays convinced the Navy to allow them to search the area further. Two more weeks of dives passed before the *Alvin* crew spotted the bomb, and stormy weather and technical difficulties delayed the recovery three weeks longer. On the first attempt to lift it, the bomb was dropped, and *Alvin* had to locate it a second time. It was finally raised from 2,500 feet using a device called *CURV* (Controlled Underwater Recovery Vehicle), developed by the Navy to recover torpedoes. *CURV* became entangled in the bomb's parachute, which was still attached, and was lifted to the surface with the bomb trailing. *Alvin* had proved its ability to the world.

Eleven months later, when *Alvin* sank in 5,000 feet of water, it had to be rescued by the *Aluminaut*. An unexpected benefit of this was the discovery of *Alvin*'s lunch box, its contents preserved in edible, although soggy, condition in the cold water. This indicated an extremely slow rate of microbial degradation, although microbes were well known to be common inhabitants of the deep ocean, and some had adapted to that environment



Alvin's Many Hands

The submersible's versatility as a research tool is shown in this illustration by the *National Geographic* Art Division for a 1979 story on biological and geological expeditions to the then newly-discovered vent communities on the Galapagos Rift and the East Pacific Rise.



Courtesy, National Geographic Society

so as to enjoy enhanced growth rates there. This led to research (using better controlled experiments!) to measure the effects of temperature and pressure on microbial capacity for the breakdown of organic matter in the ocean. Results indicate that deep ocean disposal of sludge or other wastes may not remove pollutants.

A number of adventures were in store for *Alvin* in 1967: during a dive in the Bahamas, the sub was attacked by a swordfish, which became entrapped in *Alvin*'s skin. When the sub resurfaced, the fish was found to be intact and was subsequently served for dinner. During another dive, *Alvin*'s mechanical arm was lost. It was later found, repaired and reinstalled.

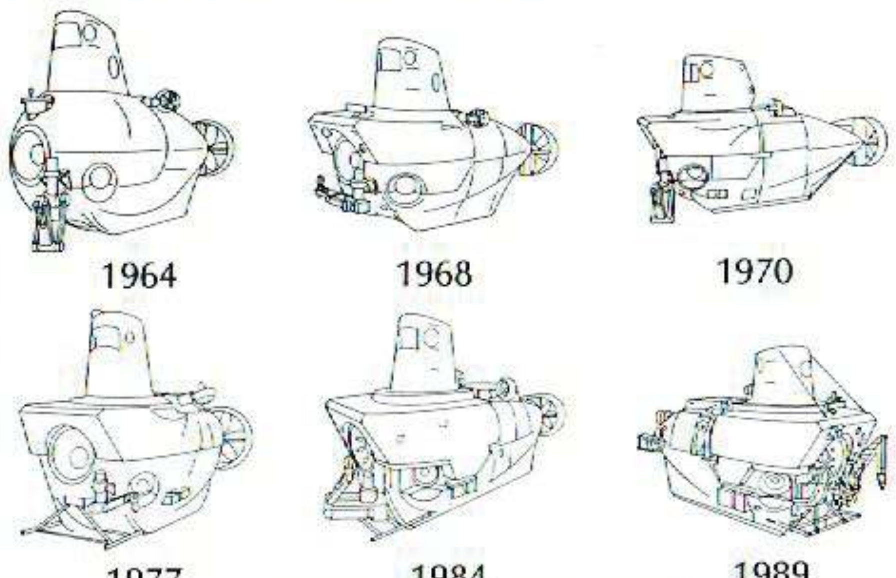
In 1974, *Alvin* joined an international oceanographic party to explore the Mid-Atlantic Ridge, the mountain range that bisects the Atlantic Ocean. Project FAMOUS (French-American Mid-Ocean Undersea Study) consisted of *Alvin*, the French bathyscaphe *Archimede*, and their deep-sea submersible *Cyana*. They explored a site near the Azores, where a pair of undersea volcanoes mark the end of a series of canyons which form an undersea rift. Rock samples were taken, and highly unusual underwater volcanic formations, made by still erupting lava, were observed. It was discovered that the rift was formed not by volcanic activity, but by tectonic plate movement. This expedition established *Alvin* as a unique scientific research tool which could contribute significantly to knowledge of landform creation.

