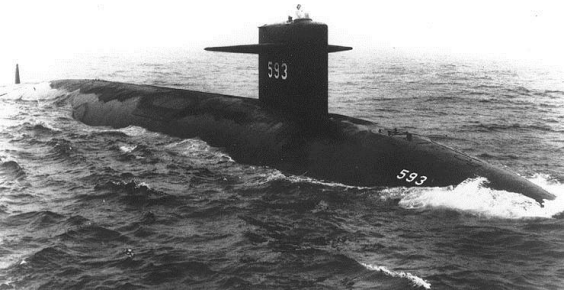
Photo # NH 97544 USS Thresher (SSN-593) underway, July 1961



Submarine Life and Submarine Safety

Photo # NH 97557 Upper rudder of the sunken USS Thresher, photographed by USNS Mizar, 1964

John D. Shaw

Disclaimer

This presentation does not represent the views of the Departments of Defense or Energy or Sandia National Laboratories

Agenda

1. Submarine types in the US Navy
2. John's boats, the submarine environment, and life on a submarine
3. Submarine design and operational safety, with a discussion of submarine losses

Types of US Submarines

Strategic Submarines

USS Ohio (SSBN 726) Class
Fleet Ballistic Missile Submarine
(18 constructed, 4 converted to SSGN)

565 ft. long, 19,700 tons, 42 ft. hull diameter, 155 crew

USS Ohio (SSBN 726) Class
Fleet Ballistic Missile Submarine

USS Ohio (SSBN 726) Class Fleet Ballistic Missile Submarine

SSBN Battle Readiness Test (BRT)

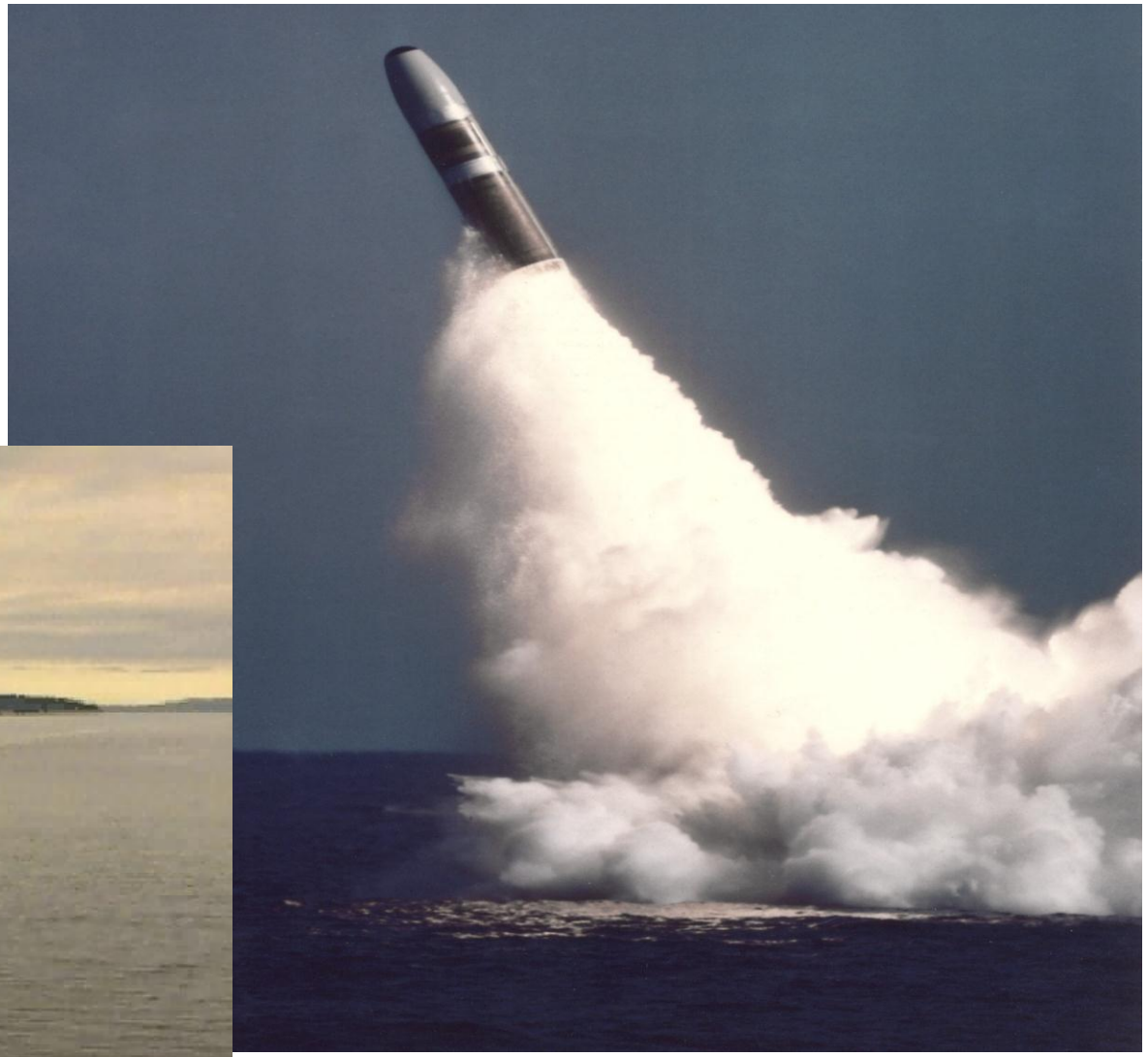
Trident D-5 Missile

FPU 1987
Still in production

130,000 lbs.

Up to 24 missiles/boat

Up to 8 warheads/missile



Trident D-5 Missile

Guided Missile/Special Forces Submarines

USS Ohio (SSGN 726), USS Michigan (SSGN 727), USS Florida (SSGN 728), USS Georgia (SSGN 729)

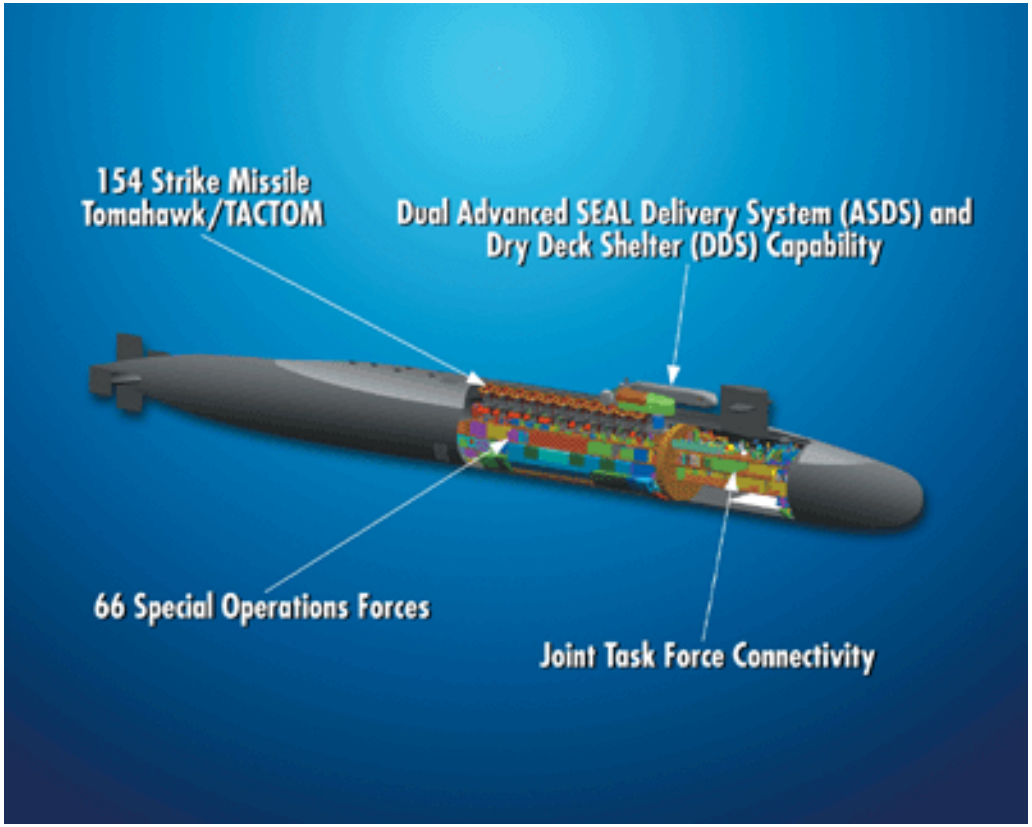
Two are based at Bangor, WA and two at King's Bay, GA. Ships operate out of Diego Garcia, BIOT.

