EFFECTS OF THE USS THRESHER DISASTER UPON SUBMARINE SAFETY AND DEEP-SUBMERGENCE CAPABILITIES IN THE UNITED STATES NAVY

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(ABSTRACT)

The loss of the nuclear-powered submarine USS Thresher (SSN 593) acted as a catalyst that accelerated improvements in submarine design, construction and operations. Such improvements resulted in a substantially safer submarine force, thereby making it more operationally reliable. The disaster also dramatically increased the influence of Admiral Hyman G. Rickover in submarine development by giving him the opportunity to promote the system of management he used as head of the U.S. Navy's Nuclear Propulsion Branch. During Congressional hearings on the loss of the Thresher, Rickover convinced members of the Joint Committee on Atomic Energy that his management system, based upon stringent standards of quality control and principles of engineering, was the standard that should be applied to submarine development. The disaster also highlighted the need for greatly improved deep-submergence capabilities within the fleet. Subsequently, deep-ocean search, location and recovery assets were developed, as well as improved deep-sea rescue capabilities.

ACKNOWLEDGEMENTS

A substantial part of my thesis is based upon interviews of individuals who were intrinsically involved with the Thresher disaster, or involved with the U.S. submarine force since 1940. I offer my greatest thanks to the following persons for their time and assistance: The Honorable Fred Korth, former Secretary of the Navy; Vice Admiral Marmaduke Bayne, USN (ret.); Rear Admiral Dean Axene, USN (ret.); Rear Admiral John Mooney, Jr., USN; Captain William Anderson, USN (ret.); Captain Frank Andrews, USN (ret.); Captain Edward Beach, USN (ret.); Captain John L. Byron, USN; and Dr. John Craven. I also thank the following persons who helped me with their knowledge and experience: Tom Allen, Dave Baker, Tom Clancy, Norman Friedman, Barbara Lynch, Patty Maddocks, Norman Polmar, Fred Rainbow, Ray Robinson, Paul Stilwell, Rear Admiral William Thompson, USN (ret.), John Vajda and Milan Vego.

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"Indeed, failures appear to be inevitable in the wake of prolonged success, which encourages lower margins of safety. Failures in turn lead to greater safety margins and, hence, new periods of success."

--Henry Petroski

INTRODUCTION: THE WORST SUBMARINE DISASTER IN HISTORY

The loss of the nuclear-powered attack submarine USS _Thresher_ (SSN 593) on April 10, 1963 was the worst submarine disaster in world history. When the ship sank about 220 miles east of Cape Cod at a depth of more than 8,000 feet, it carried one hundred twenty-nine crew members, other naval personnel, and civilian observers to their deaths. A specific cause for the submarine's loss has never been established.

Ultimately, the Navy benefited from the _Thresher_'s loss because the disaster acted as a catalyst in requiring increased quality control for nuclear submarine construction, thereby making the U. S. submarine force more operationally reliable. The margin of safety in submarine operations was increased through the improvement of procedures, training and equipment. In addition, the _Thresher_'s loss resulted in the development of deep-sea rescue and deep-submergence capabilities within the fleet.

When the ship went down with all hands, the U. S. nuclear submarine force was barely eight years old, having been bornJanuary 17, 1955, when the world's first nuclear-powered submarine, the USS _Nautilus_ (SSN 571), became fully operational. The mysterious sinking of the _Thresher_ was especially distressing since it was the first in a new class of submarines designed to engage in anti-submarine warfare, _i.e._, destroying enemy submarines in underwater combat. The _Thresher_ class was a hybrid of two earlier submarine concepts, embodied in the _Skipjack_ (SSN 585) and _Tullibee_ (SSN 597) designs. It incorporated the best available weapon systems, sonar equipment, noise-reduction characteristics, and could operate at a substantially deeper depth than its predecessors. Quite arguably, the *Thresher* was the most powerful undersea weapons system then in existence.

Designed and constructed at the Portsmouth Naval Shipyard, the *Thresher* was commissioned on August 3, 1961. Its hull displaced 4,300 tons submerged and measured 278 feet in length. The ship carried the new and more powerful AN/BQQ-2 sonar suite and was powered by a Westinghouse S5W nuclear reactor which drove a single propeller by means of a steam turbine. The submarine's top speed was rated at more than 30 knots.[1] In unclassified sources, the *Thresher*'s maximum operating depth, or test depth, is estimated to have been between 800 and 1,300 feet.

The agony caused by the *Thresher* loss within the naval community was not only an emotional response to the death of shipmates; it was born of national security concerns as well. Since the late 1950s, the Soviets had accelerated their submarine production, putting several new classes of diesel and nuclear boats into service: the "Hotel" and "Golf" ballistic missile submarines; the "Juliett" and "Echo" guided-missile submarines; the "November" and "Foxtrot" attack submarines, as well as development of the revolutionary "Alfa"-class nuclear attack submarine.[2] Against this growing Soviet undersea threat, the U.S. Navy intended to produce "hunter-killer" submarines, of which the *Thresher* was the first. With their improved speed, diving capabilities, sonar and silencing technology, the Navy leadership believed these submarines would hold their own in undersea combat against numerically superior, but technologically inferior, opponents.

When the *Thresher* sank, the Cuban Missile Crisis was not yet six months in the past. Superior U.S. naval forces had turned back Soviet merchantmen attempting to deliver ballistic missiles and their launchers to Cuba. Despite its submarine buildup, the Soviet Union had not marshaled sufficient sea power in the Caribbean to challenge the U.S. blockade, and Soviet Deputy Foreign Minister V.V. Kuznetsov vowed "never to be caught like that again."[3] As a result, the Soviets restructured their economy to support a larger effort in military production, with emphasis placed on strengthening the Soviet Navy, "for naval forces could help to counter the U.S. Navy's Polaris submarines, could help to redress the 'missile gap' that existed in favor of the United States, and might make future incursions into the Third World more successful."[4] In the spring of 1963, just as Admiral Sergei Gorshkov, head of the Soviet Navy, prepared to lead his fleet into a new, more offensively minded stage of development, the U.S. Navy's most advanced anti-submarine weapon lay in pieces on the ocean floor.

The disaster was further complicated by the fact that, given the circumstances of the submarine's loss, no specific cause could be established for the sinking. Naval experts pondered the available data, attempting in vain to find a precise answer to the question of what caused the *Thresher* to be lost. The U.S. Navy convened a Court of Inquiry the day after the *Thresher* sank, and eventually compiled 1,700 pages of testimony from dozens of witnesses. Although the court's actual findings remain classified as "secret" to this day, the Navy publicly concluded that a pipe fitting in the ship's engine room had probably given way, flooding the compartments in seconds with tons of water.[5] But other observers thought the ship may have succumbed to welding defects in the hull and flaws in the new type of high-yield (HY) steel that had recently been introduced for submarine construction.[6] Quality control procedures at shipyards came under the scrutiny of Admiral Hyman G. Rickover, whose driving management style had transformed the first nuclear-powered submarine from concept to operational ship in only ten years. He decried the "carelessness, looseness, and poor practices" that had crept into the Navy's shipbuilding program. It was obvious that Rickover believed poor workmanship and inadequate technical management may have contributed to the Thresher disaster.[7]

Ironically, the Soviets used the possibility of poor workmanship as a contributing cause of the Thresher's loss for their own purposes: "How could it happen that a ship which the Americans tirelessly advertised as the most 'modern' and 'dependable' perished not far from its great naval base without having time to send even a distress signal?" a Soviet naval officer wrote. "Businessmen in uniform," he went on, "seized by atomic delirium, sent out the Thresher, despite the fact that the crew and the physical plant had not been sufficiently prepared for sea, much less deep-water diving. Definitive trials of the boat were conducted with criminal haste. Thus safety was again sacrificed to the goal of bringing the boat into the active fleet as quickly as possible."[8]

Soviet naval experts also agreed that a piping failure was the probable cause of a flooding casualty from which the Thresher could not recover. "The greatest danger is represented by accidents connected with the rupture of sea water piping or damage to the fittings installed in them," a Soviet naval publication explained in 1971. "One such accident ended with the loss of the nuclear-powered submarine _Thresher_ on 10 April 1963."[9]

Although the official explanation of _Thresher_'s loss was a flooding casualty probably caused by a piping system failure, some naval experts did not accept this judgment. Norman Polmar, whose _Death of the Thresher_ in 1964 remains as the definitive work on the disaster, argued that the submarine sank either because its diving planes had malfunctioned or because it experienced a sudden loss of propulsion from its nuclear power plant. Final communications from the submarine minutes before sinking indicated that it was experiencing a "minor" problem,[10] after which sounds of the ship blowing its ballast tanks were heard by Navy personnel communicating with the _Thresher_ from the bridge of the Navy submarine rescue ship USS _Skylark_.

Polmar wrote that Lieutenant Commander John Wesley Harvey, the submarine's skipper,

> ...apparently decided, whatever the trouble and however minor it was, to shed the _Thresher_'s main ballast in order to give her more buoyancy. Since the same amount or greater upward lift could also be provided by increasing speed coupled with proper use of his diving planes, it appears that he did not have the ability to control either propulsion, and hence speed, or the diving planes. Probably this non-availability of propulsion or diving plane control was the minor difficulty the submarine announced....[11]

Although Polmar, in 1964, advanced two probable causes for _Thresher_'s sinking, he has since concluded that the initial problem which led to the sinking was a loss of propulsion.[12] Rear Admiral Lawson P. Ramage, USN (ret.), who commanded the U.S. Navy's submarine force in the Atlantic Fleet when the _Thresher_ was lost, agrees that the ship's crew "wouldn't have been blowing if they had not lost power and weren't in trouble. In other words, they were dead as soon as they lost power."[13] The probability that loss of nuclear propulsion in the Thresher may have been the initial cause for its sinking was emphatically denied by Admiral Rickover, ignored in Congressional hearings and not mentioned in official Navy statements.

Ironically, the effects of the submarin disaster may not have been as comprehensive if a specific cause for the sinking had been identified. Because the Navy was unable to pinpoint a reason for Thresher's loss, it was forced to review all areas of endeavor related to submarine development. Accordingly, deficiencies were uncovered in submarine design, construction, operation and overhaul that may have been overlooked by a more focused investigation.

Although these areas were profoundly affected by the Thresher loss, the disaster had little impact on basic submarine hull design. In fact, it can be said that, a quarter of a century later, the Thresher concept--in spite of the lead ship's tragic end--remains as the benchmark of contemporary submarine design.[14] Instead, the Thresher sinking has substantially influenced submarine construction and overhaul practices, deep-submergence capabilities, and has increased the safety margin of submarine operations.

In the months following the diaster, the U.S. Navy began to reevaluate its deep-submergence capabilities, which had remained essentially static since World War II. While this review progressed under the Deep Submergence Systems Review Group (DSSRG) led by Rear Admiral Edward Stephan,[15] the Navy faced a technical challenge of tremendous magnitude:

to locate the wreckage of a submarine that lay more than one and a half miles below the surface of the sea.

Footnotes for Introduction

1. U.S. Navy news release #128-61, Public Information Office, Headquarters, First Naval District, July 25, 1961.

2. Norman Polmar, Guide to the Soviet Navy, 3rd ed. (Annapolis, Md.: Naval Institute Press, 1983), p. 72.

3. Ibid.

4. Ibid.

5. Department of Defense news release, June 20, 1961.

6. Norman Friedman, Submarine Design and Development (London: Conway Maritime Press, Ltd., 1984), p. 83

7. U.S. Congress, House and Senate, Loss of the U.S.S. Thresher, Hearings before the Joint Committee on Atomic Energy, 88th Cong., 1st and 2nd sess., June 26-27, 1963; July 23, 1963; and July 1, 1964 (Washington: U.S. Government Printing Office, 1965), p. 66 (hereafter cited as Thresher hearings).