In 1977, *Alvin* passed through the Panama Canal to study the Galapagos Rift. A major discovery was the abundance of warm water animal life on and in the immediate proximity of warm water vents caused by volcanic action deep in the icy sea. Many new types of animal life were discovered. Giant tube worms and other unusually large animals found there showed that life at the vents was qualitatively different from life elsewhere. Since no light is able to penetrate such deep waters, scientists concluded that the animal chemistry there is based on chemosynthesis, not photosynthesis. In addition, the animal life around the vents must adapt to toxic levels of hydrogen sulfide and other chemicals by rapid growth and the production of large numbers of larvae, in contrast to other deep-sea animals, whose growth and reproduction rates are low. These discoveries generated many additional dives to study deep-sea vents around the world. By 1980, *Alvin* had made many dives at the Galapagos Rift, and it has since explored deep-sea life near vents and seeps at the Marianas Trench, the coasts of Japan, Oregon, California, Florida, and the Mid-Atlantic Ridge.

In 1986, *Alvin* took part in an expedition to explore the wreckage of RMS *Titanic*, following its discovery the previous year by surface ships using towed cameras and sonar. *Alvin* took along a self-propelled, free-floating remote viewing system called J.J. (for Jason Junior), a robotic whose cameras were controlled from *Alvin* via a 62 foot cable. The wreckage was mapped in detail, and photos were taken of the debris. In addition to explaining the fate of the Titanic more clearly, exploration of the wreckage ended any hope that the ship could ever be refloated.

In 1989, *Alvin* celebrated its 25th birthday as the world's first and most active small, deep-diving research submarine.

The Evolution of a Submersible



Twenty-Five Years of Change

Alvin is not the same sub that was first launched in 1964. Innumerable repairs and improvements in its design have been made over the years. After its first year of local exploration, *Alvin* was completely dismantled for inspection and minor refit in preparation for its first deep dives. It underwent a major, two-year overhaul at Woods Hole in 1970, following its sinking and subsequent rescue by the *Aluminaut*. Its original steel pressure-sphere was replaced in 1973 with a 4.9 centimeter thick titanium alloy hull, which doubled *Alvin*'s depth capability without increasing its weight. In 1976, *Alvin* was certified for 4,000 meters from its original operational depth of 1,829 meters. In 1978, a new titanium frame and a second manipulator arm were installed.

In 1983, *Alvin* was again overhauled, and its frame was altered to allow for a single-point lift system. At the same time, the *Atlantis II, Alvin*'s new mother ship, was fitted with a very large A-frame on her stern to launch and recover the sub.

In 1985-86, *Alvin* was given another major overhaul. The large stern and six small side lift propellers were replaced by six small electric thrusters, to increase speed and maneuverability. Brushless DC motors designed especially for *Alvin* replaced the hydraulic propulsion system, providing increased reliability, efficiency and performance. *Alvin*'s electrical system was converted from 60 to 120 volts, improving its propulsion and lighting power. New explosive-bolt battery safety release devices were installed, and *Alvin* was fitted with three new battery boxes of laminated construction, using syntactic foam and fiberglass. The aluminum battery support framework was replaced with titanium. Payload capacity, personnel sphere internal arrangement, and the data logging/display system were also upgraded.

By *Alvin*'s 25th birthday, the little sub had made 2,150 dives averaging 6,115 feet each and had carried 4,500 researchers to study geology, biology, chemistry, geochemistry, geophysics and oceanography. *Alvin* today is a product of continuing efforts in the improvement of transportation engineering for its specialized environment.

Alvin's Mother Ships

Lulu, *Alvin*'s original mother ship, was a twin-hulled vessel made from two surplus Navy pontoons. Named after Allyn Vine's mother, *Lulu* was designed and built at Woods Hole in 1964. Two archways were welded to the pontoons to create a catamaran, and a bridge was added along with vans to house mechanical, electronics, and electrical shops. *Lulu*'s power plant and machinery were installed in the port pontoon, and living quarters for 25 were built in the starboard pontoon, with her galley in a trailer on deck.

The catamaran design has less motion than a conventional ship, which is important for handling sensitive oceanographic equipment. It also provided an operating deck large enough to support large, heavy equipment. *Lulu* was the only sizeable twin-hulled vessel to be used extensively in oceanographic research.