Because of their complexity, the CO is a Captain (O-6), unlike attack or strategic submarines

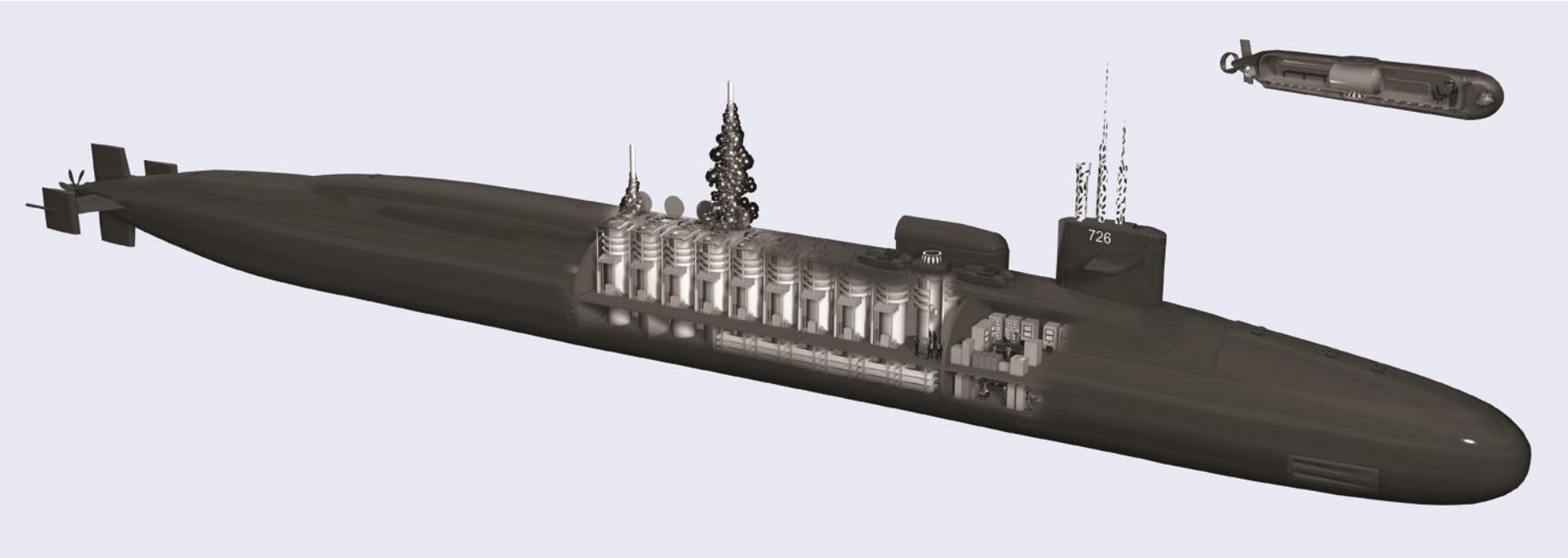
565 ft. long, 19,700 tons, 42 ft. hull diameter

159 crew + 66 SEALS = 225 total personnel aboard

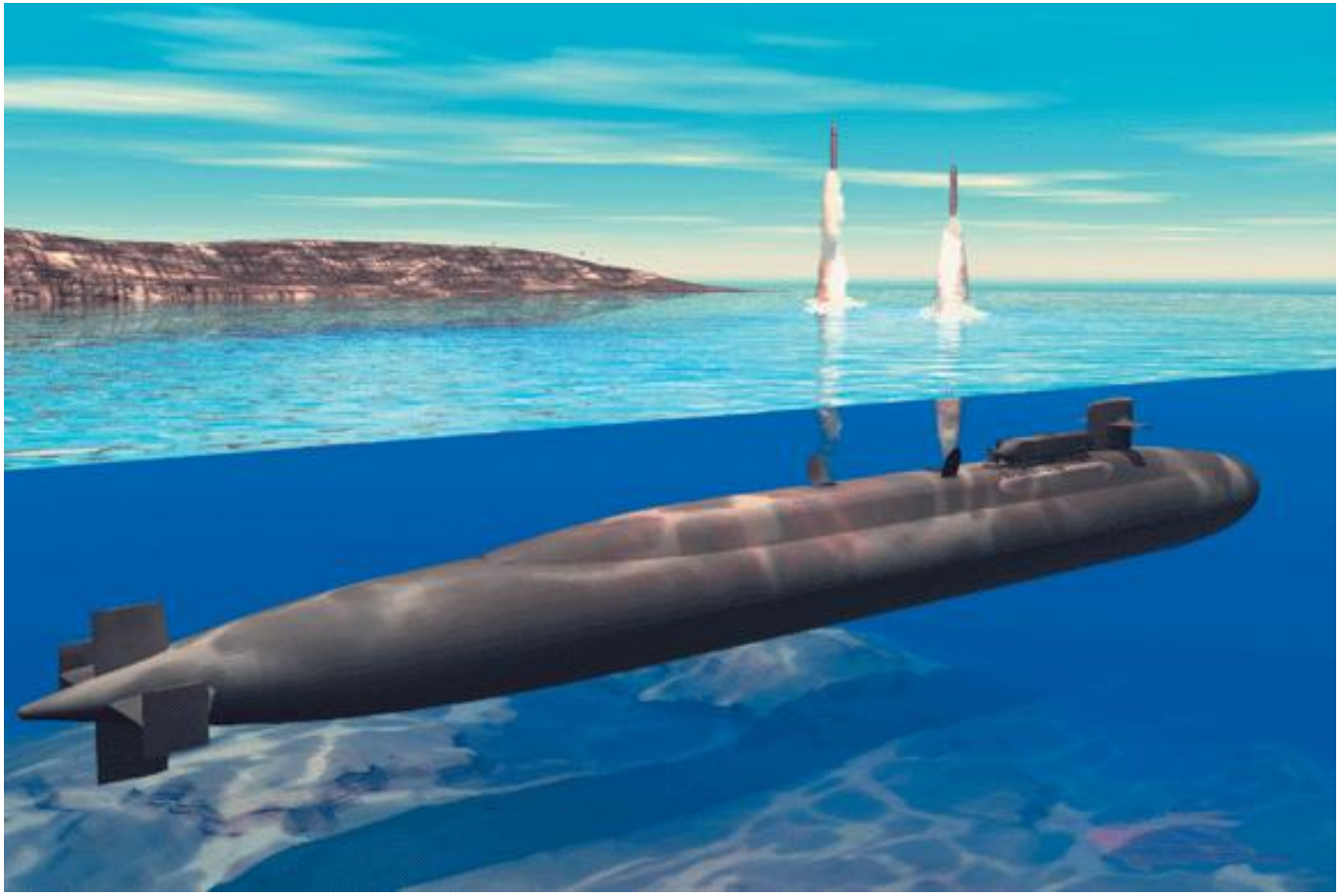
USS Ohio (SSGN 726), USS Michigan (SSGN 727), USS Florida (SSGN 728), USS Georgia (SSGN 729)



