Nuclear Submarines

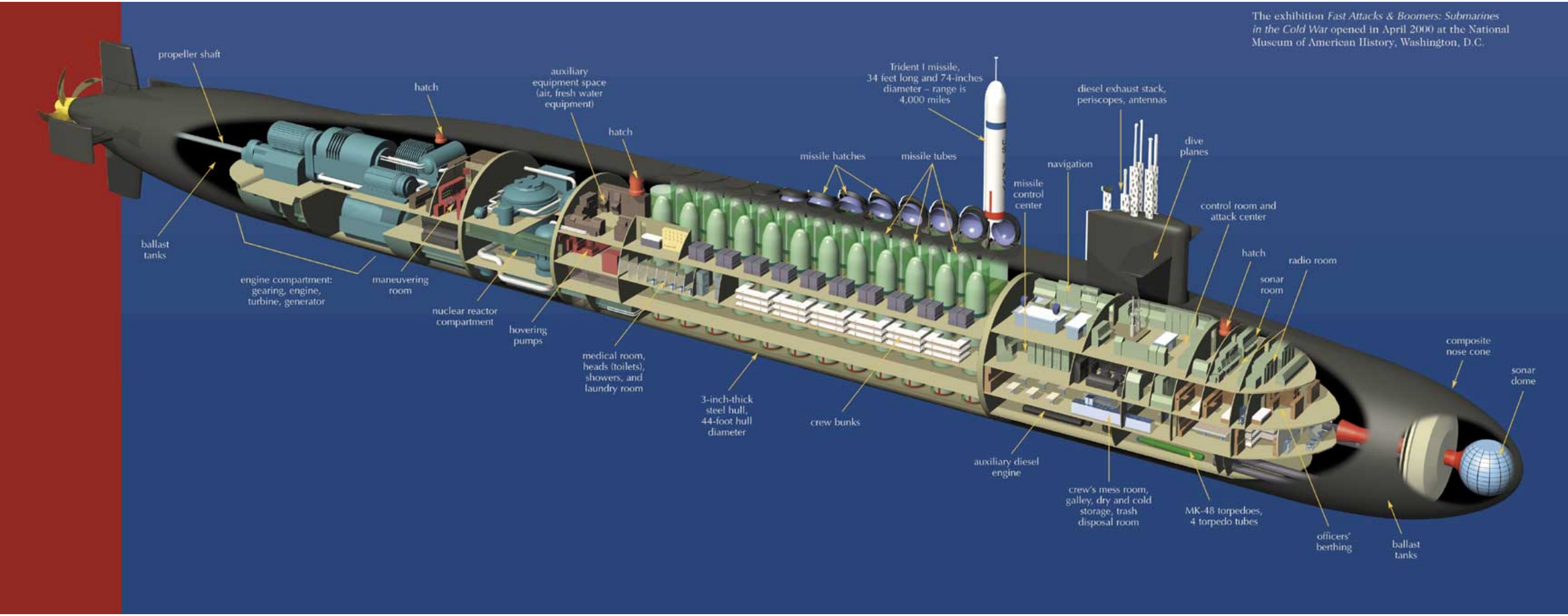
An overview (from the 1960s)

Agenda

- Submarine Overview
- Operations
- Submarine reactor plant overview
- Reactor plant controls
  - Control panel
  - Control Rods
  - Moderator
- The role of Admiral Rickover
- Safety components
  - Elements of training
- Other
  - Neutral Buoyancy
  - Atmosphere in the sub
  - Missile launch control

Operational information

- A typical Polaris sub patrol cycle was about 90 days, with alternating Blue and Gold crews.
  - Replacement crew flies to remote base. 28 days for a crew change-over, maintenance, supply parts, food and refresher training
  - 2 months submerged, traveling to assigned patrol locations
  - After change-over, the off crew returned to home base in the U.S. for training
- The reactor on the John Adams SSBN 620, a Polaris missile boat was rated at 93 megawatts
  - Commercial nuclear generating plants range in size from 600 to 1,100 megawatts
- The ship could achieve mid-twenty knots, submerged
- The design max operating depth was over 1,000 feet, but this was reduced after the Thresher sinking; in part because there was limited operational need.
- Because of the limited range of the Polaris missile, the subs operated from remote bases in Scotland, Spain, and Guam.
- With the advent of longer-range missiles, the boats now operate from the east coast of the U.S. and Hawaii or Guam.
- On patrol, the missile boats maintain continuous radio contact (listening only) with no outbound messages. Routine inbound messages convey patrol locations and routing to insure there is no other submarine traffic in the patrol area.