8. S. Osokin, "The *Thresher*, Victim of Adventurism," review of A.A. Narusbayev and G.P. Lisov, *Secret of the Death of the Thresher* (Moscow: Sudostroenie Press, 1964), *Krasnaya Zvesda* (Red Star), November 28, 1964.

9. A.A. Narusbayev, "The Accident Rate of Submarines Abroad," *Morskoy Sbornik*, No. 2, 1971, p. 109.

10. Norman Polmar, *Death of the Thresher* (Philadelphia and New York: Chilton Books, 1964), p. 108.

11. Ibid., pp. 110-111.

12. Interview with Norman Polmar, Alexandria, Va., June 11, 1986.

13. Oral History of Rear Admiral Lawson P. Ramage, USN (ret.), U.S. Naval Institute (unpublished), p. 369.

14. Friedman, *Submarine Design*, p. 83.

15. *Thresher* hearings, p. 3.

CHAPTER ONE: THE PROBLEM DEFINED

Immediately after the USS Thresher was officially declared lost, the Navy held a court of inquiry to investigate the sinking. Headed by Vice Admiral Bernard L. Austin, who at the time was president of the Naval War College in Newport, R.I., the court adjourned on June 5, 1963 after interviewing dozens of witnesses. It submitted its findings to the Navy's Office of the Judge Advocate General, which released a summary of the findings twenty days later to the Joint Committee on Atomic Energy.

In that summary, difficulties experienced with the Thresher's high-pressure air system were described; it was further reported that these difficulties had been corrected before the ship stood out for its sea trials that began April 9, 1963. Eight days earlier, the submarine had held a flooding casualty drill; it had taken twenty minutes to find and isolate the simulated leak.[1]

The court noted that although Portsmouth Naval Shipyard had recently increased spending and added personnel in its quality control program, the shipyard also tended to deviate from building specifications in "certain areas." Also, in construction and overhaul procedures, the shipyard's management looked upon specifications as "goals" rather than "requirements."[2]

The findings commented on the increased complexity of modern submarines, and how "greatly increased speeds and operating depths has made it essential that all information affecting their safe operation be analyzed and promptly disseminated." At the time, the Navy had no organization that was solely responsible for submarine safety.[3]

The court concluded that the basic Thresher design was a good one, but "there are certain improvements desirable, as set forth in the recommendations, to increase the safety margin."[4] Those recommendations included improvement of quality assurance programs in shipbuilding and repair yards, the rescheduling of submarine construction and overhaul to take advantage of the new ultrasonic testing method for high-pressure piping systems, and establishment of an organization that would be "responsible for the analysis of events and developments which pertain to submarine safety and the timely dissemination of such information."[5]

The Court of Inquiry's findings did not include any recommendations that related to the nuclear propulsion systems on board submarines. The subject was extensively discussed throughout the proceedings, with two problems becoming apparent: the amount of time required to recover from a reactor scram may have been too long, given the nature of submarine operations, and reactor operations had to be modified in a way that would allow the crew to make use of latent heat in the cooling system for emergency propulsion.[6] Initially, the Court of Inquiry intended to articulate its concerns in this area. But Admiral Rickover seems to have convinced the court to remove any recommendations regarding nuclear plant operations from the final draft of its findings.[7]

Hearings of the Joint Committee on Atomic Energy

One day after the Navy released its conclusions about the *Thresher* disaster and had enumerated its "lessons learned," the Joint Committee on Atomic Energy convened to hold its own investigation into the loss of the submarine. The hearings were conducted in three sessions: June 26-27, 1963; July 23, 1963; and July 1, 1964.

In contrast to the Navy's court of inquiry findings, the Congressional hearings on *Thresher* were released to the public with classified matter deleted. Most of the deletions, judging from the context, refer to the depth and speed of the *Thresher* at the time of its accident, depth and speed capabilities of other submarines, and to details concerning reactor plant characteristics and operations. Such deletions generally do not seriously impair the written record of the hearings, which provide a substantial amount of data and documents related to safety in the nuclear submarine force. Of particular note is the inclusion of long passages of testimony given by Vice Admiral Hyman G. Rickover to the Navy's court of inquiry.

The hearings record a few vignettes illustrating communication breakdowns between the military establishment and the U.S. government. Often the importance of the committee's findings became unnecessarily obfuscated by various exchanges among congressmen and Navy witnesses. In their ardor to find concrete answers to explain the loss of a multimillion dollar, state-of-the-art submarine, congressmen often got bogged down in technical details, thereby missing opportunities for a more comprehensive understanding of conditions that may have contributed to the _Thresher_'s loss.

The Navy witnesses, determined to defend themselves and make the best of a most difficult situation, sometimes seemed evasive and unnecessarily complicated in their responses. The main exception was Admiral Rickover, whose testimony is characterized by directness and full documentation. Yet it must be realized that Rickover not only was well-versed in providing testimony to Congress, but he also had great influence over the Joint Committee on Atomic Energy and could afford to be less cautious.[8] It also should be understood that much of Rickover's testimony was intended to prove that quality control, safety standards and management techniques were better in his Nuclear Propulsion Branch than they were in the Bureau of Ships organization that was responsible for the non-nuclear portions of submarines.

For its part, the Joint Committee on Atomic Energy expressed little interest in finding fault with Rickover or his organization. They viewed Rickover as a champion of innovation who, with the help of Congress, had waged a successful war against the Navy bureaucracy to make nuclear-powered submarines a reality. The admiral had asked the committee for assistance, funding and otherwise, on several occasions and the committee had obliged him. They had no interest in tracing any possible causes for the _Thresher_ disaster to their major Navy ally.

Still, the hearings were valuable in forcing the Navy to admit certain deficiencies in connection with the _Thresher_ disaster, as well as making much information, probably covered in the official court of inquiry, part of the public record.

The Congressional hearings made it clear that the Navy suffered from mismanagement in its shipbuilding program, insofar as it related to nuclear-powered submarines. Construction specifications were deviated from regularly at Portsmouth without the knowledge of the shipyard superintendent or other key management personnel.[9] The designs of nuclear-powered submarines had not been thoroughly reviewed in the area of deballasting capability.[10] Although it was common knowledge throughout the submarine force that the USS Barbel had experienced a very serious flooding casualty because the silver brazing in a pipe joint had come loose, the Thresher was still allowed to go to sea with an estimated 14 percent of its silver-brazed pipe joints categorized as "below standard."[11]

The meaning of such testimony is unclear, as unclear as the definition of the phrase "below standard." While much was made of the physical condition of pipe joints in the Thresher following its overhaul, it is far from certain that such a condition represented an inexcusable compromise of the submarine's seaworthiness. Among those who are unconvinced is Rear Admiral Dean Axene, U.S. Navy (ret.), first commanding officer of the USS Thresher:

> One of the things that's always bothered me about the aftermath of the Thresher, people naturally would like to be able to figure out what happened to the ship--nobody would like that better than I. But in my view, too many people got mesmerized by the salt water joints and the piping and the ultrasonic testing, and jumped to the conclusion that...the most probable thing was a salt water leak which led to some other problems that led to the loss of the ship. But I don't necessarily subscribe to the fact that it was a failed silver-brazed joint. There's a lot of other places where salt water could get into the ship.[12]

The *Thresher* hearings made it quite clear that U.S. submarines were being designed, constructed, operated and overhauled by two separate management systems. While the Chief of the Bureau of Ships and his staff were responsible for the non-nuclear part of a submarine--essentially the entire ship--Rickover and his Nuclear Propulsion Branch were responsible for the reactor components, including related piping systems. These two management systems operated under different criteria and did not share the same bureaucratic truth, *i.e.*, that set of principles which justify an organization's existence. Rather, they competed against each other in a program with limited resources. This competition was not particularly constructive and may have, in its own way, contributed to the loss of the USS *Thresher* by dividing the Navy's attention between the needs of the submarine operating forces and the needs of nuclear propulsion development.[13]

The combined efforts of the Navy's court of inquiry and the Joint Committee on Atomic Energy's hearings to find out what may have contributed to the *Thresher*'s loss pointed to major deficiencies in submarine construction, quality control and technical management. Nuclear-powered submarines represented a new weapons system based upon emerging technologies, and the *Thresher* class had deeper diving capabilities than its predecessors. These greatly improved performance characteristics also implied greater operational stress for nuclear-powered submarines. In this regard, the deficiencies identified by the Navy and by Congress had reduced the safety margin in undersea operations to such a point that operational reliability had become seriously impaired.

Norman Friedman, warship design expert and author, has said that the _Thresher_ disaster marked a tragic discrepancy between the expectations and the realities of submarine performance: "What probably happened was that quality control and safety standards were all right down to operating depths of pre-_Thresher_ subs. But when they built one to go much deeper, the standards just weren't good enough anymore....The implications of the deeper depth weren't totally grasped."[14]

Navy management had made mistakes in developing a new weapons system, both the Rickoverian system and the Bureau of Ships. Yet Congress had been convinced by Admiral Rickover that his system of management, based upon principles of engineering and stringent quality control standards, had fewer defects and should be used as the standard for submarine development.

Footnotes for Chapter One:

1. Department of the Navy, Office of the Judge Advocate General's Corps, "Summary of Events Concerning Loss at Sea of U.S.S. Thresher.", June 25, 1963 (hereafter cited as Court of Inquiry findings), Thresher hearings (app.), p. 152.

2. Ibid.

3. Ibid., pp. 152-53.

4. Ibid., p. 153.

5. Ibid., pp. 153-54.

6. Interview with The Honorable Fred Korth, former Secretary of the Navy, and Vice Admiral Marmaduke Bayne, USN (ret.); Washington, D.C., April 5, 1987 (hereafter cited as Korth and Bayne interview).

7. Ibid.

8. Ibid.

9. Thresher hearings, pp. 13-15.

10. Ibid., p. 15.

11. Ibid., pp. 16-17.

12. Interview with Rear Admiral Dean Axene, USN (ret.), Pensacola, Fla., April 30, 1987 (hereafter cited as Axene interview).

13. Interview with Captain William Anderson, USN (ret.), Alexandria, Va., March 1, 1987 (hereafter cited as Anderson interview).

14. Interview with Norman Friedman, New York City, April 29, 1987 (hereafter cited as Friedman interview).

CHAPTER TWO: CHALLENGE AND RESPONSE

To its credit, the response of the U.S. Navy to the deficiencies revealed by the Thresher sinking was immediate, comprehensive and adroitly managed. Some changes of an operational or procedural nature, intended to increase the safety margin within the submarine force, were made within days of the disaster. Other programmatic changes were more gradual, and their progress was highlighted in a final hearing held on the disaster by the Joint Committee on Atomic Energy on July 1, 1964. Still other changes, involving research and development efforts for new designs and equipment, took several years to achieve results; some intended results were never achieved.

Soon after the loss of the Thresher, depth restrictions were applied to all submarines with a deep-design test depth (below 400 feet). New requirements included test dives being made in depths no more than one and a half times the test dive depth, *i.e.*, collapse depth.[1]

The collapse depth of a submarine is the depth at which its hull will be crushed by sea pressure. Typically, collapse depth is rated at 150 percent of a submarine's test depth. For example, if a submarine's test depth is rated at 400 feet, its collapse depth is 600 feet. The Thresher's collapse depth was probably between 1,200 and 2,000 feet.