Lulu originally utilized an elementary hoisting system, similar to those used in shipyards, to lift *Alvin* into and out of the water. By 1966, it was replaced by an elevator platform cradle. Her original, single forward engine, which made towing necessary on nearly every voyage, was replaced in 1966, and two stern engines were added in the pontoons to allow *Lulu* more independence. Together, *Lulu* and *Alvin* explored the Mid-Atlantic Ridge, the Cayman Trough, and the Galapagos Rift, among other regions of the deep sea, over a period of 19 years, until *Lulu*'s retirement in 1983.

Atlantis II, named after the first research vessel at Woods Hole, is WHOI's flagship. She was designed by the Bethlehem Steel Company in Quincy, Massachusetts, and built by the Maryland Shipbuilding Company in Baltimore, Maryland in 1961. *Atlantis II* was refitted in 1979 and converted from steam to diesel power to increase efficiency, range and selection of ports. She was converted to handle *Alvin* in 1983. A deck hangar and a large A-frame to launch and recover the sub from her stern were installed. *Atlantis II* has traveled the world from both polar ice caps to the equatorial tropics in her work. In recent years, the ship has been engaged along with *Alvin* in extensive geological and geophysical studies in the Atlantic and Pacific oceans.

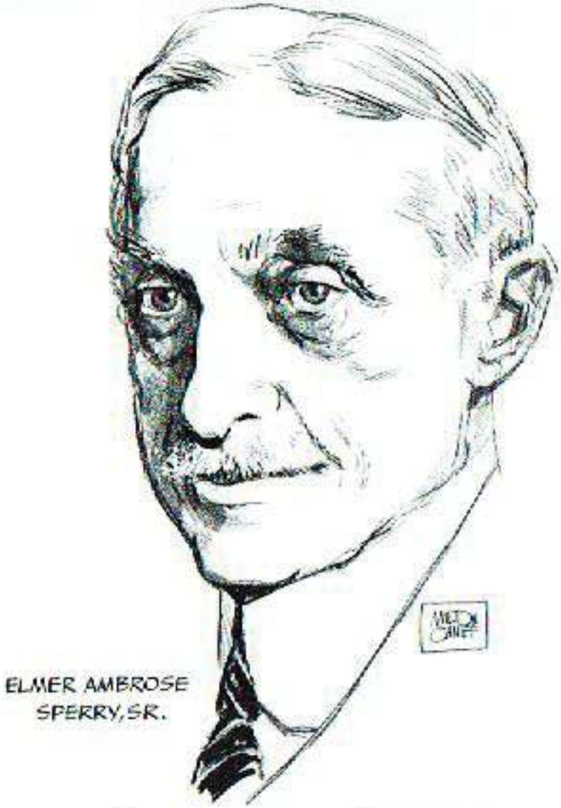
Alvin and *Lulu*

Alvin about to be launched from R/V *Atlantis II*

Woods Hole Oceanographic Institution

The Woods Hole Oceanographic Institution grew from the work of Spencer Fullerton Baird, the first Director of the U.S. Commission of Fish and Fisheries, who came to Woods Hole in 1871 to study marine fauna in the region's pure waters. In 1888, the Marine Biological Laboratory was established to study essential life processes using simple, marine animals. Following the National Academy of Sciences' recommendation that an oceanographic laboratory be built on the American Atlantic Coast, WHOI was founded in 1930 under the Directorship of Henry Bryant Bigelow, a biologist from Harvard University, as a private, non-profit organization. The Rockefeller Foundation provided money for a building, a research vessel, and operating funds. Scientists and students were recruited from the academic world to work during summer months.

