FEATURE FOCUS: *Nuclear Power*

nuclear navy

The *Nautilus* set a new course for the Atomic Age.

by Frank Wicks

Fifty years ago this month, a nuclear submarine named the SSN 571 *Nautilus* was launched at the Electric Boat Co. on the Thames River in Groton, Conn. It was the world's most complicated machine. A crowd of 20,000 shipyard workers, engineers, naval personnel, and dignitaries cheered as Mamie Eisenhower broke the ceremonial bottle of champagne over the hull on Jan. 21, 1954.It was only nine years since the world had first witnessed the incredible destructive power of fission. The uncontrolled chain reaction of fissionable materials in a single bomb could destroy an entire city. Civilization had progressed from the Stone Age through the Electric Age. The new era was dubbed the Atomic Age.Atomic weapons had been the vision and accomplishment of a small group of physicists, working so secretly that even Vice President Harry Truman didn't know about the Manhattan Project until he was sworn in as president. The step of harnessing nuclear energy would be a different engineering challenge.

Generating nuclear power for a submarine was difficult. The very limited space would require a high-power-density reactor and would present unprecedented heat transfer challenges. The tight space also made it difficult to shield the crew from the deadly radiation that is released as a co-product of splitting the atom.A less challenging first application for a controlled nuclear reactor would have been a land-based electric power plant, or possibly a surface

ship. However, nuclear power for a submarine could provide a unique advantage. The boat could stay submerged almost indefinitely. Diesel electric submarines had to surface to run air-breathing engines to charge their batteries. Range and submerged time of a submarine with a reliable nuclear propulsion system would be limited only by food supply and endurance of the crew. The rumor among the first nuclear submariners was they would surface every four years to reenlist.Fantasy was becoming fact. In his 1870 science fiction classic, *20,000 Leagues Under the Sea*, Jules Verne imagined a submarine powered by electricity extracted from the elements in the seawater. Naming the first nuclear submarine the *Nautilus* was a tribute to Verne's creation.

UNDERWATER VISION

The reason that the submarine was the first application of controlled nuclear power is a tribute to the vision of another man, Admiral Hyman Rickover of the U.S. Navy. He was born in Russia in 1900, immigrated with his family to Chicago, and studied engineering in the Naval Academy class of 1922. After shipboard duty, he went to graduate school at Columbia University.Rickover studied diesel electric submarines and even translated Admiral Hermann Bauer's treatise on submarine warfare, Das Unterseeboot, from German into English.

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Rickover was assigned to General Electric in Schenectady, N.Y., where he observed advances in shipboard electrical and mechanical equipment, along with manufacturing processes, quality control, and corporate management. He attended Navy Submarine School, where he received his

dolphins, the badge of a submariner.Submarine duty was dirty and hazardous. The air was foul. A lurking danger was an explosion of hydrogen released by faulty batteries. Thomas Edison had developed higher-performance batteries for World War I submarines, but they were also more treacherous and led to some devastating accidents and loss of life. Rickover was serving on a submarine when a battery fire started. He responded by donning a gas mask and successfully smothering the fire.Rickover served three years on submarines and was disappointed not to become a skipper. His only command was a minesweeper.He was an inspector in the Philadelphia Naval Yard and served most of World War II in charge of the Electrical Section of the Bureau of Ships. He transferred to Okinawa in July 1945 to participate in the naval support for the invasion of Japan. The invasion did not happen. The atomic bombings of Hiroshima and Nagasaki in August were followed by Japan's unconditional surrender. Rickover's new job was mothballing ships.

NUCLEAR SCHOOLING

Meanwhile, the huge facilities and labs that had developed the atom bomb needed a new mission. In 1946, Rickover was invited to join other officers and industry people to learn about the atom at Oak Ridge.He concluded that the science and physics were well enough understood to develop a nuclear-powered submarine. He believed the project would be mostly a matter of solving engineering problems.He formed a team of smart and enthusiastic naval officers. They included Commander Louis Roddis, who had assisted in the postwar atom bomb tests on the Bikini Atoll, and Commander James Dunford, who had been Roddis's