USS Ohio (SSGN726), USS Michigan (SSGN727), USS Florida (SSGN728), USS Georgia (SSGN729)

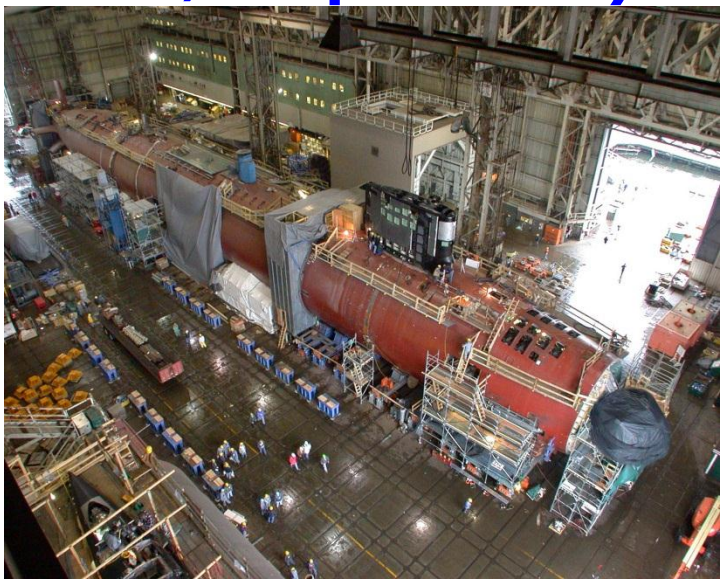


USS Ohio (SSGN726), USS Michigan (SSGN727), USS Florida (SSGN728), USS Georgia (SSGN729)



Attack Submarines

USS Virginia (SSN 774) Class
(7 in service, 2 nearing completion, 30 planned)

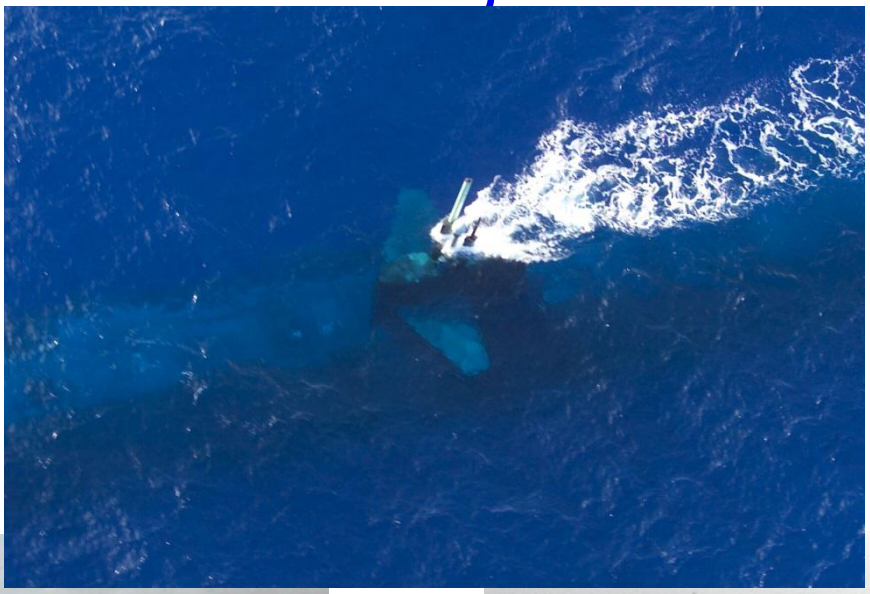


377 ft. long, 7,800 tons, 34 ft. hull diameter, 135 crew

USS Seawolf (SSN21), USS Connecticut (SSN22), USS Jimmy Carter (SSN23)

353 ft. long, 9,137 tons, 40 ft. hull diameter, 140 crew

USS Los Angeles (SSN 688) Class
(42 in commission, 20 deactivated)



365 ft. long, 6,900 tons, 33 ft. hull diameter, 129 - 165 crew

Research Submarine
(now decommissioned)

NR-1 (153 feet, wheels, windows, arms, crew of 10)

John’s Boats, The Submarine Environment, and Life on the Boat

John's Boats

USS Daniel Webster (SSBN 626)

USS Salt Lake City (SSN 716)

USS Thomas A. Edison (SSN 610)

USS Lafayette (SSBN 616)

USS Sam Houston (SSN 609)

The Submarine Environment

“As complex as space”
ADM Bruce DeMars

The Submarine Environment

- **Los Angeles Class Attack Submarine**
  - **Steel tube 365 feet long, 33 feet in diameter, 7,000 tons.**
  - **Doesn't float very well – 90% of ship is submerged when on the surface. Not designed for surfaced operations.**
  - **Atrocious sea - keeping on the surface.**
  - **Can't walk in a straight line more than about 20 feet.**
  - **Up to 165 people on board.**
  - **112 bunks, including 6 temporary bunks – each bunk slightly larger than a coffin. >100 people "hot bunk".**
  - **2/3 of the internal volume is the nuclear propulsion plant.**
  - **All people except 11 at any time are in 90 feet of the hull length.**
  - **Submerged for months in a corrosive ocean.**
  - **Makes its own atmosphere and water.**
  - **EVERYTHING MOVES!!!**
  - **One of only five programs in the military from which women have historically been excluded. Women officers started training in June 2010 and entered the fleet in December 2011.**
- **All in a fundamentally hostile environment.**

The Submarine Environment

- **Consider the hazards and resultant operational and safety issues**
  - **Nuclear propulsion plant.**
  - **High pressure steam.**
  - **Numerous sea-connected systems.**
  - **25,000 valves.**
  - **150 miles of pipes.**
  - **1500 miles of electrical cables and wires.**
  - **High voltage, high current electrical systems.**
  - **A lead-acid battery bigger than a tractor-trailer.**
  - **Electrolytic oxygen generators.**
  - **4500 psig air systems.**
  - **3000 psig oxygen, nitrogen, and hydraulic systems.**
  - **Many weapons containing high explosives and propellants.**
  - **Potential to carry nuclear weapons (SSBNs only).**
  - **Sonar systems that can produce up to very high db levels.**
  - **High power RF systems.**
  - **Modern submarines are quieter than the background of the ocean.**
  - **Drive your car with the windows covered, listening to the traffic.**

Why No Women in the Submarine Force Until 2011?