World War II brought the Navy's need to develop submarine and anti-submarine warfare to Woods Hole on a year-round basis under the guidance of WHOI's second Director, Columbus O'Donnell Iselin. Research focussed on underwater explosives, ship fouling, and submarine detection. As the work of WHOI grew, greater financial support for naval and oceanographic research became necessary. Today, WHOI's activities are funded by U.S. Government organizations, individuals, foundations and corporations, with 500 overlapping grants and research contracts. WHOI's organization includes departments of biology, chemistry, geology and geophysics, ocean engineering, and physical oceanography. Interdisciplinary research projects are also made necessary by the nature of marine ecology. Research at WHOI targets all aspects of the ocean environment, from the deep sea explorations of *Alvin* to salt marshes and tidal inlets. Research vessels include the 210-foot *Atlantis II, Alvin*'s mother ship; the 177-foot *Oceanus* and the 46-foot *Asterias*, used for near-shore work. Land facilities are located on a 190-acre campus and include the Clark Laboratory for geosciences research, the Coastal Research Center and the Fye Laboratory for advanced chemical studies. Educational programs initiated by director Paul Fye include a Ph.D. in Oceanography, in a joint program with MIT, and post-doctoral work. The present director of WHOI is Craig Dorman.



Elmer A. Sperry, 1860-1930

After attending Cornell University in 1879-80, Sperry invented an improved electric generator and arc light and opened an electric company in Chicago. He invented electric mining equipment, locomotives, streetcars and an electric automobile. He developed gyroscopic stabilizers for ships and aircraft, a successful marine gyro-compass and gyro-controlled steering and fire control systems used on Allied warships during World War I. Sperry also developed an aircraft searchlight and the world's first guided missile. His gyroscopic work resulted in the automatic pilot in 1930. The Elmer A. Sperry Award was established in 1955 to encourage progress in transportation engineering.

Dedication

The Sperry Board of Award joins Harold E. Froehlich, Charles B. Momsen Jr. and Allyn C. Vine in recognizing the contributions of many individuals who helped design, build and operate *Alvin*. The Board also gratefully acknowledges the contributions to this Award booklet made by the Award recipients, the Woods Hole Oceanographic Institution, and National Geographic magazine.

The 1989 Elmer A. Sperry Board of Award

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PREVIOUS ELMER A. SPERRY AWARDS

1955 To *William Francis Gibbs* and his Associates for development of the S.S. United States.

1956 To *Donald W. Douglas* and his Associates for the DC series of air transport planes.

1957 to *Harold L. Hamilton, Richard M. Dilworth* and *Eugene W. Kettering* and Citation to their Associates for the diesel-electric locomotive.

1958 to *Ferdinand Porsche* (in memoriam) and *Heinz Nordhoff* and Citation to their Associates for development of the Volkswagen automobile.

1959 to *Sir Geoffrey De Havilland, Major Frank B. Halford* (in memoriam) and *Charles C. Walker* and Citation to their Associates for the first jet-powered aircraft and engines.

1960 to *Frederick Darcy Braddon* and Citation to the Engineering Department of the Sikorsky Aircraft Division, *Sperry Gyroscope Company*, for the three-axis gyroscopic navigational reference.

1961 to *Robert Gilmore Letourneau* and Citation to the Research and Development Division, *Firestone Tire and Rubber Company*, for high speed, large capacity, earth moving equipment and giant size tires.

1962 to *Lloyd J. Hibbard* for application of the ignition rectifier to railroad motive power.

1963 to *Earl A. Thompson* and Citation to his Associates for design and development of the first notably successful automatic automobile transmission.

1964 to *Igor Sikorsky* and *Michael E. Gluhareef* and Citation to the Engineering Department of the Sikorsky Aircraft Division, *United Aircraft Corporation*, for the invention and development of the high-lift helicopter leading to the Skycrane.

1965 to *Maynard L. Pennell, Richard L. Rouzie, John E. Steiner, William H. Cook* and *Richard L. Loesch, Jr.* and Citation to the Commercial Airplane Division, *The Boeing Company*, for the concept, design, development, production and practical application of the family of jet transports exemplified by the 707, 720 and 727.

1966 to *Hideo Shima, Matsutaro Fuji* and *Shigenari Oishi* and Citation to the *Japanese National Railways* for the design, development and construction of the New Tokaido Line with its many important advances in railroad transportation.

1967 to *Edward R. Dye* (in memoriam), *Hugh DeHaven*, and *Robert A. Wolf* and Citation to the research engineers of *Cornell Aeronautical Laboratory* and the staff of the Crash Injury Research projects of the *Cornell University Medical College*.

1968 to *Christopher S. Cockerell* and *Richard Stanton-Jones* and Citation to the men and women of the *British Hovercraft Corporation* for the design, construction and application of a family of commercially useful Hovercraft.