Submarine rescue ships in attendance during the test dives of submarines were given an additional requirement to record all inter-ship communications on tape. The Navy's court of inquiry had to piece together final message traffic between the Thresher and the submarine rescue ship

Skylark from incomplete notations in the *Skylark*'s logbook and from the recollections of several officers and crewmen. The lack of agreement as to the precise wording of the submarine's final messages only served to complicate the disaster further. It was realized that an automatic audio recording device placed aboard ship, similar to the "black box" carried in a commercial passenger plane, could provide an exact record of verbal communications for later interpretation.[2]

Main ballast tank blow capabilities of submarines had to be tested at dockside and during shallow dives before a deep dive could be made.[3] The *Thresher*'s blow system had never been fully tested during its operational lifetime.[4] A test conducted on a sister ship after the *Thresher* sank revealed that simulated ocean pressure at test depth had frozen compressed air as it was discharged through reducer valves with wire strainers across their openings. The valves were blocked, and the submarine was unable to clear its ballast tanks of seawater. Presumably, the same effect resulted when the *Thresher* attempted to blow its ballast tanks at or near its test depth.[5] Subsequent to the *Thresher* sinking, all deep-diving submarines were equipped with an emergency main ballast blow system, which circumvented the use of reduction valves and provided a much faster and more direct method for blowing tanks.

Other procedural changes were made to improve the safety of submarine operations. Speed restrictions were placed on various operating depths to allow submarines more time to recover from diving plane casualties before they passed collapse depth. Submarine officers were instructed to maintain positive buoyancy in their ships whenever feasible. This would stop a submarine from drifting to deeper depths if it should experience a sudden loss of propulsion.[6]

While the official court of inquiry into the Thresher disaster deliberated in New London, Conn., and then in Portsmouth, N.H., from April 11 to June 5, 1963, the Deep Submergence Systems Review Group (DSSRG) examined existing literature on deep-submergence operations. Rear Admiral Andrew I. McKee, USN (ret.), was called back to active duty to chair an ad hoc committee set up to reevaluate the design of the Thresher-class submarine.[7]

A Submarine Safety Task Group was established in the Bureau of Ships (now the Navy Sea Systems Command) to carry out specific tasks intended to improve submarine design safety. This group identified fifteen project areas for safety review and improvement. Most of the projects involved changes in submarine design specifications and construction procedures: sea water systems, fabrication methods, machinery components, high pressure air systems, protection of electrical systems, piping penetrations into the pressure hull, diving planes, habitability, and shock tests.[8] While many of these tasks were design changes in a technical sense, it should be remembered that the essential hull design of the Thresher class, embodying substantial improvements in such areas as streamlining and sonar placement, was preserved.

Other projects related to areas of management. The Navy wanted to require shipbuilders to follow its design plans for submarine classes and use designated components for vital systems--deviations were no longer allowed. Information pertaining to damage control was consolidated into the ship's information book for submarines. Perhaps most important, the quality assurance program in the shipyards was expanded and revised.[9]

On June 3, 1963, the Chief of the Bureau of Ships ordered creation of a Submarine Safety Program.[10] Established the following month, the program included more than a hundred separate tasks to be performed in the design, fabrication, testing and maintenance of submarines in the interest of safety.[11] These tasks--known as the "Subsafe Package"--included a design review of sea-water systems subjected to submergence pressure; examination of high-pressure air systems such as the main ballast tank blow systems; further protection of electrical systems from sea water; investigation of reliability in ship control systems; revision and expansion of quality assurance programs; and further review of submarine location, salvage, and rescue capabilities.[12]

For a time, this Submarine Safety Program curtailed the normal operating routines of the naval submarine force because, eventually, all of the submarines had to go into shipyards for the lengthy inspections, retro-fitting, radiography, ultrasonic testing and many other tasks required by the program.[13]

By July 1964, the Navy had made substantial long-term changes intended to increase the safety of the submarine force. Subsafe packages were being completed on deep-diving submarines as they became available for overhaul. Tests of the newly installed emergency main ballast tank blow system were also made. Before a submarine was allowed to undergo sea trials, its material condition had to be certified by the Bureau of Ships. This certification was obtained after an extensive audit of the ship and building records was made. Certain modifications were also made to engineering plant procedures.[14]

Chief among these modifications were a substantial reduction in scram recovery time on board submarines and modification of reactor operating procedures to effect emergency propulsion from the latent heat energy stored in reactor cooling systems. Both of these changes, resisted by Rickover before the loss of the Thresher, were intended to reduce the risk of sustained propulsion loss.[15] Neither of these operational changes for submarine reactor plants was touched upon in the Congressional hearings on the Thresher disaster.

Accidental scrams on board nuclear-powered submarines were not infrequent but had caused no great concern before the Thresher was lost. As long as a submarine did not become heavy from too much negative buoyancy or a flooding casualty, a temporary loss of propulsion presented no grave threat. But pre-Thresher submarines operated at shallower depths, which means that flooding rates were slower and the time available for recovery was longer. The greater diving depth of the Thresher meant that if it should have a flooding casualty at test depth, the stronger sea pressure would increase the rate of flooding, thereby making the boat heavier more quickly. As a result, the Thresher would have had less time to recover from a loss of propulsion before a flooding casualty caused it to pass beyond collapse depth. From an engineering standpoint, it probably never occurred to anyone that if the Thresher got into trouble at deeper depth, a reactor scram would put the ship in extremis. Yet that is precisely what happened: either the ship lost propulsion first, or started flooding first, but both events took place at roughly the same time.[16] The amount of time the Thresher had left as it passed from test depth to collapse depth was insufficient for recovery.

Scram recovery is a matter essentially dicated by submarine design. Regardless of personnel quality and crew training, a ship's design establishes the minimum amount of time in which recovery from a scram may be accomplished. According to Admiral Axene, the Thresher's first commanding officer, scram recovery time on board the early nuclear-powered submarines was surprisingly quick, given the complexity of the technology. The dangers involved in losing propulsion were also well understood. "It was perfectly true that if you lost your reactor, you didn't have much in the way of backup power to last you until you got back on line again....The backup diesel engine was a small one, which was there just for the purpose of sustaining that battery until you could get things going again."[17]

The nuclear reactor was the only dependable source of power. If a submarine ran into serious problems at deep depth, the auxiliary diesel engines could not power it to the surface. The boat might blow its ballast tanks, but that also was no guarantee for survival. The Thresher class had been designed with little reserve buoyancy, i.e., the degree to which it can float on the ocean's surface. Nuclear power had proven to be extremely reliable, and that became an axiom to be followed by engineers. Deballasting capability became less important and ballast tanks became smaller.[18]

Such trends in submarine design made continuous nuclear propulsion tantamount to submarine survival at deep depth. Rickover found ways, by modifying the reactor system and its operation, to reduce the scram recovery time. This, along with a method for using latent heat in the reactor system for emergency propulsion, may have been the most important effect to come out of the "Thresher disaster.[19]

Other major changes were generated by Navy management in its effort to alleviate shortcomings in the submarine force. The Submarine Safety Center was established at Groton, Conn., on 18 February 1964. Its task was "to devote full-time attention to all aspects of submarine safety in order to advise and assist the Chief of Naval Operations, fleet, and the submarine force commanders in promoting and monitoring safety of all submarines."[20]

The Thresher's loss also affected the training of nuclear submarine personnel.[21] Soon after the disaster, the Chief of Naval Operations directed the submarine training community to provide future submariners with flooding and plane casualty simulations. As far as at-sea operations were concerned, one of the most significant shifts in training philosophy was the emphasis placed on the need to maintain a positive trim on board nuclear submarines when submerged.[22] To "maintain a positive trim" means to retain enough buoyancy within the submarine's hull to ensure the ship stays lighter than the surrounding water pressure. Under such conditions, a submarine would not sink if it suddenly lost propulsion.

The nuclear submarine community had not been overly concerned about keeping a positive trim in their boats. They had become accustomed to the luxury of nuclear power and knew they could surface from any depth by simply increasing power and riding to the surface on their diving planes. Operating with a ship's hull heavier than the surrounding water pressure was not nearly as dangerous a practice as it was with diesel-powered submarines that ran underwater on limited battery power. Thus it was not uncommon to operate nuclear submarines underwater with negative buoyancy; the events of April 10, 1963 abruptly changed such an attitude.[23]

It must be noted that submarine crews in nuclear-powered boats became dependent upon propulsion by necessity and not by choice. In order to achieve desired speed capabilities, noise-reduction characteristics and sonar performance, certain trade-offs had to be made in other areas of nuclear submarine design. One of these compromises was a reduction in the size of the main ballast tanks, which also reduced the blowing capacity as a means of regaining the surface. Submariners of the time were well aware of their limited deballasting capacity and understood that propulsion was the only reliable source for surfacing in the event of a serious flooding casualty at deep depth.[24] As Admiral Axene put it, "It was well understood by all of us that the capacity to deballast at depth was severely limited. That never was considered, by me at least, to be a major source of recovery potential."[25]

Submarine trainers (similar to the Link trainers used by naval aviators) were modified so they could provide flooding and plane casualty simulations. Fleet commanders were now accountable for the preparation of submarine crews to conduct safe operations at sea. A period of uninterrupted time was set aside at the shipyards for submarine crews to conduct operational training. The findings of the Thresher's court of inquiry were disseminated widely throughout the submarine forces.[26]

In describing such improvements in the submarine force to the Joint Committee on Atomic Energy during the final hearing on the Thresher, Rear

Admiral C.A. Curtze, deputy chief of the Bureau of Ships, indicated that concerns about submarine safety had not begun with the *Thresher* disaster, but had been a major consideration beforehand:

> During this period there has been a tendency, even within the Navy family, to associate the genesis of our submarine safety effort to the loss of *Thresher*. It is important that we place the Navy's current effort in this field in proper perspective. Therefore I must emphasize that submarine safety has been a continuing program in the Bureau of Ships; it has been a matter given to closest scrutiny by all engineering personnel within the Bureau's organization who are associated with the design, construction, and maintenance of submarines. The genesis of this effort was not *Thresher*'s loss but stemmed from our very first attempts to design and construct combatant submarines.[27]

Curtze wanted Congress to know that safety in the submarine program had not been a static issue at the Bureau of Ships. In 1958, for example, he pointed out that Project Pressure had been initiated to analyze the impact of greater depth operations on submarine design. This was at a time when the *Thresher* was still on the building ways. The findings of that project, as well as a similar one called Project Glaucus, had been used to improve design features, quality control and fabrication techniques.[28] Other safety improvements initiated before the *Thresher* loss included an emergency breathing system on board submarines to be used in case of fire or toxic gas casualties when surfacing was not possible. Remote hydraulic closure of sea-water valves had also been installed for faster isolation of flooding casualties.[29]

Having defended the Navy's pre-*Thresher* safety effort in the submarine force, Curtze added that "following *Thresher*'s loss, we must in all honesty say, as Rear Admiral Brockett, Chief of the Bureau of Ships, has already said, with respect to submarine design, we moved too fast and too far in areas of offensive and defensive capabilities. Submarine safety did not keep pace."[30]

Testimony by submarine commanding officers at the time indicates that the submarine force had a theoretical understanding of the new operational dangers represented by deeper-diving, nuclear-powered boats. Yet the consensus of the submarine community was that its ships were built well enough and its crews were trained well enough to avoid disaster. According to Captain Edward L. Beach, U.S. Navy (ret.), submariners at the time knew that problems might be encountered as the result of increased depth and speed, but they did not really accept the reality of such dangers until the Thresher went down.[31] As far as the submarine force was concerned, nuclear power was a tremendous asset to a ship's maneuverability underwater; it was not considered to be a potential problem. No inordinate concern was expressed among the community that a submarine might be driven outside its safe operating envelope much faster, given the much higher operating speeds sustained by nuclear reactors.[32]

While Navy management's attention to submarine safety had not been static in the years preceding the Thresher disaster, it had not responded particularly well in alleviating certain deficiencies. Serious problems in radiography and welding had been identified yet not corrected. Perhaps the worst oversight committed in submarine safety was a lack of thorough understanding on the part of chief decision makers that, given the increased operational parameters in depth and speed, nuclear-powered submarines would undergo far more stress than their diesel counterparts.