Inability to meet societal privacy standards for berthing and heads

Los Angeles Class example

- **Up to 165 total crew.**
- **CO/XO share a head with one toilet and one shower.**
- **13 other officers share a head with one toilet, one sink, and one shower.**
- **15 Chief Petty Officers share a head with one toilet, one sink, and one shower.**
- **21 man bunkroom shares a head with one toilet, one sink, and one shower.**
- **The remaining 114 crew, in Crews Berthing, share a head with three toilets, two showers, and four sinks.**

Rep. Patricia Schroeder (D-CO) & ADM Frank Kelso example.

Tridents can accommodate women, but career rotation nominally cannot be met. Women are currently stationed on the Tridents and a decision on attack submarine assignment will be deferred to the future because of the segregation of the sexes issue.

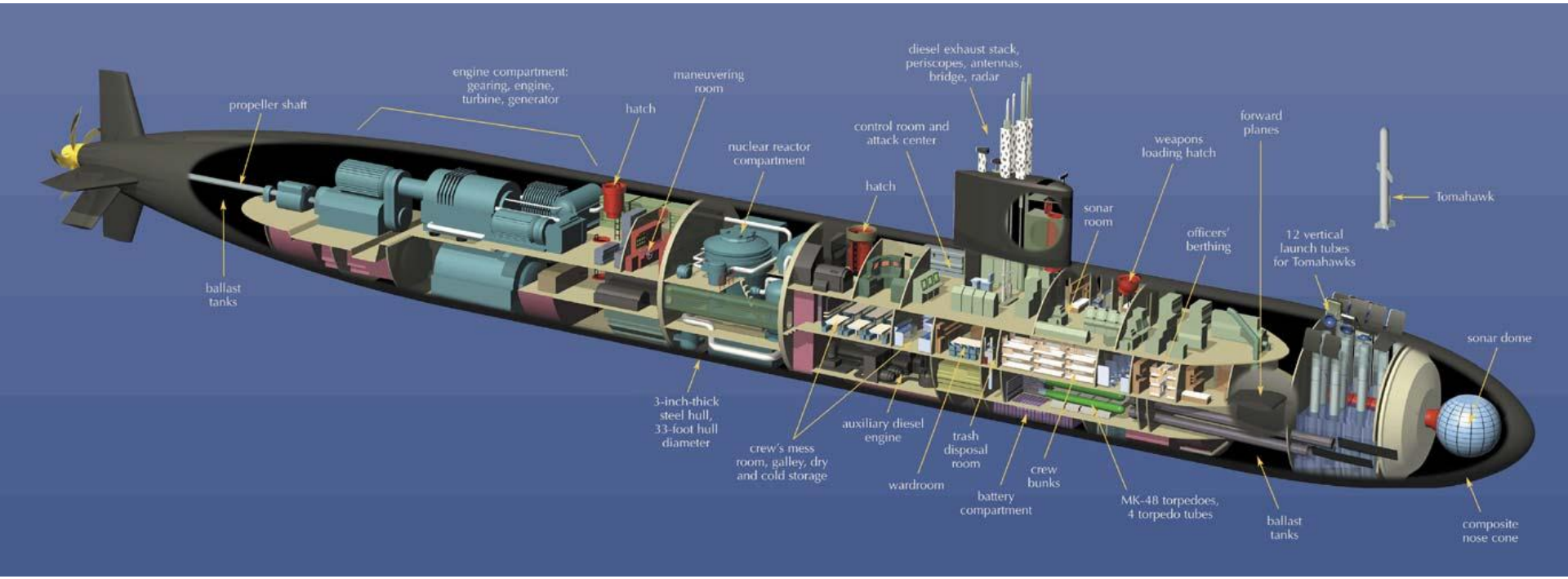
Initial assignment is two nuclear officers and an experienced supply officer.

DACOWITS has made an effort to require the Navy to design submarines for mixed - gender crew. Navy to date has refused, for design reasons.

What's it Like to Serve on a Nuclear Submarine?

- Four types of officers in the US Navy (tongue in cheek).
- Very highly educated and senior crew. (Example)
- Relationship between officers and enlisted personnel very different from all other areas of the military except for Special Forces.
- Everybody has to know how to do the basics of everybody else's job. (Submarine Qualification)
- When you're gone, you're gone! No phones, no email, no CNN.
- An 18 hour day. Lights are always off in the berthing spaces and always on everywhere else.
- Clocks set to Zulu time.
- Deployments up to 6 months, up to 90 days continually submerged.
- After the first week, nothing but canned and frozen food.
- When underway, only the officers ever see the light of day, and then only through a periscope.
- The 55 day phenomenon.
- Get underway and everybody gets sick for 10 days. Surface at the end of a run and everybody gets sick for 10 days.
- "Find a person's weakness and then exploit it. If they crack, they didn't belong here."

View of an Attack Submarine



The Submarine Environment – Life Aboard the Boat – the Control Room

The Submarine Environment – The Control Room (Again)

The Submarine Environment – Fire Control System

The Submarine Environment – Sonar – A “Flat Screen Mentality”

The Submarine Environment – The Crew's Mess

The Submarine Environment – The Longest Open Space

The Submarine Environment – The Torpedo Room

An Unusual Place To Go

USS Providence (SSN719) at the North Pole on the 50th Anniversary of USS Nautilus (SSN571) at the Pole

USS Seawolf (SSN21) at the North Pole

Friends?

More Friends?

Submarine Design and Operational Safety

U.S. Naval Nuclear Propulsion Program

1. ADM Rickover testified to Congress in 1953 that nuclear propulsion would not limit the operational and combat capabilities of the ships. This has guided the design, operation, and safety of naval plants since then.
2. Except for carrier plants, are at least an order of magnitude in power below commercial plants.
3. Almost all of the power goes to propulsion turbines. A small amount goes to turbine generators. On carriers, steam also goes to Special Frequency Turbine Generators, catapults and regeneration boilers.
4. Incredibly expensive, by rumor (Cost is the only piece of Secret info in NR and even the COs of the ships don't know it!).
5. Very high power densities as compared to commercial plants – lots of unusual and complex technologies to allow for very long core life.
6. As compared to commercial plants, capable of very rapid power changes.
7. As compared to commercial plants, capable of very rapid startups.
8. Cores last from 15-35 years. USS Virginia class will not require refueling.
9. Commercial plants are designed to make useful power and if anything goes wrong to shut down and remain safe. Naval plants are designed to make useful power, continue to operate safely under attack, and, if lost, to remain safe and retain fission products indefinitely. (>10e6 years)
10. Authorized visits in many ports in many countries. Russian nuclear ships have only visited China, India, Cuba and (the former) Warsaw Pact.


VFA-86
LTJG D.B. FREEMAN
"JIGGLES"
41

Basic Precepts

The nuclear submarine program and the Naval Reactors/Naval Nuclear Propulsion Program (NR/NNPP) (hereafter collectively referred to as NR) are inseparable. The way that NR/NNPP looks at safety is driven throughout all aspects of the submarine program.

Two major factors have influenced the unique approach to engineering in the submarine program:

1. **Admiral Rickover's approach to using nuclear power as a way to propel ships – with personal accountability given to Congress and no program legacy.**
2. **Only five people in charge of NR since 1947**
    - **Admiral Hyman Rickover**
    - **Admiral Kinnaird McKee**
    - **Admiral Bruce DeMars**
    - **Admiral Frank Bowman**
    - **Admiral Kirkland Donald**

Great information – www.NASA.gov then search for NNBE (NASA/Navy Benchmarking Exchange, Vols. 1, 2, 3.)