The exhibition *Fast Attacks & Boomers: Submarines in the Cold War* opened in April 2000 at the National Museum of American History, Washington, D.C.

Officers and Crew

- **Captain (usually a full Commander)**
- **Executive Officer (usually a Lt. Commander)**
- **Engineering Officer**
  - **Main Propulsion Assistant**
  - **Electrical and Reactor Control officer**
  - **Auxiliary Division Officer, ships Diving Officer**
- **Navigator**
  - **Assistant Navigator**
- **Communications Officer**
- **Sonar Officer**
- **Supply and Commissary Officer**
- **Weapons Officer**
  - **Assistant Weapons Officer**
- **Ship's Doctor**
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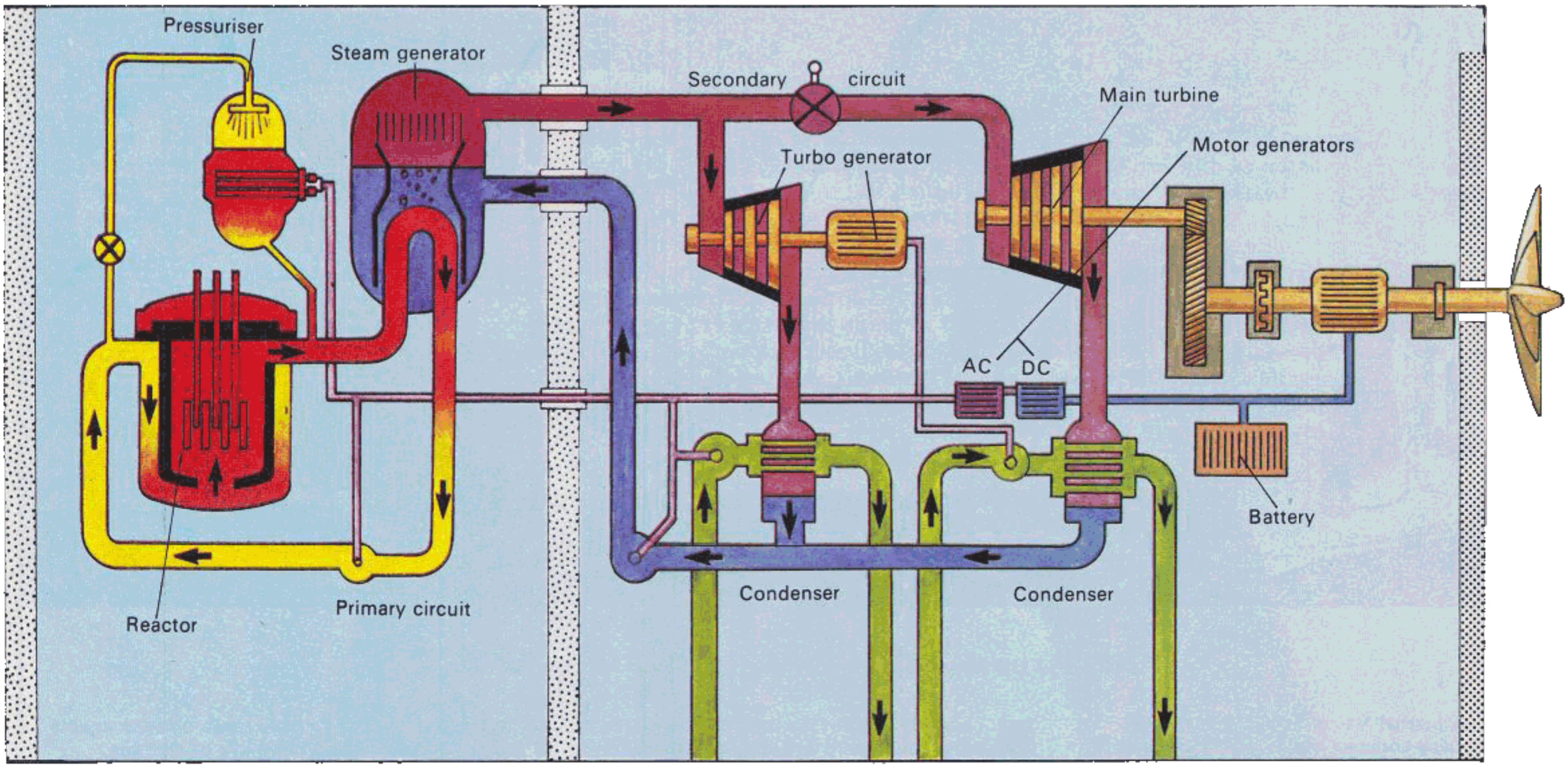
- **Crew: 7 Chief Petty Officers, 10 first-class petty officers, 99 other petty officers and seamen**