Such problems already had arisen with the fleet's first nuclear submarine, the Nautilus. A very serious structural problem had developed after the ship had become operational. Stress on the hull had caused cracks in the submarine's forward ballast tanks to such an extent that the tanks could no longer hold ballast. Although a group of technical experts at the Navy's David Taylor Model Basin near Washington, D.C., eventually resolved the problem, the situation clearly indicated that structural difficulties associated with nuclear propulsion and increased parameters of undersea performance were far from minor.[33]

Before the Thresher stood out for its sea trials in April 1961, Admiral Rickover had become aware of the ship's small blow capacity after running some casualty studies on a new reactor plant design. Rickover passed on his discovery to several key offices in the Navy management hierarchy: the Bureau of Ships Submarine Type Desk, the Portsmouth Naval Shipyard, the Board of Inspection and Survey, and Commander of Submarine Forces Atlantic Fleet representatives. Rickover then modified procedures for the Thresher's sea trials to increase the margin of safety while diving to test depth. He was concerned about the potential danger represented by the Thresher's limited blow capacity at test depth, and he considered the extra precautions to be necessary "since this was the first time one of our submarines was to go to so great a depth, and particularly because of the large number of new development items, including sea valves and rubber piping." Rickover characterized the planning of the Bureau of Ships for the Thresher's first test dive as "casual."[34]

From Rickover's testimony, it is evident that, although the Navy had an established safety policy for its submarine force, implementation of the policy in terms of specific safety procedures was not always well executed. The lack of response to Rickover's concern over the

Thresher's inadequate deballasting capacity also shows the difference in perspective between the two management systems involved with nuclear submarine development.

Rickover, more oriented toward safety and quality control, was concerned about deballasting deficiencies in the *Thresher* and sent warnings far and wide to the other half of the Navy management "house." But that half, which was more mission-oriented, knew about the deficiency and understood why it existed. What was probably difficult for Bureau of Ships management (at least in some circles) to understand was Rickover's insistence that this "deficiency" be corrected at the expense of the submarine's mission capabilities. It was as if Rickover had said, "I want you to reduce the speed, stealth and detection capabilities of the *Thresher* so we can be more certain that it will come back up to the surface." Curiously, Rickover's actions imply that he must have had some reservations about the reliability of his reactors.

The proposition that the mission capabilities of the *Thresher*, or any other submarine, be further sacrificed for the sake of increasing the safety margin in operations must have seemed most peculiar to combat-experienced submariners. The sole justification for a military submarine's existence is its value as a weapon of war--in other words, what it can do to destroy the enemy. Although crew safety is an important consideration, it does not override the mission capability of a submarine. In fact, it would be detrimental for a submarine crew to operate with the understanding that their safety is more important than their ability to destroy the enemy.[35] Danger is an inherent condition of warfare, and safety features in combat systems are seen as advantageous only insofar as they can guarantee the accomplishment of a mission. Submarine crews need to be protected because a submarine cannot operate itself. A safety margin must be sufficient to provide a reasonable guarantee that personnel can survive to carry out their mission. To extend a safety margin merely for additional protection of lives--at the expense of mission capabilities--is absurd within the framework of military logic. This philosophical aspect of weapons development, known as the "safety vs. mission trade-off" is an axiomatic concern in submarine development that was highlighted by the Thresher disaster.

On the last day of testimony for the Thresher hearings in Congress, it was established that the Navy had been remiss in fully testing the deballasting capacity of the Thresher. Modifications to the sub's blow system had been recommended but not carried out.[36] Such revelations were hardly surprising to those who operated deep-diving submarines for a living. They realized that blowing capacity was quickly becoming a moot point as the test depths of submarines became greater. Yet Rickover emphasized this deficiency to the point where, at least for some members of the Joint Committee on Atomic Energy, it became a serious oversight in submarine design. He also emphasized a general lack of quality control in construction involving non-nuclear portions of submarines, documenting numerous instances of piping failures and other mishaps apparently caused by poor workmanship.

Despite the many mechanical flaws indicated by Rickover, the Bureau of Ships endorsed the basic Thresher design after concluding a review. The Navy's court of inquiry agreed, noting that "the basic design of

Thresher class submarines is good, and its implementation resulted in the development of a high-performance submarine."[37]

Because the Rickoverian management system had made a stronger showing in Congress and operated under more stringent criteria for quality control as the result of its essential involvement with nuclear power, it became the standard by which submarine construction and overhaul would thenceforth be measured. After the *Thresher* disaster, quality control standards were increased for non-nuclear portions of submarines so as to achieve parity, relatively speaking, with the standards of the Nuclear Propulsion Branch. That Rickover's quality control standards were indeed higher and better enforced than in the rivaling Bureau of Ships management system is an assertion that has yet to earn a consensus from experts in the field.[38]

Such an evolution, by necessity, permeated all aspects of submarine development and had the effect of substantially increasing the costs of submarine construction. While construction costs for the *Nautilus* prototype amounted to about $100 million, the projected cost for the next generation of *Seawolf* (SSN 21) attack submarines is about $1 billion apiece. Inflation aside, the cumulative effect of changes made to increase the safety margin of the nuclear submarine force has been to make such submarines more expensive than they might otherwise have been. In terms of force structure, this means that the Navy possesses a fleet of submarines that are extremely reliable in their operation. It also means that the Navy cannot afford as many submarines as it could in the pre-*Thresher* days.

Over the past three decades, the Soviet Navy has built submarines at a much faster rate--with many more design prototypes--than the United States. More Soviet submarines have been lost at sea or have experienced serious accidents than have U.S. submarines. Yet the Soviet submarine force is about three times the size of current U.S. assets. Should the two navies engage in widespread and sustained hostilities, and given the probable attrition rates in naval combat (recently demonstrated by events of the Falklands War), the exchange of quantity for increased safety and operational reliability may come into question. Depending upon the performance of our submarine force in the next war, the post-_Thresher_ decision to build more reliable but fewer submarines may be seen, via hindsight, as a poor one, even among those who strongly supported the Rickoverian era of submarine development.

Footnotes for Chapter Two:

1. *Thresher* hearings, p. 93.

2. Ibid.

3. Ibid.

4. Ibid.

5. Ibid.

6. Ibid., p. 94.

7. Ibid., p. 4.

8. Ibid., pp. 45-46.

9. Ibid.

10. Ibid., p. 97.

11. Ibid., p. 98.

12. Ibid., p. 99.

13. Oral History of Dr. Waldo K. Lyon, Director, Arctic Submarine Laboratory, U.S. Naval Institute (unpublished), p. 233.

14. _Thresher_ hearings, pp. 93-94.

15. Korth and Bayne interview, April 5, 1987.

16. Friedman interview, April 29, 1987.

17. Axene interview, April 30, 1987.

18. Friedman interview, April 29, 1987.

19. Korth and Bayne interview, April 5, 1987.

20. _Thresher_ hearings, p. 94.

21. Ibid.

22. Ibid., p. 117.

23. Ramage oral history, p. 379.

24. Axene interview, April 30, 1987.

25. Ibid.

26. Thresher hearings, p. 94.

27. Ibid., p. 95.

28. Ibid., p. 96.

29. Ibid.

30. Ibid., p. 97.

31. Interview with Captain Edward L. Beach, USN (ret.), Washington, D.C., February 7, 1987 (hereafter cited as Beach interview).

32. Axene interview, April 30, 1987.

33. Interview with Dr. John Craven, Honolulu, Hawaii, April 28, 1987 (hereafter cited as Craven interview).

34. Testimony of Vice Admiral Hyman G. Rickover, U.S. Navy, before the U.S. Navy Court of Inquiry into the Thresher disaster, April 11 to June 25, 1963 (hereafter cited as Rickover testimony), cited in Thresher hearings, pp. 85-86.

35. Friedman interview, April 29, 1987.

36. Thresher hearings, p. 112.

37. Thresher hearings, p. 153.

38. Friedman interview, April 29, 1987.

CHAPTER THREE: "THE NEVER-ENDING CHALLENGE"

On October 29, 1962, Vice Admiral Hyman G. Rickover delivered a speech to the National Metal Congress. His essential message was that if U.S. industry expected to meet the challenge of fabricating high-quality components for nuclear reactors, it must maintain high standards of training within its work force and enforce rigorous standards of quality control. "My remarks today," Rickover said, "concern the harmful results caused by failure of American industry to live up to the exacting standards of reactor technology." Describing chronic defects in welding, radiography and casting, he revealed that "naval reactors...have had their full share of these problems." Rickover explained that he insisted on design excellence and high-quality workmanship because nuclear-powered submarines had to operate submerged for long periods of time and under conditions where "it may not be possible to come to the surface."[1]

The admiral expressed his bewilderment as to why private-sector management had not faced up to its responsibilities in meeting contractual specifications. He then prescribed an antidote. "Quality control must be recognized as an essential tool to enable management to meet today's technological imperatives. One of the best ways you can help raise the level of technical excellence of American industry is by insisting, as I have, on high standards of design, workmanship, and quality control."[2] He went on to say that U.S industry, in order to meet the rising standards of technology, "must relinquish comfortable routines and practices rendered obsolete because they no longer meet the new standards. This is our never-ending challenge."[3] While Rickover delivered his message to the National Metal Congress, the USS _Thresher_ was undergoing its final overhaul at the Portsmouth Naval Shipyard.

The major problem with the U.S. nuclear submarine force, insofar as it was defined by the public record, was one of poor quality control in construction procedures--not the ones concerned with nuclear reactors, but those concerned with the non-nuclear portions.

Both the Nuclear Propulsion Branch and the Bureau of Ships had ample warning that all was not well in the construction and overhaul of its nuclear-powered submarines. Since these new weapons of war were controlled by two separate management systems, it should be no surprise that the Navy responded to the same indicators in two separate ways. The indicators of faulty submarine construction procedures that will be examined here are in the areas of radiography, pipefitting, welding and quality control (or quality assurance).

The Navy had experienced problems in radiography at its Portsmouth Naval Shipyard some time before the _Thresher_ disaster. Radiography is a process of X-ray photography used to determine the quality of welds that join sections of steel together; it is an important part of any naval shipyard's quality control apparatus. In April 1960, three full years before the _Thresher_ was lost at sea, a report of inspection procedures at Portsmouth stated that "Until recently no adequate identification method was used and most radiographs taken on the SS(N) 593 (_Thresher_)...cannot now be identified with location on the submarine hull."[4]

Not only was the Portsmouth yard remiss in its quality control methods for matching radiographs with the actual hull welds, the quality of the radiographs themselves was inadequate:

> ...in a number of instances technically poor radiographs had been accepted for final weld inspection. Radiographic personnel advised that production schedules precluded retaking of radiographs in most instances. The viewing facilities were, in general, poor and not conducive to accurate reading of films.[5]

The situation at Portsmouth should not be construed as standard among those naval shipyards involved with submarine construction. A review of radiographs at Electric Boat in Groton, Conn., for example, found them to be excellent in quality, with few defects or interference from obstructions.[6] There, the reviewer had found that "The radiographic inspection of the submarine hull welds was at high quality. The production radiographs aside from occasional minor items were excellent and represented almost complete coverage...."[7]

Admiral Rickover noted deficiencies in radiography at Portsmouth almost two years later in February 1962. Responding to Bureau of Ships criticism of his stringent standards for reactor plant welding in submarines, Rickover said that radiographs at the Portsmouth yard "were of extremely poor quality--worse than those of any other shipyard."[8]

The admiral went on to describe how, after radiographs of reactor welds were re-done, about 30 percent of the welds had to rejected because they did not meet specifications. Rickover concluded that the Bureau of Ships could not be at all certain that the quality of welds in submarines being built at Portsmouth was adequate.[9]

With the loss of <u>Thresher</u>, any part of submarine construction related to quality control became a penultimate concern for the Bureau of Ships.