1969 to *Douglas C. MacMillan, M. Nielsen* and *Edward L. Teale, Jr.* and Citations to Wilbert C. Gumprich and the organizations of *George G. Sharp, Inc., Babcock and Wilcox Company*, and the *New York Shipbuilding Corporation* for the design and construction of the N.S. Savannah, the first nuclear ship with reactor, to be operated for commercial purposes.

1970 to *Charles Stark Draper* and Citations to the personnel of the *MIT Instrumentation Laboratories, Delco Electronics Division, General Motors Corporation*, and Aero Products Division, *Litton Systems*, for the successful application of inertial guidance systems to commercial air navigation.

1971 to *Sedgwick N. Wight* (in memoriam) and *George W. Baughman* and Citations to William D. Hailes, Lloyd V. Lewis, Clarence S. Snavely, Herbert A. Wallace, and the employees of *General Railway Signal Company*, and the Signal & Communications Division, *Westinghouse Air Brake Company*, for development of Centralized Traffic Control on railways.

1972 to *Leonard S. Hobbs* and *Perry W. Pratt* and the dedicated engineers of the Pratt & Whitney Aircraft Division of *United Aircraft Corporation* for the design and development of the JT-3 turbo jet engine.

1975 to *Jerome L. Goldman, Frank A. Nemec* and *James J. Henry* and Citations to the naval architects and marine engineers of *Friede and Goldman, Inc.* and *Alfred W. Schwendtner* for revolutionizing marine cargo transport through the design and development of barge carrying cargo vessels.

1977 to *Clifford L. Eastburg* and *Harley J. Urbach* and Citations to the Railroad Engineering Department of *The Timken Company* for the development, subsequent improvement, manufacture and application of tapered roller bearings for railroad and industrial uses.

1978 to *Robert Puiseax* and Citations to the employees of the *Manufacture Francais des Pneumatiques Michelin* for the design, development and application of the radial tire.

1979 to *Leslie J. Clark* for his contributions to the conceptualization and initial development of the sea transport of liquefied natural gas.

1980 to *William M. Allen, Malcolm T. Stamper, Joseph F. Sutter* and *Everette L. Webb* and Citations to the employees of *Boeing Commercial Airplane Company* for their leadership in the development, successful introduction and acceptance of wide-body jet aircraft for commercial service.

1981 to *Edward J. Wasp* for his contributions toward the development and application of long distance pipeline slurry transport of coal and other finely divided solid materials.

1982 to *Jorg Brenneisen, Ehrhard Futterlieb, Joachim Korber, Edmund Muller, G. Reiner Nill, Manfred Schulz, Herbert Stemmler* and *Werner Teich* for their contributions to the development and application of solid state adjustable frequency induction motor transmission to diesel and electric motor locomotives in heavy freight and passenger service.

1983 to *Sir George Edwards, OM, CBE, FRS; General Henri Ziegler, CBE, CVO, LM, CG; Sir Stanley Hooker, CBE, FRS* (in memoriam); *Sir Archibald Russell, CBE, FRS;* and *M. Andre Turcat, Ld'H, CG;* commemorating their outstanding international contributions to the successful introduction and subsequent safe service of commercial supersonic aircraft exemplified by the Concorde.

1984 to *Frederick Aronowitz, Joseph E. Killpatrick, Warren M. Macek* and *Theodore J. Podgorski* for the conception of the principles and development of a ring laser gyroscopic system incorporated in a new series of commercial jet liners and other vehicles.

1985 to *Richard K. Quinn, Carlton E. Tripp,* and *George H. Plude* for the inclusion of numerous innovative design concepts and an unusual method of construction of the first 1,000-foot self-unloading Great Lakes vessel, the M/V Stewart J. Cort, which revolutionized the economics of Great Lakes transportation.

1986 to *George W. Jeffs, Dr. William R. Lucas, Dr. George E. Mueller, George F. Page, Robert F. Thompson* and *John F. Yardley* for significant personal and technical contributions to the concept and achievement of a reusable Space Transportation System.

1987 to *Harry R. Wetenkamp* for his contributions toward the development and application of curved plate railroad wheel designs.

1988 to *J. A. Pierce* for his pioneering work and technical achievements that led to the establishment of the OMEGA Navigation System, the world's first ground-based global navigation system.