Pressuriser
Steam generator
Secondary
circuit
Main turbine
Motor generators
Turbo generator
AC
DC
Battery
Condenser
Condenser
Primary circuit
Reactor

Reactor Controls (control rods and moderator)

- There are two materials that control the power of a submarine reactor:

  - **A control rod** is a device that is used to absorb neutrons so that the nuclear chain reaction taking place within the **reactor** core can be slowed down or stopped completely by inserting the **rods;** or accelerated by removing them slightly. Their compositions includes chemical elements such as boron, cadmium, silver, or indium, that are capable of absorbing many neutrons without themselves fissioning.

  - When the reactor is shut down, the control rods are fully inserted, absorbing neutrons and preventing the fission chain reaction.

  - On start-up, the rods are raised slowly, gradually allowing the reactor to become "critical", the point at which the nuclear fission reaction is self sustaining, but at minimal power. Basically it is just sitting there awaiting a demand for power.

  - If something goes wrong, the reactor may be "SCRAMed" either automatically or manually, whereby the control rods are instantaneously inserted into the reactor core, completely stopping the chain reaction. The control rods are held out of the core electrically. They are spring-loaded to be fully inserted if electrical power is lost.

  - Under normal shutdown, the control rods are slowly inserted manually.

Reactor Controls (the moderator)

- Once the reactor is brought just “critical”, the control rods are only slightly adjusted to fine tune the reactor as it ages, using fuel, for example.

- The operational control of reactor power generation then falls to the “moderator”.
  - In a naval nuclear reactor the moderator is the “primary side” water that flows through the reactor.
  - Once the reactor is critical and at temperature, but not being called upon for power, the moderator takes control.
    - The way this works is quite amazing. When the main turbine throttle is opened (see the wheel a couple of slides ago), steam is drawn out and this causes the water temperature in the reactor core (the moderator) to fall, slightly.
    - With a slightly lower temperature, the water (moderator) becomes more-dense, reflecting more neutrons back into the reactor core, increasing the chain reaction and generating more power.
    - The dynamics are such that the reactor, generating more power, will raise the moderator water temperature back to it previous level, but the reactor will now be operating at a new higher steady state, equal to the power demanded by the main turbine throttle.
    - If the throttle is closed, the moderator temperature rises and the opposite occurs, all without any other reactor adjustments.

Admiral Rickover

- Chaim Godalia Rickover, a Polish Jew was born in 1900.
- At age 6, his family fled Russian' pogroms, arriving in NYC, and 2 years later, Chicago
- Congressman Adolph J. Sabath, a Czech Jewish immigrant nominated him for appointment to the Naval Academy (1918).
- Graduated 107 of 540 in 1923 and served impressively in destroyers, minesweepers and a battleship.
- 1930 - earned an MS in electrical engineering from Columbia University. ("Columbia was the first institution that encouraged me to think rather than memorize.")
- 1929-1933 served in submarines. Rickover translated *Das Unterseeboot* (*The Submarine*) by World War I German Imperial Navy Admiral Hermann Bauer. Rickover's translation became a basic text for the U.S. submarine service.[8]
- In WWII he served as head of the Electrical Section in the Bureau of Ships.
- 1945 he was assigned to work with General Electric at Schenectady, New York, to develop a nuclear propulsion plant for destroyers.
- He was the driving force for shifting the Navy's nuclear power focus from destroyers to submarines.

Admiral Rickover (continued -2-)

- Rickover’s nuclear submarine vision was not initially shared by his immediate superiors: he was recalled from Oak Ridge and assigned "advisory duties" with an office in an abandoned ladies' room in the Navy Building.

- He subsequently went around several layers of superior officers, and in 1947 went directly to the Chief of Naval Operations, Fleet Admiral Chester Nimitz, also a former submariner.

- Nimitz immediately understood the potential of nuclear propulsion in submarines and recommended the project to the Secretary of the Navy, John L. Sullivan.

- Sullivan's endorsement to build the world's first nuclear-powered vessel, USS *Nautilus*, later caused Rickover to state that Sullivan was "the true father of the Nuclear Navy."