Thus, the Navy announced on June 7, 1963, that the completion of another Thresher-class submarine, the USS Tinosa (SSN-606), would be delayed because some radiographs taken of the ship's hull welds were missing. Although the Navy denied any "direct connection" between Thresher's loss and the delay of Tinosa's completion, its chief of legislative affairs, Rear Admiral R.Y. McElroy, Jr., indicated in correspondence that "application of newly developed ultrasonic inspection techniques to submarine high pressure piping systems was emphasized as a result of the (Thresher) investigation."[10] To act as though the Thresher's loss had not heightened sensitivity in areas of quality control for submarine construction was a less than candid posture taken by Navy management.

Almost two years before the Thresher sank, the Office of the Chief of Naval Operations had articulated the seriousness of flooding casualties on board submarines caused by piping defects. In a memorandum that reached all major Navy submarine commands by September 1961, the CNO's office noted that, despite corrective measures, saltwater piping incidents in the Atlantic Fleet "continue to occur with alarming regularity."[11] Incidents involving piping failures that had occurred in the Skate, Thresher, Ethan Allen, Snook and Barbel were then outlined. The gravity of the condition was spelled out:

> We have been fortunate thus far in that casualties have been handled promptly and correctly....Continued dependence upon such tenuous and fortunate circumstances, particularly when considering additional hazards imposed under wartime conditions, is obviously unacceptable....it is considered that urgency of problem and inherent danger of disaster must be brought more forcibly to attention of all concerned and that corrective preventive action must be pursued even more aggressively than has been done.[12]

The memo then recommended several corrective measures, one of which was to "impress on all building yards the serious consequences of laxity in design and fabrication of submarine piping systems. As exemplified in Ethan Allen, a seemingly minor departure from the rules can produce complex casualties which imperil the lives of submarines and/or render the ship unable to perform her mission."[13]

Eleven days after this memo was received by the Navy's submarine commands, the Thresher returned to Portsmouth for about three weeks of modification and repair. It was not until a year later, on August 28, 1962, that a Bureau of Ships memo recommended that the Thresher's silver-brazed piping be ultrasonically tested, that a 40 percent-bond standard be required for all the joints, and that a pilot test for ultrasonic testing be funded.[14]

Ultrasonic testing of pipe joints was a new method of quality control being tried out during the Thresher's final overhaul. For reasons which were not explained by witnesses during the Congressional hearings on the Thresher, such testing was terminated at the Portsmouth yard in November or December 1962. As a result, most of the Thresher's pipe fittings were not ultrasonically tested. The yard was required to file a report on such undertakings with the Bureau of Ships. When asked when this reported was received, a Navy admiral replied lamely that it was sometime after April 11, 1963--the day after Thresher went down.[15]

Admiral Axene recently has explained that ultrasonic testing in the Thresher was not simply "knocked off." Rather, a consensus was reached among those in charge of the submarine's overhaul that the testing had to be stopped if ship's work was to be completed within a reasonable time frame. The test program did not take priority over returning an attack submarine to regular operations at sea.[16] Such a decision reflects the compromises involved in balancing concerns about safety and mission. After a certain amount of pipe fittings had been ultrasonically tested, it was determined by individuals responsible for the Thresher's overhaul that further testing was unnecessary and only would have hindered the submarine in performing its mission.

One of the most poignant statements in the hearings is when Representative Chet Holifield of California quoted from a report turned in by Axene a few months before the Thresher sank: "In my opinion the most dangerous condition that exists in Thresher is the danger of salt water flooding while at or near test depth."[17] The submarine had experienced at least two piping failures during its builder's trials.[18] When asked if the Thresher's last commanding officer, Lieutenant Commander John Wesley Harvey, had ever received the report stating that 14 percent of the submarine's silver-brazed joints were substandard, Admiral Austin replied: "We do not know, sir, whether Harvey actually ever saw the ship's copy of the report about the number of joints that had failed to meet specified requirements. We do not know that. But it was on the ship."[19] If a requirement existed for a new commanding officer to sign off on ship's condition reports before departing for trials at sea, it was not enforced in this instance.

While Axene's comments about flooding dangers in Thresher probably took on an apocalyptic importance to Holifield and other members of the Joint Committee on Atomic Energy, as well as the public at large, they were in fact typical of ship's condition reports submitted by commanding officers to higher authorities. Axene was simply stating the obvious: the worst thing that can happen to a submarine at any substantial depth is a flooding casualty. Since the Thresher could dive much deeper than any other submarine, the potential danger from flooding was also greater. But Axene's concern for flooding on board the Thresher was certainly not peculiar and he "would have felt the same about any sub."[20]

Admiral Rickover's response to the problem of defective piping in submarines was much more immediate. Following a May 1961 failure of a silver-brazed joint in the Thresher's trim system, Rickover decided that silver brazing would no longer be used in piping for nuclear reactor compartments. Henceforth, all reactor systems exposed to salt water would be welded, along with any other seawater piping systems that passed through the reactor compartment, although such systems were not part of Rickover's responsibility. Such work had been completed in the Thresher before its final sea trials began on April 9, 1963.[21]

In contrast, the Navy's pilot program for ultrasonically testing the silver brazes in Thresher's piping had been discontinued in order to return the ship to operations, or, as another witness put it, to meet production deadlines.[22] Less than three weeks after the Thresher was lost, a Navy survey of 36 silver-brazed joints in another submarine showed that seven joints had less than 40 percent bonding--the Navy's own standard--and that two of those joints had ten percent bonding or less.[23] From such data, it is evident that Rickover's management system was more efficient in correcting piping deficiencies on board nuclear-powered submarines than were other departments or branches within the Bureau of Ships. In fact, pipe welding specifications for non-nuclear portions of submarine construction had been relaxed.[24]

Another danger signal had been raised in 1959 when Rickover came across construction irregularities in the welding of high-yield steel used for submarine hulls. The particular type of steel used to fabricate hulls for the Thresher class was known as HY-80. This designation meant that the steel could withstand pressures up to 80,000 pounds per square inch.

At the Mare Island Naval Shipyard in California, a representative of the Nuclear Propulsion Branch had discovered unsatisfactory conditions in hull welds, as well as inadequate radiography and quality control practices. Rickover insisted that hull sections enclosing the reactor compartment of a submarine be completely inspected; it was found that the welds connecting the reactor compartment to the inside of the submarine's hull were inadequate and needed replacement. These deficiencies were reported to the Bureau of Ships, which conducted its own investigations. HY-80 steel had not been accepted by Rickover as a construction material for any nuclear-related components in submarines.[25]

The improved strength characteristics of HY-80 steel, as well as improved welding techniques, were the key behind the greater depth capabilities of U.S. submarines. Although Rickover claimed the steel was defective and susceptible to cracking after long-term stress, the Navy turned in its final verdict in a July 15, 1963 report: "HY-80 clearly is the best steel for military submarine hull construction and the only satisfactory material available today." HY-80, the Navy contended, was "the only proven material in common usage among submarine builders which will give the structural strength, toughness, resistance to brittle fracture, workability, weldability, and fatigue resistance with an adequate strength-to-weight ratio to achieve the vertical sea room required by modern high-performance submarines."[26] The Navy was not prepared to reduce the dive capacity of its new attack submarines by substituting HY-80 with a less pressure-resistant steel, even on the recommendation of Admiral Rickover.

During the Thresher hearings, Admiral Brockett explained that "This quality control problem is a difficult one...the pride of workmanship of the individual mechanic is not enough even where it exists. It is a difficult thing to sell. You have to have it, and you have to have an active program of inspection. Quality control of material, and audit to make sure that those who are supposed to be assuring the quality are in fact doing it, this is our attack. This is not a shipyard phenomenon. This is a national phenomenon."[27] Members of the committee agreed that the decline in quality control was affecting industry in general, not just shipbuilding.

Increases in cost and time had been cited by the Bureau of Ships as the main reasons why more stringent quality control standards had not been applied to overall construction of nuclear submarines. Yet the risk the Navy took in holding to such a management policy, according to one member of the Joint Committee on Atomic Energy, was to have its entire nuclear submarine program shut down if sinkings became too frequent for the public to bear.[28] Other nuclear submarines had become near-casualties before the Thresher was lost. William R. Anderson, a former commanding officer of the Nautilus, recalled that the submarine had once experienced a serious flooding casualty at test depth during the late 1950s. Had the _Nautilus_ lost propulsion at that same moment, then it probably would have ended up just like the _Thresher_.[29]

Secretary of the Navy Fred Korth later denied that the continuation of the nuclear submarine program had been endangered by the loss of the _Thresher_. President John F. Kennedy had given strong support to the program, and there had never been indications from him or his cabinet that the nuclear submarine program should be terminated or reduced in the tragedy's aftermath.[30] It may be that such a suggestion on the part of the Joint Committee was politically motivated, _i.e._, a public endorsement of Rickover's concerns for better quality control in submarine construction.

Far more visible were the effects of the _Thresher_'s loss on equipment modifications and construction practices in the nuclear submarine force. In addition to the testing and replacement of welded joints and piping systems on board the ships, each received new quick-closing valves in its major saltwater pipelines and an emergency main ballast tank blow system.[31]

This system was successfully tested and installed on board all other operational submarines in the fleet after the _Thresher_'s ability to deballast had proven inadequate. This new system had a minimum of piping, joints, and other components in order to reduce the potential for failure and to speed the deballasting process.[32]

While the Navy had been remiss in testing deballasting capacity in the _Thresher_ before it sank,[33] it made certain that the new emergency system worked beyond the bare minimum of expectations. One former submariner from that era recalled that "they had a central manifold and they had these huge pipes where you could push one button and all of the high pressure air would just go through this big opening to the ballast tank rather than be wire-drawn. Boy, they practiced this thing. Even a Polaris submarine will pop to the surface in practically nothing flat because they had thousands of pounds of high-pressure air going into the ballast tank. It really gave you a real fast ride."[34]

The emergency main ballast tank blow system never would have been developed had the Thresher not been lost. This safety measure, as well as the other safety measures in the Subsafe package and increased quality control criteria in shipyards, was a response by the Bureau of Ships management system to imitate the Rickoverian way of doing things; given political realities, the bureau had no choice. Rickover had convinced the Joint Committee on Atomic Energy that quality control was the key to the matter of avoiding further disaster, and Congress wanted the Navy to do something about it. Rickover was more than willing to expand his influence into the entire realm of submarine development.

Rickover's "never-ending challenge" became the never-ending dilemma of submarine construction for the next quarter-century. Quality control arose again and again as a most difficult issue to resolve between Navy management and private industry. Whether Rickover's emphasis on stringent quality control was necessary for all aspects of submarine construction is irrelevant. The fact remains that his methodology became the cornerstone of submarine development in this country after 1963.

Footnotes for Chapter Three

1. Vice Admiral Hyman G. Rickover, U.S Navy, "The Never-Ending Challenge," speech presented at the 44th annual National Metal Congress, New York, N.Y., October 29, 1962, cited in Thresher hearings (app.), p. 141.

2. Ibid., p. 143.

3. Ibid., p. 144.

4. H.S. Sayre, "Review of Inspection Procedures for HY-80 Submarine Hull Welds," SSIC No. 3960, Serial No. 634B-284, June 13, 1960, cited in Thresher hearings (app.), p. 183.

5. Ibid., p. 184.

6. Ibid., p. 185.

7. Ibid., p. 183. 8. Memorandum from the Nuclear Propulsion Branch of the Bureau of Ships, serial no. 1500-M-1504, February 13, 1962, cited in Thresher hearings, p. 73.

9. Ibid.

10. Letter, Rear Admiral R.Y. McElroy, Jr., USN, chief of legislative affairs, to John T. Conway, executive director, Joint Committee on Atomic Energy, U.S. Congress, July 23, 1963, cited in Thresher hearings (app.), p. 156.