classmate at the Naval Academy and at MIT. There was also Lieutenant Ray Dick, a metallurgical engineer from Ohio State, and Lieutenant Miles Libbey, a Naval Academy graduate.Rickover identified civilians, too, and recruited them to the team's shared living quarters. They included John Simpson, a rising manager at Westinghouse who had gone to the Naval Academy; Harry Stevens, an electrical engineer educated at Union College and working for General Electric, and Sid Simon, a materials engineer from the National Advisory Committee on Aeronautics.Rickover had each officer in the group write and present a definitive report on topics such as the effects of neutrons on materials, properties of beryllium, radiation sources, and shielding.Rickover was convinced that a nuclear-powered submarine was possible. His next step was to persuade others. He received the support of Edward Teller, who was arguing his own case for developing the hydrogen fusion bomb. It would be a thousand times more powerful than the fission bomb. Rickover also was encouraged by Ernest Lawrence, whose 1929 invention of the cyclotron allowed charged particles to penetrate the nucleus, to reveal a new understanding of its structure.

President Truman had signed the Atomic Energy Commission into existence in 1946. The purpose was to transfer the lead responsibility from the Army to a civilian agency. Rickover studied the legislation. He was assigned to the Division of Reactor Development with the new AEC, at the same time that he was director of naval reactors in the Bureau of Ships.There was a need for an industrial infrastructure and workable designs. The Electric Boat Co. would build the submarine. Westinghouse in Pittsburgh and

General Electric in Schenectady were to develop independent reactor and power plant designs. Westinghouse designed a pressurized water reactor that would power the *Nautilus*. General Electric would design a liquid metal sodium-cooled reactor that would power the second nuclear submarine, the *Seawolf*.An operating prototype of the *Nautilus* was built at Arco, Idaho, for testing, crew training, and a simulated Atlantic crossing. A prototype for the *Seawolf* was built near Schenectady at West Milton.Both the *Nautilus* and the *Seawolf* performed admirably during sea trials. The *Nautilus* traveled 62,000 miles, which is about 20,000 leagues, before its first refueling. The sodium-cooled *Seawolf* produced steam at a higher temperature, resulting in greater efficiency. It traveled 71,000 miles before it needed refueling. However, it had an inherent risk of chemical explosion in the form of a sodium and water reaction.Shielding was also more difficult with the sodium-cooled reactor. As a result, the pressurized water reactor would become the standard for the nuclear navy and for most civilian electric power plants.President Dwight Eisenhower was eager to show that the atom could also be harnessed for commercial purposes. He initiated an international Atoms for Peace Conference in Geneva in 1955 to explore the possibilities. It would also require declassifying some nuclear technology.Rickover got the task of building the world's first civilian nuclear power plant in Shippingport, Pa. It went on line in December 1957. The plant also would demonstrate the production of a new type of nuclear fuel. Excess neutrons from the chain reaction converted non-fissionable thorium, which is relatively abundant, into fissionable uranium 233, which does not occur in nature. ASME would designate the Shippingport

power station a Historical Mechanical Engineering Landmark in 1980.Meanwhile, the Soviet Union was becoming a nuclear power. The arms race was producing more and deadlier weapons. The Soviets tested a fission bomb in 1949 and a fusion hydrogen bomb in 1954. In October 1957, they launched the world's first orbiting satellite, which was called *Sputnik*. There were fears of the Soviets' launching nuclear weapons from space.Eisenhower needed to restore American prestige. A possibility was for the *Nautilus* to traverse the polar ice cap via the North Pole. It would be a secret and dangerous mission. The waters were uncharted and navigational instruments and techniques were unproven. After an initial failed attempt, the submarine succeeded in August 1958. The reaffirmation of United States superiority was celebrated with a tickertape parade for the crew in New York, while the *Nautilus* was escorted up the East River.