Admiral Rickover – Congressional support

- **_Time_ magazine featured him on the cover of its January 11, 1954 issue. The accompanying article described his wartime service:**

  - **Sharp-tongued Hyman Rickover spurred his men to exhaustion, ripped through red tape, drove contractors into rages. He went on making enemies, but by the end of the war he had won the rank of captain. He had also won a reputation as a man _who gets things done._[12]**

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- **While his team and industry were completing construction of the world's first nuclear submarine, USS _Nautilus_ (SSN 571), Rickover was promoted to the rank of rear admiral, however this was anything but routine**

- **His peers in the Navy thought to get rid of him through failure of promotion above captain. This would entail automatic retirement at the thirty-year mark. But someone made the case to the U.S. Senate, charged by the Constitution with formal confirmation of military promotions. In 1953 the Senate failed to give its usual perfunctory approval of the Navy admiral promotion list.**

- **Without Senate approval nobody could be promoted. Ultimately an enlightened Secretary of the Navy, Robert B. Anderson, ordered a special selection board to sit and it did what it had been ordered to do.**

- **Ninety-five percent of Navy captains must retire regardless of how highly qualified because there are only vacancies for 5 percent of them to become admirals, and never before or since have pressures from outside the Navy overturned this form of career-termination."**

Rickover (continued -3-)

- Rickover was promoted to vice admiral in 1958, the same year that he was awarded the first of two Congressional Gold Medals.[ ]

- He exercised tight control for the next three decades over the ships, technology, and personnel of the nuclear Navy, interviewing and approving or denying every prospective officer being considered for a nuclear ship.

- Over the course of Rickover's career, these personal interviews numbered in the tens of thousands; over 14,000 interviews were with recent college-graduates alone.

- Regarding the quality of those selected into his program he responded to the comment "you managed to recruit an extraordinary group of people and bring them in." The admiral replied: "I did not recruit extraordinary people. I recruited people who had extraordinary potential—and then I trained them."[52]

- As head of Naval Reactors, Rickover's focus was dedicated to reactor safety rather than tactical or strategic submarine warfare training. This extreme focus was well known during Rickover's era as a potential hindrance to balancing operational priorities.

Rickover's Navy Career

- Rickover served in a flag rank for nearly 30 years (1953 to 1982), ending his career as a four-star admiral.
- His years of service exceeded that of each of the U.S. Navy's five-star fleet admirals—Leahy, King, Nimitz and Halsey—all of whom served on active duty for life after their appointments.
- Rickover's total of 63 years of active duty service make him the longest-serving naval officer, as well as the longest-serving member of the U.S armed forces in history.

Nuclear submarine safety record

- Rickover's stringent standards are largely credited with being responsible for the U.S. Navy's continuing record of zero reactor accidents He made it a point to be aboard during the initial sea trial of almost every nuclear submarine completing its new-construction period.

- Following the Three Mile Island accident, Rickover was asked why naval nuclear propulsion had succeeded in achieving a record of zero reactor-accidents, as opposed to the dramatic one that had just taken place. In his testimony, he said:

  - I am always chagrined at the tendency of people to expect that I have a simple, easy gimmick that makes my program function. Any successful program functions as an integrated whole of many factors. Trying to select one aspect as the key one will not work. Each element depends on all the others.

- The accident-free record of United States Navy reactor operations stands in stark contrast to those of the Soviet Union, which had fourteen known reactor accidents.

- U.S. submarines far outperformed the Soviet ones in the crucial area of stealth, and Rickover's obsessive fixation on safety and quality control gave the U.S. nuclear Navy a vastly superior safety record to the Soviet one.[66]

Elements of Safety

- Reactor design – fail safe design; backup emergency cooling system
- Redundancy: there were two of every critical system (except the reactor and the main turbine).
- State of the art metallurgy; every weld subject to 100% ultrasonic and liquid penetration testing.
  - At 1,000 feet depth, water pressure is 440 psi, or 63,000 pounds per square foot.
- Crew selection
- Extensive crew and officer training (see next slide)
- Very demanding at-sea graded operational reviews by Naval Reactors teams, testing knowledge, skills, casualty performance. Poor performance was career changing.
- On-going radiation monitoring. Every crew member wore a dosimeter, with 1/7th of the crew checked daily. Radiation sensors throughout the engineering spaces. Liquids from systems that interacted with the nuclear plant where checked daily.
- “Red tag” maintenance procedures rigidly enforced
- Highly effective sonar systems