Naval vs. Commercial Plants

104 commercial plants in USA – no two are the same!

270 Naval plants (over the years, to date) as follows:

Submarines

- **S1W/S2W/S2Wa – prototype + 2**
- **S1G – 1**
- **S1C – prototype + 1**
- **S3G – prototype + 2 (USS Triton (SSN 586) had two plants)**
- **S3W/S4W – 5**
- **S5G – prototype + 1**
- **S5W – 98**
- **NR-1 – 1**
- **S6G – 62**
- **S6W - 3**
- **S7G – prototype only**
- **S8G – prototype + 18**
- **S9G – 8 operational to date; 30 planned**

Aircraft Carriers

- **A1W/A2W – 2 prototypes + 8 (USS Enterprise has 8 reactors)**
- **A4W – 24 (each carrier has two plants)**

Cruisers/Destroyers

- **C1W – 2 (USS Long Beach (CGN-9) had two plants)**
- **D1G – prototype + 24 (each cruiser had two plants)**

Basic Rules of Submarine Safety

"In the submarine environment . . . There is only one way to ensure safety: it must be embedded from the start in the equipment, the procedures, and most importantly, the people associated with the work."

"The only way to operate a nuclear power plant and indeed a nuclear industry – the only way to ensure safe operation, generation after generation, as we have – is to establish a system that ingrains in each person a total commitment to safety: a pervasive, enduring devotion to a culture of safety and environmental stewardship."

ADM Bowman

"One must create the ability in his staff to generate clear, forceful arguments for opposing viewpoints as well as for their own."

ADM Rickover

Failures and the Duties of Engineers

Failures – "the phantasmagoria that haunts the engineer's nights and dogs his days."

"The great liability of the engineer compared to men of other professions is that his works are out in the open where all can see them. His acts, step by step, are in hard substance. He cannot bury his mistakes in the grave like the doctors. He cannot argue them into thin air or blame the judge like the lawyers. He cannot, like the architects, cover his failures with trees and vines. He cannot, like the politicians, screen his shortcomings by blaming his opponents and hope the people will forget. The engineer simply cannot deny he did it. If his works do not work, he is damned."

Herbert Hoover, President of the United States

(The only Professional Engineer (Geologist and Mining Engineer) who has been President)

The Gospel According to HGR


Admiral Rickover
Inspecting USS Nautilus (SSN 571)

Responsibility is a Unique Concept

It can only reside and inhere in a single individual.

You may share it with others, but your portion is not diminished.

You may delegate it, but it is still with you.

You may disclaim it, but you cannot divest yourself of it.

Even if you do not recognize it or admit its presence, you cannot escape it.

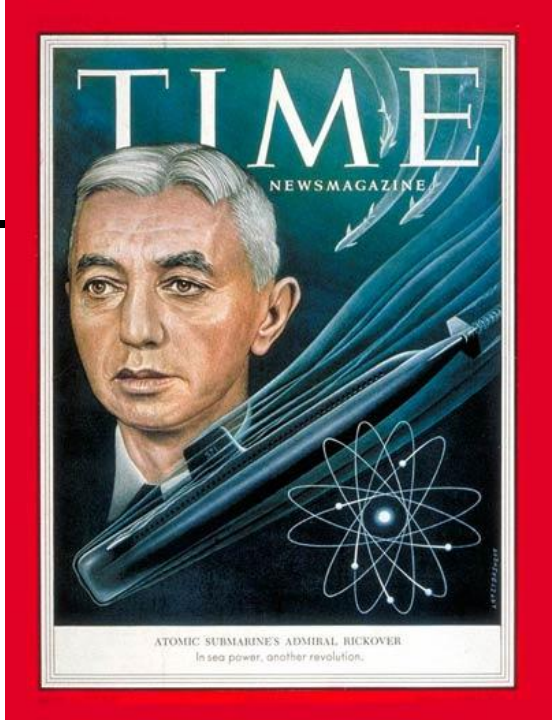
If responsibility if rightly yours, no evasion, or ignorance, or passing the blame can shift the burden to someone else.

Unless you can point your finger at the man who is responsible when something goes wrong, then you have never had anyone really responsible.

More of the Gospel

“My program is unique in the military service in this respect: You know the expression ‘from the womb to the tomb’ My organization is responsible for initiating the idea for a project; for doing the research, and the development; designing and building the equipment that goes into the ships; for the operations of the ship; for the selection of the officers and men who man the ship; for their education and training. In short, I am responsible for the ship throughout its life – from the very beginning to the very end.”

Even More of the Gospel



"In accepting responsibility for a job, a person must get directly involved. Every manager has a personal responsibility not only to find problems but to correct them. This responsibility comes before all other obligations, before personal ambition or comfort."

"When important decisions are not documented, one becomes dependent on individual memory, which is quickly lost as people leave or move to other jobs. In my work, it is important to be able to go back a number of years to determine the facts that were considered in arriving at a decision. This makes it easier to resolve new problems by putting them into proper perspective. It also minimizes the risk of repeating past mistakes. Moreover, if important communications and actions are not documented clearly, one can never be sure they were understood or even executed."

Implementation of HGR's Gospel

- Conservatism in design
- Quality in construction, maintenance, and repair
- Appropriate funding for R&D, construction, O&M
- Selection of personnel
- Processes and procedures
- Compliance with operational procedures
- Education, training, and qualification – with thorough knowledge for those instances when there are no procedures
- Personal accountability – "You bet your crow"
- The highest standards for integrity (example)
- Performance - AND compliance - based inspections

- The standards are the same for senior officers and junior enlisted people

Submarine Losses

United States

Combat Losses (WWII)	**41 submarines, 3044 crew lost**
Accidents/Perils of the Sea	**18 submarines, 765 crew lost**
Accidents without loss of boat	**17 submarines, 101 crew lost**

US Submarine Force had the highest casualty rate of any branch of the US Military in WWII. 33% death rate

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The WWII German Navy, by comparison

Combat Losses	**753 submarines**
Sunk along side piers	**350 submarines**

75% of all WWII German submariners died in the conflict. Of the German submarine officers on duty at the beginning of WWII, 97% were dead by the end of the war.

The United Kingdom has lost 171 submarines since 1904.

Russia has lost 5 – 10 nuclear and at least 3 conventional submarines from 1960 to the present, with at least 12 others having major casualties, including numerous reactor accidents.

Examples

USS Thresher (SSN 593) Loss – 10 April 1963
USS Scorpion (SSN 589) Loss – 2 June 1968
USS Guitarro (SSN 665) Sinking - 15 May 1969
USS Tautog (SSN 639) Collision – June 20, 1970
USS Baton Rouge (SSN 689) Collision – 11 February 1992
USS Thomas Edison (SSN 610) Collision – 29 November 1992
USS Greenville (SSN 772) Collision – 9 February 2001
USS San Francisco (SSN 711) Grounding – 16 May 2005
USS Minneapolis-St. Paul (SSN 708) Crew Deaths – 29 Dec 2006
USS Newport News (SSN 750) Collision – 10 Jan 2007
USS Hartford (SSN 768) Collision – 29 March 2009

Echo II K22 Collision – 28 Aug 1977
Komsomolets K278 Loss – 07 April 1989
Kursk K141 Loss – 13 August 2000
K159 Loss – 30 Aug 2003
HMS Vanguard and Le Triomphant collision – 3 – 4 March 2009

Related Problems
Loss of Challenger – 28 January 1986
Loss of Columbia – 01 February 2003

USS Thresher (SSN 593)

Thresher sank on sea trials from Portsmouth Naval Shipyard, about 220 miles off Cape Cod, MA, 10 April 1963. 129 perished. Cause was flooding followed by inability to blow main ballast due to freezing of the lines. It took 8.5 minutes for the ship to slowly descend to collapse depth. Thresher rests in 8,800 feet of water.