11. Letter, Chief of Naval Operations, serial no. 1356-P-43, August 25, 1961, cited in Thresher hearings (app.), p. 133.

12. Ibid.

13. Ibid., pp. 133-34.

14. Bureau of Ships memorandum of August 28, 1962, cited in Thresher hearings (app.), pp. 134-35.

15. Thresher hearings, pp. 17-18.

16. Axene interview, April 30, 1987.

17. Thresher hearings, p. 20.

18. CNO letter, August 25, 1961, in Thresher hearings, p. 133.

19. Thresher hearings, p. 27.

20. Axene interview, April 30, 1987.

21. Rickover testimony, cited in _Thresher_ hearings, pp. 67-68.

22. _Thresher_ hearings, p. 14.

23. Rickover testimony, cited in _Thresher_ hearings, p. 68.

24. Ibid., p. 71.

25. Ibid., pp. 77-79.

26. _Thresher_ hearings, pp. 102-103.

27. Ibid., p. 47.

28. Ibid., p. 75.

29. Anderson interview, March 1, 1987.

30. Korth and Bayne interview, April 5, 1987.

31. Reported in the _National Observer_, June 3, 1968.

32. _Thresher_ hearings, p. 111.

33. Ibid., p. 112.

34. Oral History of Rear Admiral Charles E. Loughlin, USN (ret.), U.S. Naval Institute (unpublished), p. 299.

CHAPTER FOUR: FOR THOSE WHO MAY SURVIVE

Had the *Thresher*, in its descent toward the bottom, been stopped by some undersea cliff or mountain before passing its collapse depth, the 129-man crew would have been doomed nonetheless. In 1963 the U.S. Navy had no capability for rescuing surviving submariners from sunken hulls beyond the depth of 850 feet. Such was the limit of the McCann diving bell, a product of pre-World War II rescue technology. The fact was that the Navy had been operating submarines for several years before the *Thresher* sinking at depths from which no rescue could have been effected.

The rationale for such a policy is similar to that which allowed engineers to design submarines with insufficient deballasting systems. Within the military framework of logic, it is not unreasonable that deep-sea rescue capabilities were overlooked as submarines began to operate at depths beyond the range of the McCann diving bell. First, let us draw a rough but illustrative analogy.

In management theory, the "rules of thumb" (also known as heuristics) that managers use to make decisions are evaluated in terms of how they affect judgment. Research has shown that, although heuristics are useful in reducing the strains of more complicated reasoning, they also can produce actions that are inconsistent with one's beliefs. One such rule of thumb is called the availability heuristic, in which the recency of a certain event becomes the basis for judging the frequency and probability of similar events. For example, if a person has not been in an automobile accident for twenty years, he is not likely to believe that he will be involved in another one any time soon.

Before the Thresher sank, the Navy community had not experienced a submarine accident in which undersea rescue was an option since May 1939, when the USS Squalus sank off New England in about 240 feet of water. At that time, the McCann diving bell was used with good effect, the trapped crew was rescued, and life in the submarine force returned to normal. If we use the availability heuristic as an analogy to explain the general attitude of Navy management in the 1950s, we may conclude that deep-sea rescue capabilities did not evolve at a pace commensurate with deep-diving capabilities in submarines because they had not been needed for about twenty years. When undersea rescue had been necessary, the McCann diving bell had proved to be sufficient.

The Thresher loss served to underscore the possibility that a submarine could sink to a depth where it would survive intact, yet the crew would suffocate because no means existed with which to recover them. In the aftermath of the worst submarine disaster in history, the Navy committed itself to develop the necessary technology for the rescue of submariners from any depth which their boats could survive.

Two weeks after the Thresher sank, Secretary of the Navy Fred Korth established the Deep Submergence Systems Review Group (DSSRG), chaired by retired Rear Admiral E.C. Stephan, a former Oceanographer of the U.S. Navy. It was assigned to "review Navy plans for the development and procurement of components and systems related to location, identification, rescue from, and recovery of deeply submerged large objects from the ocean floor; to recommend changes to such plans as will result in expeditious improvement and long-range optimization; to develop a five-year program including systems definitions, funding, and personnel requirements; and to recommend organizational means and responsibilities for implementation."[1]

The Navy had never before taken such a comprehensive look at deep submergence capabilities. On March 1, 1964, the DSSRG published an unclassified summary report. It found the two methods for recovering survivors from disabled U.S. submarines--personnel escape without any outside assistance and recovery with the assistance of a rescue chamber tethered to a surface ship--to be inadequate protection for the submarine force. The former method was reliable to a depth of only about 50 feet, and the latter, using the McCann diving bell, was theoretically useful to a depth of 850 feet. "Considering the rescue chamber limitations and the present deployment of submarines and ASRs (submarine rescue ships)," the DSSRG report concluded, "only a small percentage of today's operations are protected."[2]

In addition to several short-term recommendations, the DSSRG urged the development and construction of "a new rescue system consisting of six rescue units of two small submersible vehicles each. This system is to be capable of personnel rescue down to collapse depths of current submarines, independent of weather, surface, or ice conditions, and capable of quickly responding to emergencies at any location in the world."[3] The rescue vehicles were to be transported by either submarine or cargo plane, and the outdated ASR-McCann chamber system was to be phased out as soon as the new system became operational.[4]

The first DSRV, built by the Lockheed Missiles and Space Company, featured a computerized guidance and control system for underwater rendezvous and docking with submarines. Fifty feet in length, the rescue vehicle was designed to descend to a depth of about 5,000 feet. The first DSRV was made up of three eight-foot spheres, made of HY-140 steel, enclosed within an outer, free-flooding hull made of fiberglass. A crew of two or three occupied one sphere; the other two were designed to carry another crewman and survivors from disabled submarines. A metal "skirt" beneath the center sphere formed an airtight lock with submarine hatches. After a connection was secure, water would be pumped from the skirt, hatches would be opened, and personnel could be transferred from a stricken sub to the DSRV.[5]

Problems in the areas of equipment procurement and cost arose with the DSRV project. While the Navy maintained its plans to modify 24 attack submarines (SSNs) to support the DSRVs,[6] it was encountering difficulties obtaining necessary components from private industry, and critics argüed that the expensive DSRV would only be useful in a very small number of submarine accidents.[7]

Ultimately, only two DSRVs were constructed. The _Mystic_ (DSRV 1) was accepted for service on April 11, 1977, almost 14 years to the day after the _Thresher_ went down in the Atlantic Ocean.[8]

The _Avalon_ (DSRV 2) was accepted in January 1978. These craft can operate at depths down to about 5,000 feet, change depth at the rate of about 100 feet per minute, make a top speed of five knots submerged, remain submerged for 30 hours at a speed of three knots, maintain a position in a one-knot current, and mate with a disabled submarine at angles up to 45 degrees. Each unit can bring up to 24 persons to the surface at one time. One of the DSRV units received a potassium superoxide breathing system in 1982, providing a submerged endurance of 480 hours.[9]

Various explanations are given as to why the DSRV project, originally intended to produce twelve rescue vehicles, was reduced to only two. According to one noted authority on U.S naval developments, "a cost overrun of nearly 1,500 percent prevented the procurement of any more DSRVs."[10] Norman Polmar, who worked for Lockheed on the DSRV project in the late 1960s, disagrees that cost overrun was solely responsible for reducing the number of units produced. He claimed that the six planned DSRVs were reduced to two, and that other deep-submergence programs were cancelled altogether, because the Vietnam War was draining money allocated for research and because a Navy diver was killed during an experiment with Sealab III, a deep-sea habitat being tested at the time.

In addition, the Deep Submergence Systems Project Office, responsible for the DSRVs, was involved in some classified programs. One such program was the partially successful deep-sea salvage of a sunken Soviet "Golf"-class submarine by the Glomar Explorer in 1968. Projects of this magnitude also used funds that might otherwise have been spent on additional DSRVs. Along with strains on funding, Polmar said the number of DSRVs were reduced because "the probability of having a rescuable submarine disaster was very small.[11] In other words, the Navy's undersea rescue capability once again came under the scrutiny of the availability heuristic and was nearly managed out of existence.

Dr. John Craven, first director of the Deep Submergence Systems Project Office, characterized the probability of carrying out a deep-sea rescue of a submarine crew as "vanishingly small." According to him, calculations made long before the Thresher disaster showed that deep-diving submarines operate in "rescuable" waters for only short periods of time and that the rescue mission, as such, had little to do with the essential operations of modern-day nuclear-powered submarines. "The rescue mission," Craven explained, "which is really very popular with the public, extremely popular with the Congress...was really what I'd call almost a cover, if you will, for the total deep-submergence activities, most of which were for missions of much more vital impact to the United States Navy."[12]

It was tacitly understood by those in the Deep Submergence Systems Project Office that all the work being done on the DSRVs was satisfying a trivial part of submarine operations. A very sophisticated rescue capability was being developed that had very little prospect of ever being used. Ironically, the deep-sea rescue effort provided the office with a "cover" beneath which it conducted the more important, mission-oriented work at hand. Craven said that

> ...the deep-submergence program was doing a tremendous amount of classified work that is still not made public today. So this (rescue) work was icing on top of a cake -- the real cake. But it looked like the real substance -- that's what we wanted it to do. But it wasn't a deliberate cover, it was a convenient cover upon which to operate.[13]

The manner by which Craven's office conducted its work reflects the dichotomy of needs it had to satisfy: safety and mission. On the one hand, public and Congressional outrage generated by the Thresher disaster demanded that the Navy find a solution to the gap in rescue technology, trivial as it may have seemed from the military point of view. On the other hand, the Navy demanded improvement of its deep-submergence capabilities for reasons of national security, many of which were of a classified nature. Craven said that it was not the Vietnam War, but all of the classified programs, that used the greater part of the budget for his office. While the total budget never really decreased, DSRV production was gradually whittled down from the original complement of twelve units. "I don't know what we would have done with twelve DSRVs," Craven said recently.[14]

Thus, the Navy did not abandon the DSRV program completely, partly because of public pressure and partly because it served as a convenient cover for classified work. Rear Admiral John B. Mooney, Jr., who located the broken hull of the Thresher in 1964 as commanding officer of the Trieste II, was in charge of the deep-submergence vehicles "desk" in the Navy's submarine directorate at the Pentagon when the DSRV numbers were being debated. According to Mooney, construction of the DSRVs was very difficult in that it embodied the application of aircraft technology to deep-ocean work. He advised his superiors that six vehicles would not provide much more rescue capability than two vehicles. The Navy's capacity to transport a DSRV to any place in the world was only so efficient, and the number of available DSRVs would not improve that efficacy. Mooney recommended that the Navy purchase only two DSRVs and build more if necessary. "I think they were surprised that I would come forward with that recommendation," Mooney recalled, "because they knew how involved I was in trying to come up with this (rescue capability).[15]

The DSRVs are intended to operate both with attack submarines fitted to carry them on their decks at submerged speeds up to 15 knots and with the fleet's two Pigeon (ASR-21)-class rescue ships. These ships, designed specifically to support the DSRVs, were built with catamaran-style hulls. This created a center well, or "moon pool," in the ships through which DSRVs could be deployed. A center well creates a more stable environment at sea for the launching of vehicles. The Pigeons were also designed to support saturation diving, which allows Navy divers to work at depths down to about 1,000 feet for long periods of time without decompressing. This saturation method is achieved by means of a pressurized room in the ship which is filled with a helium-oxygen breathing mixture. Divers breathe this mixture at an air pressure that equals the water pressure in which they will work. By remaining in a pressurized environment underwater or in the ship, divers do not have to go through the lengthy process of decompression after each dive.