Navy Nuclear Power Training

- Nuclear Power School curriculum – 6 months
  - Electrical engineering and electronics
  - Metallurgy
  - Nuclear physics
  - Reactor materials and design
- Nuclear prototype training – 6 months. (GE Knolls Atomic Power Laboratory, West Milton, NY).
  - Classroom and hands on training and operation of a nuclear submarine plant (S3G).
- Submarine School – New London, CT. – 6 months
  - Detailed systems knowledge
  - Operational simulators
  - Training cruises
  - Weapons and warfare tactics
- Qualification in submarines 3-6 months). Required for watch standing
  - Onboard research and training requiring detailed knowledge of all systems: electrical, hydraulic, hi-pressure air, mechanical, atmosphere
  - Operational procedures: surfacing, diving, battle stations, etc.
  - Damage control procedures

Neutral Buoyancy

- Submerged, a submarine must be neutrally buoyant, that is, it neither sinks or rises unless the crew takes action.
- The engineering to make this possible must be incredibly precise, comprehending the interior space, and the weight of all equipment, personnel, consumables, etc. inside the hull enclosure.
- And, things change.
  - Consumables are used and waste disposed overboard
  - With increased depth, the hull is compressed, reducing buoyancy; water temperature, salt content, the weight of weapons launched are factors that must be compensated;.
- The role of “negative”, a large internal tank capable of holding water.
  - When the sub dives, the vents on the outer hull are opened, flooding the outer hull and the sub will begin to submerge. At the same time, negative is flooded from sea to help the sub get down quickly.
  - When the desired depth is reached, the order “pump negative to the mark” is given by the Diving Officer, and just the right amount of water is pumped to sea to reduce weight and achieve neutral buoyancy.
  - The “mark” on the negative tank gage is initially set by pumping and flooding the tank when submerged. It can be adjusted as needed for changes in depth, water temperature, or other factors.

Submarine navigation

- In the ‘60s submarines navigated submerged using SINS (Submarine Inertial Navigations System).
- This is/was a computerized gyroscopic system that measured the submarine’s detailed movements and used this to continually project its position.
- The calculated position was corrected daily(?) by coming to periscope depth, raising the satellite tracking periscope and determining an exact position correction.
- The precise position data was used for navigation, and even more importantly, for missile targeting.

Internal atmosphere of a nuclear submarine

- After a week at sea, all illnesses disappeared, and none began. No flus, colds, respiratory infections, etc.

- This was in an environment with 140 men enclosed in a relatively small space at sea submerged for 2-3 months (most of whom smoked - $0.10/pack at the PX).

- Why?.............. The atmosphere was continuously replenished and cleaned.
  - Oxygen was generated by electrolysis of water (with the hydrogen pumped out to sea)
  - Carbon monoxide went thru burners converting it to carbon dioxide.
  - Carbon dioxide was scrubbed (passed thru a simple amine solution) and outed to sea.
  - Electronic precipitators caught tiny particles (cooking and cigarette smoke, etc.) and the particulate matter was periodically washed out and pumped overboard.
  - Finally, there were charcoal filters that absorbed other fumes.
  - All of this was built in line with the air circulation system, continually refreshing and purifying the air.

The reactor compartment

- The reactor compartment was located aft of the missile compartment and forward of the engineering spaces. It was about 45 long and filled the diameter of the ship.
- To get to the engineering spaces from the forward part of the ship, a person walked thru the “tunnel” from the Missile Compartment (aka “Sherwood Forest”) to the Auxiliary Machine Space (AMS).
- The tunnel was an elevated 10-foot diameter passage that crossed thru the reactor compartment. It had secure hatches at each end and included windows (very thick glass) so that the reactor and its various systems were visible from the tunnel.
- There was access to the Reactor Compartment thru a secured AMS hatch. This was only used at sea in the event of necessary maintenance or repairs to a coolant pump or other piece of reactor support equipment.

Launching nuclear missiles

- Unless the United States is actually under attack by a nuclear-capable adversary, the President can order nuclear strikes only in his capacity as a member of the two-man National Command Authority, the other member of which is the Secretary of Defense.

- Their joint decision must be transmitted to the Chairman of the Joint Chiefs of Staff, who will then direct the National Military Command Center to issue an Emergency Action Message to nuclear-capable forces.

Key developments in new submarines

- Trident missiles 4,000 mile range, multiple independently targetable nuclear warheads. (now limited by SALT and START)
- Other smaller missiles
- Comprehensive computer upgrades to all systems
- Precision GPS
- Upgrades of sonar
- Upgrades of sleuth technology
- Improved weapons.
- Increased patrol times, reducing the required number of boats
- New reactor designs designed to last the life of the boat (38 years) without refueling, eliminating major periods of overhaul, again reducing the number of required boats.