This was a watershed event in US submarining.

Photo # NH 91424-KN Insignia of USS Thresher (SSN-593), adopted in 1960

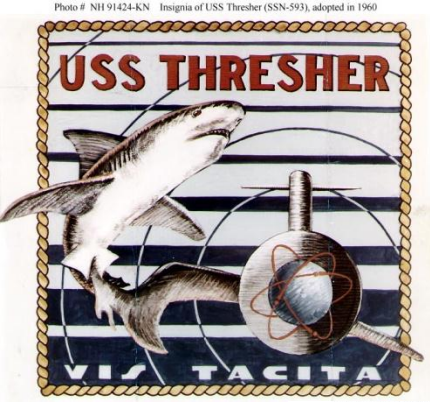


Photo # NH 97560 Mosiac of sail and other debris of sunken USS Thresher

Photo # NH 97562 Sonar dome wreckage from USS Thresher, seen from bathyscaph Trieste, 1963

Photo # NH 97557 Upper rudder of the sunken USS Thresher, photographed by USNS Mizar, 1964

USS Scorpion (SSN 589)

Scorpion, returning home from deployment, sank 2 June 1968 about 400 miles from the Azores, in 10,000 feet of water. 99 perished. The cause is believed to be a torpedo hot run from inadvertent battery activation. Much later, it was revealed that Naval Undersea Warfare Engineering Station was aware of the underlying problem, which could lead to inadvertent battery activation.

Photo # NH 97221-KN Stern section of sunken USS Scorpion, 1986

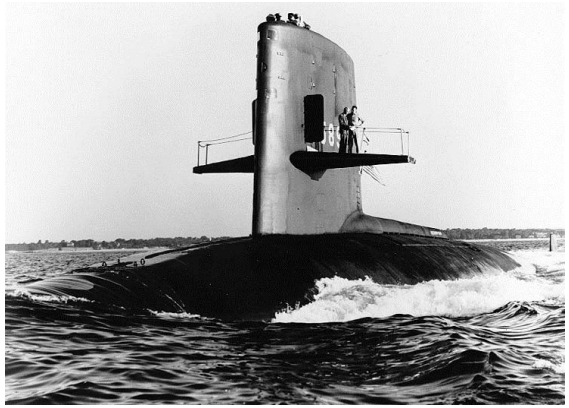


Photo # NH 70305 USS Scorpion comes alongside USS Tallahatchie County, April 1968

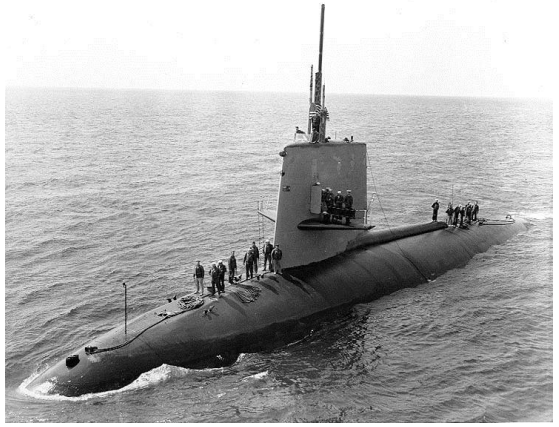
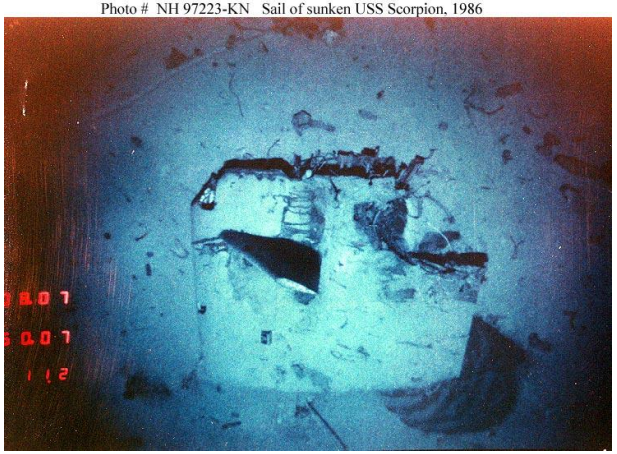
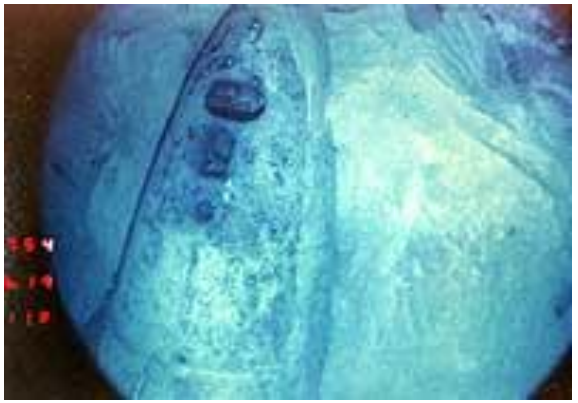


Photo # NH 97222-KN Distorted hull section of sunken USS Scorpion, 1986

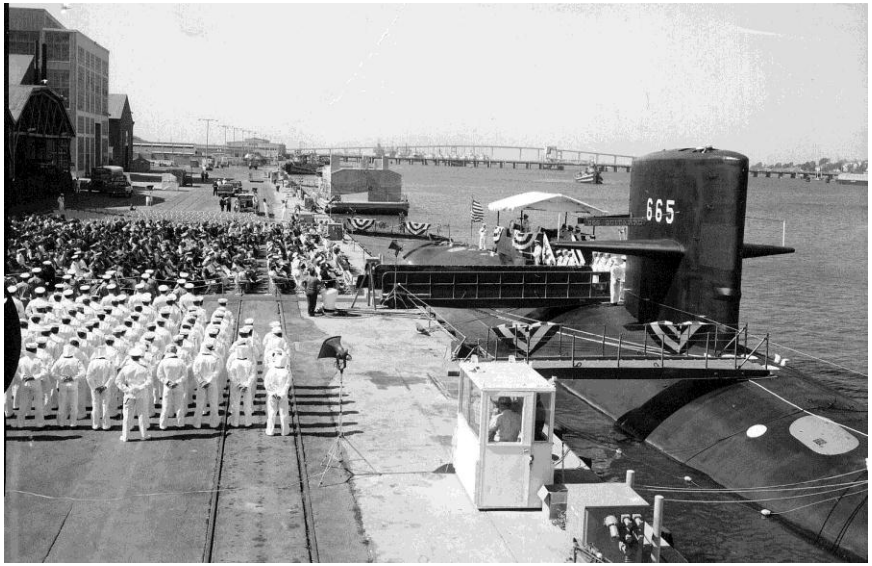
Photo # NH 97223-KN Sail of sunken USS Scorpion, 1986





USS Guitarro (SSN 665)

Guitarro sank alongside the pier in new construction at Mare Island Naval Shipyard, Vallejo, CA 15 May 1969. This was a watershed event in the shipyard business.

