Missiles & Misconceptions: Why We Know More About the Dark Side of the Moon than the Depths of the Ocean

by

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We shall not cease from exploration
And the end of our exploring
Will be to return where we started
And know the place for the first time.

— T.S. Eliot

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1 Introduction

We know less of the oceans at our feet, where we came from, than we do of the sky above our heads.

— President John F. Kennedy, 1963

We know more about the dark side of the moon than the depths of the ocean. This is startling, considering how much more tangible the ocean is than space, and more importantly, how much more critical it is to the health and survival of humanity. Tens of billions of dollars are spent on manned and unmanned missions probing deeper into space, while 95% of Earth's oceans remain unexplored.[1] The result is a perilous dearth in knowledge about our planet at a time when rapid changes in our marine ecosystems profoundly affect its habitability.

The more intensive focus on space exploration is a historically recent phenomenon. For millennia until the mid-20th century, space and ocean exploration proceeded roughly at the same pace, driven by curiosity, military, and commerce. Both date back to early civilization when star-gazers scanned the skies, and sailors and free-divers scoured the seas. Since the 1960s when Don Walsh and Jacques Piccard descended to the deepest point on the ocean floor, and Neil Armstrong ascended to the moon, however, the trajectories of exploration diverged dramatically. Cold War-inspired geopolitical-military imperatives propelled space research to an extraordinary level, while ocean exploration stagnated in comparison. Moreover, although the Cold War ended more than 20 years ago, the disparity in effort remains vast despite evidence that accelerating changes in our marine ecosystems directly threatens our wellbeing.[*] Misconception about the relative importance of space and ocean exploration caused, and continues to sustain, this knowledge disparity to our peril.

In the following section, we review the history of space and ocean exploration

[*] See the 2014 United Nations Climate Change Report. Alan B. Sielen also gives an overview of the ocean's poor health and it's repercussions in "See Change" (*Foreign Affairs.* 16 Apr. 2014. Web. 29 Apr. 2014).

before the Cold War, when the pace of exploration in each sector was more or less comparable for thousands of years. We show in section 3, however, how the relative paces and trajectories of exploration diverged dramatically during the Cold War and continue to the present. In section 4 we seek to dispel the persistent misconceptions that have led to the disparity in resources allocated between space and ocean exploration, and argue for prioritizing ocean research. Finally, in section 5 we highlight the urgent imperative for expanding our understanding of the ocean.

2 Pre-Cold War History of Space and Ocean Exploration

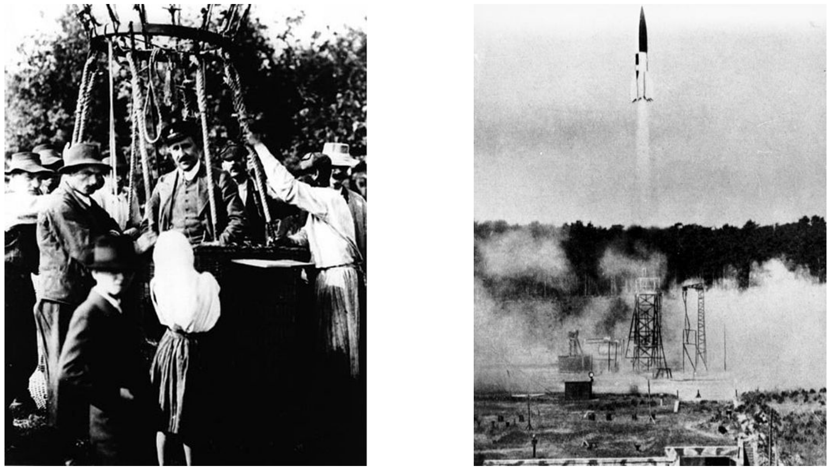
Science unfolded her treasures and her secrets to the desperate demands of men, and placed in their hands agencies and apparatus almost decisive in their character.

— *Winston Churchill, reflecting on WWI*

Space and ocean exploration proceeded at similar paces until the 1950s, when the Cold War commenced. The first star-gazers created maps of the heavens based on carefully observed patterns. During the Renaissance, they built telescopes and rockets to probe even deeper into space. Early sea explorers took to the seas for food, transportation, and military conquest. As early as Alexander the Great's era, they used technology to dive deeper and longer. Understanding of the sky and sea were tied, especially in ancient Egypt, because the stars informed navigators at sea and could predict tides and the agricultural seasons.

2.1 Early Star Gazers

The earliest space explorers were star-gazers, driven by curiosity, spirituality, and the need for an agricultural calendar. The world's oldest observatory, known as the Goseck circle located in modern Germany, dates back to 4900 BC.[2] Openings on the structure aligned with the sunrise and sunset of the winter and summer solstices, and it likely served as a place for celestial worship and as a calendar.[3] Ancient Egyptians also observed the sky to predict floods and schedule plantings.[4] The Nebra sky disk, dating from 1600 BC, contains the oldest known depiction of an astronomical phenomena and was found not far from the Goseck circle.[5] Likewise, the ancient Mesopotamians, as well as the Inca, Maya and Aztecs, were famously sophisticated star gazers.



(a) (b)

Figure 1: (a) Victor Hess (center) returning from his 1912 balloon flight, during which he discovered cosmic rays. (Credit: American Physical Society) (b) Launch of German V-2 in 1943; the developers of the rocket gave their knowledge to the US at the close of WWII as part of Operation Paperclip, which helped to launch the Cold War-era Space Age. (Credit: German Federal Archives)

In the 2nd century BC, the Greek astronomer Eratosthenes furthered a mathematical understanding of heavenly bodies when he measured the earth's circumference based on the sun's relationship to the earth.