SUBS GO BALLISTIC

The historic mission of submarines was to control the seas by sinking enemy ships. The first American submarine was the one-man, human-powered, egg-shaped *Turtle*, built by David Bushnell in Connecticut. Its one mission in 1776 was to sink an anchored British ship in New York Harbor by attaching an explosive to the hull. The charge fell off before any damage was done.Robert Fulton built a submarine powered by humans and sails in 1795. He offered it to both the warring French and English. It was also called the *Nautilus*. A decade later, Fulton's steamboat would debut on the Hudson River. During the Civil War, Horace L. Hunley built a submarine for the Confederate Navy. In 1864, it used its lone torpedo to sink the Union ship *Housatonic*. Minutes

later, the *H.L. Hunley* was lost with its entire crew.The subsequent development of electric motors and rechargeable batteries, along with diesel engines and generators provided the technologies for the submarines of World War I and II. The chief capability of all these craft, through the first generation of nuclear-powered submarines, remained the sinking of ships.The ballistic missile submarines that were introduced in the 1960s would define the next phase of the Cold War. The first, the SSBN 598 *George Washington*, was launched in June 1959. It combined virtually unlimited range and elusiveness of nuclear power with missiles and nuclear warheads.The strategy for preserving the peace during the Cold War was deterrence by means of mutually assured destruction. The acronym was MAD. The Cuban Missile Crisis of 1962 started when the United States learned that the Soviet Union was deploying missiles in Cuba that could deliver nuclear warheads. After a tense standoff, the Soviets withdrew missiles from Cuba and the United States withdrew missiles from Turkey. The security that resulted from the deterrent capability of the newly deployed ballistic missile submarines may have made this agreement acceptable to both sides.

Rickover prided himself on his ability to recruit the best people for his staff and crews. The interviews were brutal and humiliating. Rickover judged the fitness of the candidates by their responses. Lieutenant James Carter was a 1947 Naval Academy graduate with aspirations to become the chief of naval operations. Carter judged the nuclear program could be a good career path. Rickover asked about his class standing. Carter proudly said he was

59th out of a class of 820. "Why not the best?" was Rickover's response.Carter had to admit he had not always done his best. He spent the next two years in the nuclear program. He was training crew members for the *Seawolf* and organizing courses at Union College. Rickover's question continued to haunt him. It became an epiphany that would redefine his life. Carter rethought his goals and left the Navy in 1953. He would use Rickover as a model for self-discipline and work ethic. Carter would run successfully for President of the United States in 1976. *Why Not the Best?* would be the title of his campaign autobiography.

FINAL CHAPTERS

Back in 1953, while the *Nautilus* was being constructed, Rickover's naval career appeared to be over. The Navy's promotion process was not favorable for an engineering duty officer. Nuclear power put Rickover even farther out of the promotion mainstream. He had been passed over twice. This normally meant involuntary discharge from the Navy. His career was rescued by his staff members' appealing to Congress. He was recognized as a special case, and was promoted to rear admiral. Another unprecedented action by Congress resulted in his promotion to the rank of full admiral in 1973.Rickover would submit a million words of testimony to the members of Congress, who funded the construction of about 200 more nuclear-powered submarines, cruisers, and aircraft carriers. A comparable number of nuclear-powered submarines were built by the Soviet Union. Several other countries have smaller fleets of nuclear-powered submarines.An accident occurred at the Three Mile Island power plant in Pennsylvania in 1979. There was major damage to the plant, but no deaths or

injuries occurred. A report blamed operator error. It noted that Rickover had developed the engineering codes, standards, and designs on which nearly all the world's reactors were based. It suggested that such an accident would not have happened if the civilian operators were trained to the same standards as Rickover trained shipboard nuclear operators.The lessons learned from Three Mile Island led to the creation of the Institute of Nuclear Plant Operations. Its mission was to upgrade the safety and performance of civilian nuclear power plants. Admiral Eugene Wilkinson, whom Rickover had selected to be the first commander of the *Nautilus*, was named the institute's first president.The Rickover Hall of Engineering at the Naval Academy had been named in his honor in 1973. President Jimmy Carter had continued to value his service. In 1982, the Secretary of the Navy persuaded President Ronald Reagan that it was time for Rickover to go. He was 82 years old and had 63 years of active duty. A new submarine was named in his honor. Admiral Rickover died in 1986. He is buried at Arlington Cemetery.The *Nautilus* was on active duty until 1979, and is now a National Historic Landmark. It can be visited along with the Submarine Force Museum. The museum, in Groton, Conn., is located next to the submarine base on the Thames River and near the Electric Boat Co., where the *Nautilus* was built.

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President Eisenhower gives the signal to start breaking ground for the Shippingport nuclear power station, now an ASME landmark.