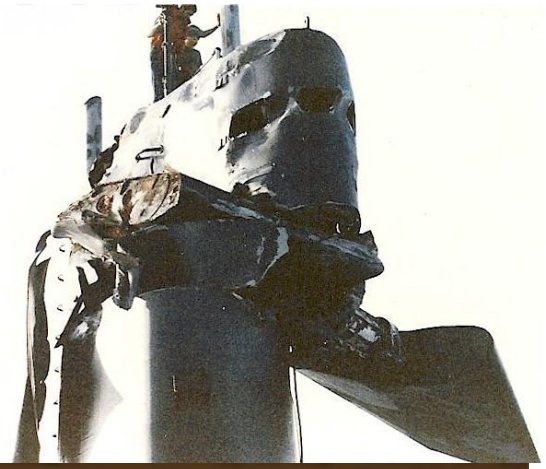


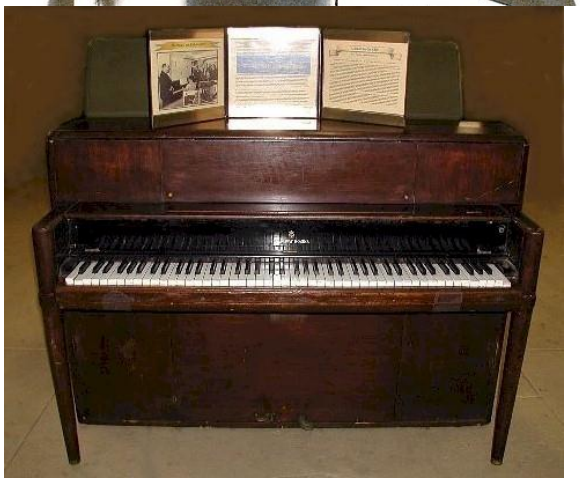
USS Tautog (SSN-639) vs. K-108

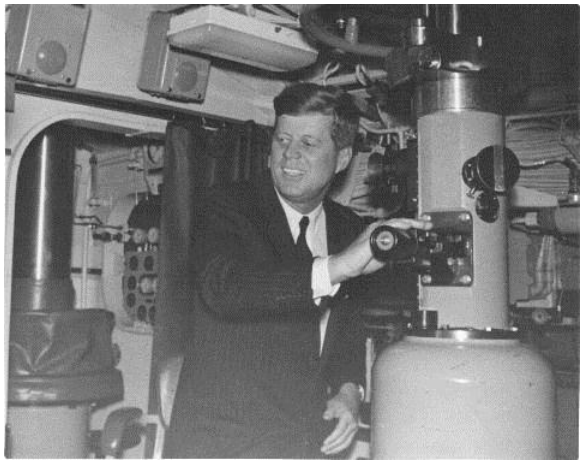
On June 20, 1970, Tautog collided with Soviet Echo I Class submarine K-108, *Black Lila* off Petropavlovsk-Kamchatsky. Both ships were significantly damaged but returned safely to port. The incident was not acknowledged until after the Cold War, when Capt. Boris Bagdasaryan (Soviet Navy, ret.) who commanded *Black Lila* at the time of the incident, described it in detail. The accident was subsequently acknowledged and was described in detail in "Blind Man's Bluff".

The root cause of the accident was not understanding the consequences of ship's sound signatures being much lower than the capability of the sonar systems to detect.

USS Thomas Edison (SSN 610) vs. USS Leftwich





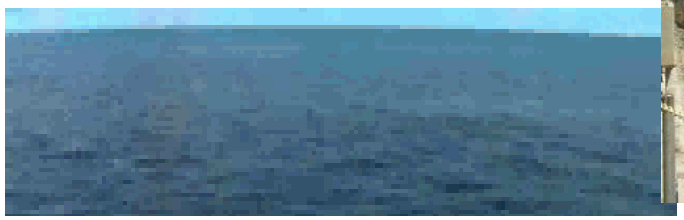


29 November 1982, Thomas A. Edison collided with USS Leftwich (DD 984) when coming to periscope depth. She was decommissioned thereafter. This emphasized the perils of treating all submarines as alike, regardless of the sophistication of their sensor suites.

USS Baton Rouge (SSN 689) vs. Tula (K239)

11 February 1992, Baton Rouge collided with the Russian Sierra (Barrakuda) Class nuclear submarine Tula (K-239) in the Barents Sea near Severomorsk. Baton Rouge suffered only minor damage and was decommissioned in 1995 as scheduled. Tula has remained in a drydock to this date. When details became known, this precipitated a major diplomatic confrontation between newly inaugurated President Clinton and the Russian Government.

USS Greenville (SSN 772) vs. MV Ehime Maru



USS Greenville collided with Ehime Maru 9 Feb 2001 off Diamond Head, HI, during an emergency surfacing evolution conducted for VIP riders. Nine Japanese students died and the Ehime Maru was sunk. The US and the Commanding Officer (CO) of the Greenville issued formal apologies to the Japanese government and the families of the deceased. The CO was relieved for cause.

USS San Francisco (SSN 711)

16 May 2005 USS San Francisco grounded on a sea mount about 400 miles from Guam. Weaknesses in track preparation and failure to understand the fathometer readings were the proximate causes. The ship decelerated from maximum speed to stopped in 4 seconds. One crewman died and most were injured. The ship was so heavily damaged that the front end of the ship was replaced with that of the decommissioned USS Honolulu at a cost of over $400 million. The CO was relieved for cause.

USS Minneapolis-St. Paul (SSN 708)

USS Minneapolis-St. Paul (SSN 708) departed Plymouth UK on 29 Dec 2006. The seas were heavy, a storm was in progress, and winds were up to 47 kt. Four crewmembers were washed overboard. Two were rescued by accompanying dinghies. Two crew members died from hitting their heads on the hull. As noted in a news account of the accident: "*Since small dinghies operated well enough in waters rough to recover four submariners, it should be evident that deckhanding on submarines is akin to logrolling. A submarine on the surface is essentially a large log with a rudder that often loses steerage in rough conditions. This hazard has been well known to* submariners for at least the last century." The CO was relieved for cause.

USS Newport News (SSN 750) vs. VLCC Mogikawa

On 09 Jan 2007, USS Newport News collided with the Japanese VLCC Mogikawa in the straits of Hormuz. No personnel were injured. Newport News proceeded to Bahrain and then to home port in Norfolk, VA on the surface. Mogikawa underwent repairs in Bahrain. The CO of Newport News was relieved for cause.

HMS Vanguard vs. Le Triomphant

On the night of 03 – 04 March 2009, HMS Vanguard and Le Triomphant, strategic missile submarines of the United Kingdom and France, collided in the Atlantic Ocean. There were no fatalities or serious injuries. Both ships were reported to have sustained minor damage (scrapes and dents to the Vanguard, extensive damage to the sonar dome of the LeTriomphant) and proceeded under their own power to their home ports of Faslane, Scotland and Brest, France.