Saturation diving was another development of the Deep Submergence Systems Project Office. It made extended deep-diving operations--for rescue, search, or salvage--far more efficient. Previously, "hardhat" divers working at a depth of 300 feet required four hours of decompression time. Using the saturation method, Navy divers worked off San Clemente Island at a depth of 1,040 feet for thirty days; after their work was finished, they took ten days to decompress on board a Pigeon-class ship.[16]

DSRV capabilities have been tested many times. In 1979 one unit was flown to Glasgow, Scotland, transported by truck to the Clyde Submarine Base, and attached to the British ballistic missile submarine Repulse. The Repulse then steamed to a simulated casualty, the submarine HMS Odin, bottomed at about 400 feet off the Isle of Arran. The DSRV was launched by the Repulse and recovered at a depth of about 250 feet; the entire operation had taken about 47 hours.[17]

Although the U.S. fleet still has four World War II-era submarine rescue ships in operation (using McCann diving bells with ranges extended to about 1,000 feet) and has no plans to replace these ships before the mid-1990s,[18] progress has been made with the two operational DSRVs and two newer Pigeon-class submarine rescue ships designed to support them. The grandiose plans of the DSSRG to create a fleet of a dozen deep-sea rescue vehicles was never realized. Yet the Navy's ability to rescue submariners has been greatly improved; a gap between rescue depth and collapse depth no longer exists. If a submarine should sink and remain intact, the Navy has the necessary equipment and training to recover them from the sea. Yet only two U.S. submarines (the Thresher and the USS Scorpion (SSN 589) in 1968) have sunk since the nuclear reactor went to sea, at least to the public's knowledge. In both cases, the ships sank in waters far beyond rescue depth. The Navy still has had no need for deep-sea rescue since the McCann diving bell was used to recover the shivering crew of the Squalus.

Footnotes for Chapter Four

1. Report of the Deep Submergence Systems Review Group, Rear Admiral E.C. Stephan, USN (ret.), chairman, NAVEXOS P-2452, March 1, 1964, p. 1 (hereafter cited as DSSRG report).

2. Ibid., p. 3.

3. Ibid., p. 4.

4. Ibid.

5. Interview with Norman Polmar, Alexandria, Va., March 1, 1987.

6. Letter, Deep Submergence Systems Project Office, Department of the Navy, serial number 5720, p. 1, May 29, 1969.

7. Craven interview, April 28, 1987.

8. A.D. Baker III, ed., Combat Fleets of the World, 1986-87, English language edition (Annapolis, Md.: Naval Institute Press, 1986), pp. 672-673.

9. Ibid.

10. Ibid.

11. Polmar interview, March 1, 1987.

12. Craven interview, April 28, 1987.

13. Ibid.

14. Ibid.

15. Interview with Rear Admiral John B. Mooney, Jr., U.S. Navy, Arlington, Va., March 2, 1987.

16. Ibid.

17. Friedman, Submarine Design, pp. 127-128.

18. Baker, Combat Fleets, p. 668.

CHAPTER FIVE: THE AGE OF TELEPRESENCE

In 1960, U.S. Navy Lieutenant Don Keach accompanied the oceanographer Jacques Piccard to a depth of 35,800 feet in the bathyscaph *Trieste*. The submersible was later acquired by the Navy, but its deep-submergence search and location abilities were still very much in their infancy when the *Thresher* sank in 8,400 feet of water. As a result, more than a year passed before the Navy located and photographed the main wreckage of the lost submarine's hull. The frustrations caused by the search impressed upon the Navy that it had an outstanding need for more effective means to find, observe, and recover objects that had come to rest at great depth.

Vice Admiral E.W. Grenfell, who was involved with the initial search for the *Thresher* wreckage, recalled the difficulties of the deepest underwater search ever conducted at the time:

> One of the major problems was that of maneuvering sensors at the far end of a mile and a half of wire beneath a ship--very similar to flying a kite to an exact point in space while blindfolded. It took as long as two hours to get a ship's motion stopped sufficiently to get a clear camera picture. Since the photo width coverage was only 30 feet, it was necessary to navigate accurately to within a 10-yard radius in the open sea in order to return to a desired spot."[1]

In its 1964 report, the Deep Submergence Systems Review Group also recommended substantial improvement of the Navy's underwater search and recovery capabilities. True, the fleet had some equipment at its disposal to investigate and recover objects at great depths, but when such equipment was "used to investigate a specific deep location on the bottom the effectiveness of these equipments is low because it is difficult to position them precisely, especially in adverse currents or weather."[2] Two methods were used to locate and identify the wreckage of Thresher, which lay off the continental shelf in about 8,400 feet of water. The first method employed was the towing of photographic and other equipment on lines from surface ships; the other involved use of the deep-diving bathyscaphs Trieste and Trieste II.

At the time, the Navy had at its disposal one deep-submergence vehicle, the Trieste, located at the Naval Electronics Laboratory in San Diego; it was brought to the East Coast to assist in the search for Thresher. The bathyscaph's operational capabilities were severely limited. It had a descent speed of less than two knots, a bottom endurance of only about four hours, and an effective search width of 100 feet. As the submersible was little more than a deep-diving elevator, it was important to fix the location of the submarine's wreckage as accurately as possible before committing the ill-equipped Trieste to the search.[3]

In September 1963, the Thresher wreckage still had not been located, and search operations were halted until the following year. In the meantime, the Navy built another deep-submergence vehicle and christened it the Trieste II.

The following year, the Trieste II located and photographed the main wreckage of the Thresher. These images showed that the submarine had been torn to pieces by implosion. During the search, the Navy had been helped by nearly every oceanographic laboratory in the country as well as its own major scientific facilities. More than ten oceanographic support ships, such as the Atlantis II from the Woods Hole Oceanographic Institute, worked together for hundreds of hours in the ultimately successful effort to find the lost submarine.[4] It had been a difficult endeavor, one in which no naval force in the world had ever before been engaged and much had been learned from the experience. The Navy claimed that its ability to find and inspect deeply submerged objects had been greatly improved. "Much valuable information for conducting future deep searches was gained from the operations of Trieste II," an official Navy news release said. "It is expected that the systems devised for orientation of Trieste II within a search area will be of great assistance in improving the capabilities of manned deep search vehicles."[5]

In its report, the DSSRG recommended that the Navy "design, construct, and operate two search units with a 20,000-foot-depth capability. Each unit is to consist of two small manned submersible vehicles and a surface support ship. The vehicles are to recover small objects as well as perform search and investigation missions. A prototype good to at least 6,000 feet, as an initial test vehicle, is to be included."[6]

That prototype turned out to be the 16-ton Alvin, operated by the Woods Hole Oceanographic Institute. Still operational, it can carry a three-person crew in a single titanium pressure sphere to a maximum depth of about 13,100 feet.[7]

The Deep Submergence Systems Project Office was also originally assigned the task of developing a deep-search vehicle (DSV) along with the previously mentioned DSRVs. But as difficulties arose in construction and component procurement for the DSRVs, and as funds for the office became more limited, the DSV project was canceled. As an alternative, the DSRVs absorbed the additional deep-search mission and were equipped with side-looking sonars and other instruments by which to carry out deep-search missions.[8]

Eventually, two deep-submergence research craft were developed in response to the DSSRG's recommendations. These craft were follow-ons to the successful Alvin prototype. They are the Sea Cliff and the Turtle, both launched in December 1968. Built by General Dynamics, they displace 29 and 21 tons respectively, are 31 and 26 feet long and about eight feet wide. Using pressure hulls made of HY-100 steel, the maximum depth for each submersible originally was about 6,500 feet. Eleven years later, the Turtle was modified for a depth of 12,000 feet. In 1984, after being fitted with a titanium pressure sphere, the Sea Cliff was certified for descents as far down as 20,000 feet, thereby meeting the DSSRG's recommendation. The Sea Cliff dove to its maximum depth for the first time on March 10, 1985, not quite twenty-two years after the Thresher sank.[9]

Another craft, the nuclear-powered research submarine, NR-1, was the brainchild of Admiral Rickover. He ordered its development as a response to the Navy's need for improved deep-sea search and recovery capabilities. The NR-1 was authorized in fiscal year 1966, laid down the next year by the Electric Boat Co., and brought into active service in 1969. It later became part of the Deep Submergence Systems Project Office's operational assets. The largest deep-sea vehicle ever built in the United States, this submarine measures 137 feet in length and 12.5 feet at the beam, displaces 700 tons submerged, and makes 4.6 knots on the surface (3.6 submerged). It is fitted for all oceanographic missions including bottom recovery. To help in this function, the submarine is equipped with wheels for moving along the ocean floor. It can dive to a depth of more than

2,600 feet and uses television cameras instead of a periscope. A crew of two officers and three men operate the craft; two additional personnel can also be carried.[10] A very successful craft, the NR-1 played a major role in recovering wreckage from the space shuttle Challenger disaster that occurred in January 1986.[11]

The Navy continues to show interest in the further development of deep-submergence craft. The recent investigation of the Titanic wreckage, which produced the first still and video photographs of the fabled sunken luxury liner, was part of a five-year, $2.8 million contract the Navy has with the Woods Hole Institute to develop an unmanned, deep-submergence system. Using the Atlantis II as a support ship, scientists located the wreck (at a depth of about 12,000 feet, half-again the depth of the Thresher wreckage) in the Alvin, then sent the camera-laden robot probe, "Jason, Jr.," into various compartments of the Titanic. It was the first operational test of the newly developed probe, which is 20" high, 27" wide and 28" long. Its titanium shell can be moved in any direction by four propellers powered by electric motors. Neutrally buoyant, Jason, Jr. carries powerful lights to take still photographs and high-resolution color videos. During the Titanic exploration, the probe was tethered to Alvin with a 200-foot, half-inch thick cable. It has been reported that a larger probe with a mechanical arm is being designed for operations this year with another unmanned probe called the Argo. Experts contend that this combination of remotely operated vehicles should be able to reach depths down to 20,000 feet.[12]

The Titanic search signalled the advent of what oceanographer Robert Ballard of Woods Hole describes as "telepresence," the ability of a video-equipped, unmanned deep-submergence vehicle to provide high-resolution images for persons to observe on surface ships via television monitors. Advances in underwater photography will continue to alleviate the need for manned deep-submergence vehicles, at least in the realm of research.

In the realm of combat, human crews will continue to operate the Navy's fleet of attack and ballistic missile submarines. Deep-submergence is a most important element of such operations by virtue of the simple fact that the deeper a submarine can go, the more survivable it becomes. Not only do submarines increase their maneuverabilty with greater depth capabilities, they can also take better advantage of thermal layers in the ocean which can hinder detection by enemy sonar. Most important, deep sea pressure acts as an insulator from external explosions. The deeper a target operates, the more powerful and accurate an anti-submarine weapon must be in order to inflict damage. Dr. John Craven claims that the Soviet "Typhoon" class, built with titanium hulls which have characteristics for resisting sea pressure, operates at such great depths that it is nearly indestructible from attack and could probably be destroyed only if a nuclear warhead exploded very close to the hull.[13]

Craven, currently an instructor at the Law of the Sea Institute at the University of Hawaii, decries the Navy's apparent lack of interest in deep-submergence technology for combat submarines.

> ...we've got a professor who's developed a brand-new radical submarine hull which will (allow us to) build submarines to go to the bottom of the ocean at very, very low cost--nobody's interested. The Navy's not interested, they won't pick it up. The Soviets have run rings around us on the titanium submarine, and are we doing anything on titanium? Not a thing.[14]

Although the Thresher loss had a tremendous influence on the Navy in the development of deep-submergence vehicles for search, observation and limited recovery, such advances have not been applied to the combat submarine force. Few innovations in design have taken place since the sodium-cooled reactor plant was removed from the USS Seawolf (SSN 575). Once Rickover developed nuclear propulsion in the Nautilus, and once he consolidated his authority in the wake of the Thresher disaster, he became more conservative in his approach to submarine design. He actually sacrificed greater depth capabilities in the current Los Angeles (SSN 688) class of attack submarine so that it could accommodate the weight of a new reactor plant.