USS Hartford (SSN 768) vs. USS New Orleans (LPD 18)

On 20 March 2009, USS Hartford collided with USS New Orleans while ascending to periscope depth in the Straits of Hormuz. 15 sailors on Hartford were slightly injured. There were no injuries amongst the 1000 sailors and Marines on New Orleans. 25,000 gallons of diesel fuel were spilled from the New Orleans. Both ships proceeded to Bahrain for evaluation. Hartford returned to the US on the surface and was repaired at a cost of more than $100 million. The CO was relieved for cause.

Echo II K-22 vs. USS Voge (FF-1074)

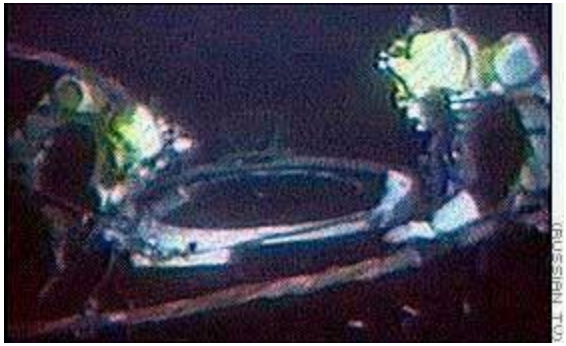
On August 28, 1977, Echo II SSGN K-22 collided with the USS Voge (FF-1047) in the Mediterranean Sea, and both ships were seriously damaged. *K-22* had damage to missile container No. 1, extension devices and the sail structure, and went to Kitira in the Aegean Sea for repairs. The American frigate was damaged at the stern, and had to be towed to Crete and from there to Toulon, France, where she was drydocked for repairs.

The cause of the accident was the Russian submarine, operating partially submerged, unexpectedly turning directly toward Voge and increasing speed. The submarine collided with Voge at 17 knots, in what the US 6th Fleet called a game of "Chicken of the Sea." This incident resulted in formation of a US/USSR committee to develop ways to prevent this sort of activity.

Komsomolets K-278

Komsomolets K-278, Project 685 (Mike Class) sank 07 April 1989 after a fire. The ship surfaced after 11 minutes but the crew was unable to stop the fires after several hours of effort. 42 of 69 crew members perished, most of hypothermia in the 36 degree water. The ship is in water a mile deep.

Kursk K-141

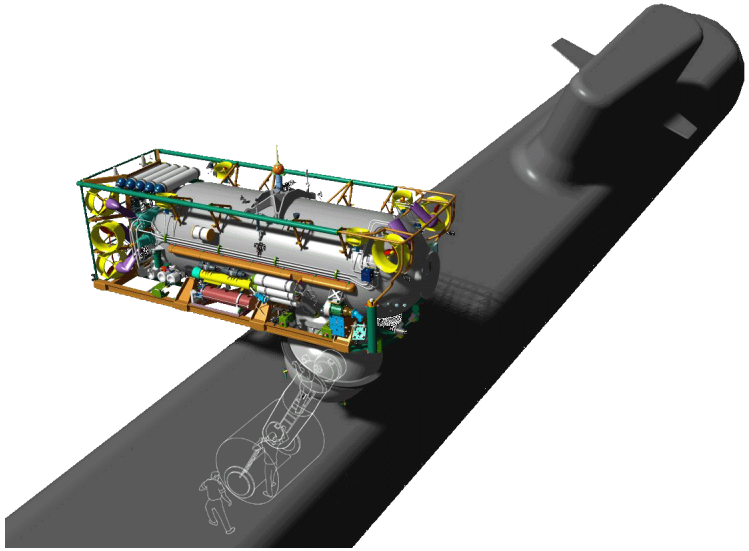


Kursk K141, Antyey Type 919 (Oscar II SSGN) sank on 13 August 2000 in the Barents Sea 100 miles from Murmansk in 300 feet of water due to a torpedo explosion . All 118 crew members died. 23 survived the initial explosion and subsequently perished from cold and CO_2 buildup. The ship was raised and taken to port where it was partially dismantled.

K-159

K-159 was being towed from Gremikha Naval Base, Murmansk, to Polyarny shipyard, Kola Peninsula for dismantling and sank about 0300 30 August 2003. Nine of the 10 crew were lost. The ship sank with the core intact in the reactor vessel. Radiation surveys in the vicinity are normal. Reactor accidents have occurred on several other Russian submarines, including K-3, K-8, K-11, K27, K-123, K-140, K-192, K-222, K-314, K329, K-431, and the Soviet Union's first strategic submarine, K-19. Reactor accidents also occurred on some nuclear surface ships, such as the Icebreaker Lenin.

Submarine Rescue Program



The SRP program is based at NAS North Island, CA. For 40 years it consisted of DSRVs Mystic and Avalon and was deployable to any location world-wide within 24 hours by USAF aircraft, which are on continuous alert. Successive administrations proposed terminating the program.

The DSRV program was deactivated on 09 March 2009 and replaced by the Submarine Rescue Diving and Recompression System (SRDRS)

The concepts of low probability, high consequence accidents are frequently misunderstood, including by politicians.

Some Program Changes From Casualties

- Diesel engines versus gasoline
- Battery ventilation systems with explosion - proof fans
- Messenger buoys to help find submarines lost on sea trials
- Changes in torpedo design after warshot failures in WWII
- Atmosphere monitoring and control systems
- Momsen lung and McCann (really Momsen) submarine rescue bell
- Emergency breathing systems
- Multiple, redundant safety systems
- Submarine Rescue Program (this program has been made available to other countries – only Russia, the PRC, and the DPRK have declined)
- Submarine Safety Program following loss of USS Thresher (SUBSAFE)
  - A complete redesign and re-engineering of nuclear submarines
  - Entire fleet Limited in Depth until all SUBSAFE requirements were met
  - Flood control and emergency ballast blow systems
  - Submarine Safety Certification Boundary Book (SSCB)
  - Material Control Standards
  - Nuclear propulsion plant equivalent QA throughout the hull integrity envelope
- Manual for Control of Testing and Ship Conditions and stringent watertight integrity controls following sinking of USS Guitarro
- Changes in weapon design following loss of USS Scorpion

Relationship between NASA and Submarine/Naval Reactors Programs

- Navy study of Challenger disaster revealed significant differences between Navy and NASA safety cultures
- NASA/Navy Benchmarking Exchange (NNBE) study from 2002 – 2004
- NASA identified key attributes of the submarine/NR safety programs
  - Safety requirements documented and achievable with minimum waivers
  - Requirements implemented through controlled processes
  - Compliance is independently verified
  - Strong safety culture with emphasis on understanding and learning from the past
  - Centralized technical authority and large operational experience base
  - NR has total programmatic and safety responsibility for all aspects of naval nuclear propulsion plants (NNPP)
  - NR is a flat organization with wide access to the Director
  - The safety and QA processes are totally embedded so that no separate offices are needed.
  - Critical programmatic decisions require concurrence of all related people
  - The airing of diverse and differing opinions is promoted.
  - An institutionally - embedded Lessons Learned process based on 5400 reactor-years of operational experience
  - NR relies on recruiting, training, and retaining highly qualified people who are held personally accountable and responsible for safety.

Embedding this level of a safety culture into NASA will not be easy.

Backup

The Difference between the Army and the Navy

Line of Sight Anti-Tank Weapon (LOSAT)