In the area of deep-submergence research vehicles, the Navy has excelled and the Argo-Jason, Jr. team that turned in such a stunning performance in the Titanic search represent state-of-the-art technology, at least in the public sector. The Navy intends to maintain and improve upon the capabilities it has developed over the past two decades to conduct search, location and observation missions at depths down to 20,000 feet. A recommendation of the DSSRG for large object salvage capability was never realized, except in the special case of the Glomar Explorer. Yet the Navy is satisfied with its current deep-submergence capabilities.[15] If a submarine hull had to be found a mile and a half below the ocean surface, the Navy would have a far easier time of it than its experience in 1963-64 with the Thresher.

Footnotes for Chapter Five

1. Vice Admiral E.W. Grenfell, U.S. Navy, "USS Thresher (SSN-593)," U.S. Naval Institute Proceedings, March 1964, p. 44.

2. DSSRG report, p. 5.

3. Grenfell, "USS Thresher," p. 43.

4. Ibid., p. 44.

5. News release, Office of Assistant Secretary of Defense (Public Affairs), Washington, D.C., Oct. 1, 1964, pp. 1-2.

6. DSSRG report, p. 5.

7. Baker, Combat Fleets, p. 673.

8. Mooney interview, March 2, 1987.

9. Baker, Combat Fleets, p. 672.

10. Ibid.

11. Lieutenant Commander James Holloway III, U.S. Navy, in a talk before the Naval Submarine League, Alexandria, Va., July 11, 1986.

12. Reported in The Roanoke Times & World News, July 17, 1986, p. NRV-1.

13. Craven interview, April 28, 1987.

14. Ibid.

15. Mooney interview, March 2, 1987.

CONCLUSIONS: LEGACY OF A DISASTER

Up to this time, the two most important events in the history of the United States nuclear submarine force were the launching of the USS *Nautilus* and the sinking of the USS *Thresher*. The first event signalled the operational deployment of a major weapons system based upon new technology. The second event marked the application of new management criteria in order to avoid another catastrophic failure of that weapon system. It also marked the moment in submarine history when public and government concerns over the safety of submarine crews forced the Navy to expand the safety margin of its operating forces. Results of this effort, such as the emergency main ballast tank blow system and the deep-submergence rescue vehicle, would not otherwise have been developed under the Navy's traditional mission-oriented criteria.

The story of how the *Thresher* disaster influenced the Navy's submarine force is essentially a story of a fundamental shift in management philosophy. Whereas submarine development was controlled by two competing management systems before 1963, the loss of the *Thresher* served to consolidate the power of Vice Admiral Hyman G. Rickover. His criticism of submarine construction and overhaul methods outside the jurisdiction of the Nuclear Propulsion Branch was applauded by the Joint Committee on Atomic Energy and was popularized among the public through extensive media coverage of the *Thresher* disaster. Therefore, his style of management, which emphasized higher standards of quality control, and his developmental vision, which demanded the use of nuclear propulsion in submarines, became the guiding forces in the submarine community after 1963. By 1968 Rickover had become powerful enough to extinguish a research and development program for a competing submarine design without ever being called to account by higher authority. In 1982, at the age of 81, he still retained such tremendous power that, singlehandedly, he nearly destroyed the attack submarine USS La Jolla and all those on board during the ship's sea trials. This incident finally resulted in his retirement from active duty.

Rickover's attention to quality control stemmed from the extreme caution typically employed in managing nuclear material. To avoid contamination of crew members by radiation and to avoid accidents that might cause a reactor meltdown or explosion, the Rickoverian management system demanded strict adherence to design specifications and proper construction methods.

The fact that Rickover's recommendations were essentially ignored by the Navy Court of Inquiry--which he then took pains to include in the record of the Congressional hearings on the Thresher--demonstrates the competitiveness of the two management systems. The fact that none of the court's recommendations related to deficiencies in nuclear propulsion on board submarines demonstrates the effectiveness of Rickover's politicking. Despite the reluctance of top Navy management to heed Rickover's advice, available documentation tends to show that the Rickoverian system operated with higher standards, worked harder to enforce those standards and was more responsive in correcting known deficiencies.

On the other hand, nuclear reactors experienced problems as well, and if Rickover did not lie outright during the Congressional hearings on the *Thresher*, he was certainly less than frank in not discussing certain difficulties encountered by his organization in developing reliable nuclear propulsion for the fleet. In both his Congressional testimony and his personal behavior, Rickover tried to create as much distance between himself and responsibility for nuclear ship construction at a time when he was making every effort to extend his power throughout the fleet.

Rickover emphasized the importance of nuclear propulsion in submarines beyond all other considerations. Such singlemindedness drew attention from proper consideration of other aspects in submarine design, construction and operations. It also caused him never to admit publicly that the initial failure the *Thresher* experienced during its last dive may have been an accidental scram of its nuclear reactor. The evidence presented by Polmar in two of his books, as well as the fact that the Navy felt it was necessary to locate the "probable" piping failure in the *Thresher*'s engineroom, indicates that nuclear propulsion failure was certainly considered during the Navy's investigations. Yet that aspect is not a matter of public record.

Two decisions of critical importance to nuclear submarine operations were made by the Rickoverian management system in response to the *Thresher* disaster. One was a reduction in the amount of time it took to recover from a reactor scram, the other was to use latent heat within the reactor cooling system for emergency propulsion power. Before the loss of the *Thresher*, Rickover had resisted suggestions from Navy management to make these changes. It is ironic that what may have been the most important effects of the *Thresher* disaster upon nuclear submarine operations are not mentioned in the Congressional hearings.

If Rickover's fault was overzealousness in defending the bureaucratic truths upon which his organization was founded, the leadership at the Bureau of Ships failed to understand that a new weapons system--based upon new technology--required new development criteria as well. Admiral Axene, who commanded the Thresher from the time of its commissioning to four months before it was lost, believes that the Navy may have been moving forward a bit too fast for its own good:

> As frequently happens, in my opinion, the decision to go into uncharted territory sometimes occurs before the technology that'll get you there is fully developed...when you move ahead of the technology, you have an accident. You have an accident, you go back and find out why and do things better.

While Navy management might have done better work in analyzing the potential dangers involved with submarine operations at greater depths, it poured tremendous effort into reviewing its entire program of submarine development and succeeded in making it a better one.

For reasons related to mission, the engineering community reduced deballasting capacity in the Thresher design. As such design trade-offs are guided by military necessity, blame certainly cannot be laid at their door. For some time before the Thresher was lost, it had been understood in the submarine community that if a submarine ran into trouble at great depth which required it to blow ballast, the trouble would probably be too serious to be overcome by deballasting alone. In other words, if a submarine had a chance of making it to the surface, it would do so with the help of nuclear propulsion or it would do so not at all. Mixed together with this understanding is the attitude of the Bureau of Ships in defending its own bureaucratic truth: that its ships were dependable and that its men were trained well enough to handle any emergency. The demons of production schedules and cost effectiveness also were involved. The old deballasting system may have been used because production deadlines did not allow enough time to develop a new one.

Regardless of the rationalizations, both the Rickoverian and Bureau of Ships systems made serious errors in managing submarine development based upon nuclear technology. As previously explained, the availability heuristic was probably operative in the case of rescue technology. But the others are more difficult to understand. Reactors had scrammed often enough to at least stir some debate over recovery time and sources for emergency propulsion; flooding casualties had been frequent enough to generate substantial alarm among the naval hierarchy.

As a corollary, the Navy had not spent much attention on its deep-submergence search and location capabilities because it never had to look for something in 8,400 feet of water before.

If the nuclear reactor in the _Thresher_ did indeed fail, we are faced with the irony that the U.S. submarine force has been shaped over the past quarter-century by the management system responsible for its most catastrophic failure. Yet the essential meaning of the _Thresher_ is that it allowed the Rickoverian management system to overcome opposition among its non-nuclear counterparts and impose stricter standards of quality control in all areas of submarine construction. It also allowed Rickover to extend his personal influence into non-nuclear areas of submarine construction and overhaul.

The _Thresher_ disaster is a most curious example of how public opinion and government pressure combined to modify the principles of warfare by which the submarine fleet operated. The tragic loss of life meant that the Navy would no longer develop its submarine force strictly along such mission-oriented guidelines. Less concern would be paid to production schedules and operational availability. More time and money would be spent on safety features and quality control. Politically, Admiral Rickover immediately grasped the significance of the safety issue and adroitly played both sides. He drew upon his own record of nuclear propulsion management, which by definition was characterized by extreme safety measures, to demonstrate to Congress and to the nation that safety had always been a major concern in his organization. He then selected documents and incidents that highlighted the "unsafe" practices among his Bureau of Ships counterparts: inadequate deballasting capabilities, unflattering quality control reports on submarine construction, and lack of deep-sea rescue technology. Witnesses from the Bureau of Ships were not as well-versed as Rickover in matters of Congressional testimony, and often did not make as strong a case as they could have. Rickover did not come to their aid and, while some of his criticisms were undoubtedly valid, he did just about as much as any individual could at the time to discredit the manner in which the Bureau of Ships went about its business.

In looking for a motive for such behavior, we need to remember that a political struggle took place between the Navy's engineers and "regular" line officers in the early 1940s: the engineers (Rickover among them) lost, and much bitterness was retained among their coterie toward the Bureau of Ships and the political attitudes it represented. In his testimony before Congress regarding the _Thresher_ disaster, perhaps Admiral Rickover saw an opportunity, at long last, for sweet revenge.

Political intrigue aside, the Navy lost no time in correcting the problems exposed by the Thresher disaster and became committed to achieving greater operational reliability in the submarine force. The Rickoverian system responded similarly, but was far more secretive in its undertakings. As a result, it offered far fewer openings for criticism by the Congress and the public.

If the Navy hierarchy did not trust Rickover's judgment implicitly, they at least realized that quality control was the essential key to be mastered in producing more reliable submarines. After 1963, quality control became the untouchable element in submarine construction as long as Admiral Rickover remained at the helm of the Nuclear Propulsion Branch.

The U.S. submarine force still lives within the shadow of the Thresher's hull. Yet as more years go by without catastrophe, the Navy may begin to reduce the safety margin of its operating submarine forces. Quality control standards may start to be relaxed, especially with last year's passing of Admiral Rickover. Many individuals who work in the admiral's organization believe that the nuclear submarine force has averted further disasters only through Rickover's perseverance over the naval bureaucracy and the industrial profit motive. With the force of his personality now missing from the management structure, the attention to detail and the enforcement of high quality control standards may atrophy and operational reliability will suffer once more. Strategic pressures, allied with cost constraints on the defense budget, may force the Navy to build cheaper, less reliable submarines. This policy shift, if effected, will probably continue until the next nuclear-powered submarine is lost at sea.

Advances in deep-sea rescue and deep-submergence capabilities should be more permanent, at least in the area of research vehicles. The DSRVs are only two in number and were most expensive and difficult in their procurement, yet they are operational with trained personnel who conduct rescue exercises and who are ready to go after a downed submarine anywhere in the world. The development of deep submersibles for search, observation and recovery was accelerated by the Thresher search and continues at a healthy pace. Such development stands on the edge of a new era of "telepresence" that was so dramatically illustrated in 1986 by the discovery of the Titanic wreckage. If the Navy harbors the desire to apply new deep-submergence technologies, such as titanium-hull construction, to combat submarines, its chance to do so is greater now that Admiral Rickover is no longer an active force in the naval community. If Soviet advances in this area are as substantial as some authorities claim, then circumstances should clearly dictate, at least logically, the Navy's response.

Both Rickover and the Thresher will remain partially wrapped in mystery until much more of the official record is declassified and open to scholars for examination and interpretation. Then, a clearer picture may emerge of how the loss of a nuclear-powered submarine in 1963 changed the essential character of the U.S. submarine force for the remainder of the 20th century.

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