Scientific understanding of the solar system spiked during the Renaissance. In the 16th century, Polish astronomer Nicolaus Copernicus provided a full mathematical description of the heliocentric system, later corroborated by the Italian physicist Galileo Galilei. Meanwhile, Galileo improved the telescope for astronomical observations, and used the device to discover moons of Jupiter and the craters on earth's moon, among other celestial phenomenon. In late 17th and early 18th century England, Sir Isaac Newton and Edmond Halley, among others, developed scientists' understanding of planetary orbits and arrangements, and improved telescope optics pioneered by Galileo to facilitate the discovery of new heavenly bodies.

We gained most of our knowledge of space during the 20th century, however, with the aid of technological advances in photography, telescopes, imaging across the electromagnetic spectrum, and rocketry. In 1912, the Austrian-American physicist

Victor Hess rode a balloon up to 5.3 km and collected data that proved the existence of cosmic rays. In 1924, using the world's largest telescope, American astronomer Edwin Hubble proved the existence of galaxies other than our own Milky Way.

Rockets eventually brought us to Space Age as we know it, enabling man to reach the moon and beyond. Rockets for military and recreational use date back to at least 13th century China,[6] although scientific, interplanetary, and industrial use did not start until the 20th century, thanks to the pioneering work of Konstantin Tsiolkovsky, Robert Goddard, Hermann Oberth, and their successors.

Tsiolkovsky, inspired by the fictional works of Jules Verne,[7] in 1903 established the principals of rocket motion in his publication "Exploration of Cosmic Space with Reactive Devices." He had difficulty funding his work, however, until the aftermath of WWI, showing the increasing relationship between geo-politics and science funding.[8]

After WWI, the Soviet government faced a paradox in encouraging scientific research. As author Walter McDougall explains,

> From the moment of seizing power in 1917, the Soviet leadership fell into debate over the proper role of science and technology, and especially scientists and technicians, in the building of Communist society. No previous government in history was so openly and energetically in favor of science, but neither had any modern government been so ideologically opposed to the free exchange of ideas, a presumed prerequisite of scientific progress.[9]

Nonetheless, the Soviets pushed scientific research, especially in space and especially for military purposes. After signing the Treaty of Brest-Litvosk that pulled Russia out of WWI, Vladimir Lenin proclaimed: "The war taught us much, not only that people suffered, but especially the fact that those who have the best technology, organization, and discipline, and the best machines emerge on top.... It is necessary to master the highest technology or be crushed."[10] Thus, he campaigned for science and technology research for military application. Accordingly, after meeting with one of Tsiolkovsky's pupils, Lenin supported the establishment of the Central Bureau for the Study of Problems of Rockets (TsBIRP) and the Study of Interplanetary Communications (OIMS) in 1924. With this move, the Soviet Union was the first government to endorse the goal of spaceflight.[11] Other countries followed suit, with the founding of the American Interplanetary Society in 1930, the German Verein für Raumschiffahrt (VfR) in 1927, and the British Interplanetary Society in 1933. In response to the competition, Soviet R& D spending *sextupled* between 1927 and 1932.[12]

It should be noted that at this point in history, ocean exploration was at the same stage (see Section 2.2), as warring countries actively pursued submarine research and new diving methods. The US, for example, established the Navy Experimental Diving Unit in 1927, and the British Royal Navy lead the Challenger survey ship in 1931 (more discussion in Section 2.2).

The American Robert Goddard, who published his treatise on rocketry in 1919, and the German Hermann Oberth, who wrote his thesis *The Rocket into Interplanetary Space* in 1923, also helped to lay the foundation for these agencies devoted to space and rocketry research. They set the groundwork for the German scientists that developed V-2 rockets, the world's first long-range ballistic missiles. Germany's V-2 rockets, developed during WWII, became the starting point for the development and launching of satellites and manned spacecraft a little more than a decade after WWII. Author Walter McDougall describes the role the V-2 rocket played post-WWII:

> Only a pure determinist could designate the V-2 a sine qua non of the origins of the Space Age in our time. What the German engineers did with their clever fabrication of what seemed even in World War II a "baroque arsenal," was to prod their enemies to the East and West into premature fear and rivalry, and to make themselves and their blueprints the most prized spoil of war.[13]

The US inherited many German rocket scientists as part of Operation Paperclip post-WWII (see Section 3.1). These scientists, with their knowledge and expertise gained from developing the V-2, helped ignite the US space program before the Soviets' Sputnik launch. The Cold War followed suit, fuelling the space program at a ferocious rate.

2.2 Sea Explorers

For millennia, ocean exploration was mainly a surface affair largely driven by commercial and military interests.

Around 4000 BC, Egyptians developed sailing vessels for the Nile River and east Mediterranean.[14] Also starting in 4000 BC, the Polynesians, known as experienced sailors, colonized the South Pacific Islands. These early sailors used the stars to navigate, so their knowledge of the sea was tied with their knowledge of space and it is no coincidence that the first maps of the sky date back to this period.

Sailors pieced together maps of the oceans throughout the following centuries. Around 600 BC, Phoenicians developed sea routes around the Mediterranean, Red Sea, and Indian Ocean, and they sailed around Africa to England. By 150 AD, the Greco-Roman geographer Ptolemy produced a map of the known world, including the continents of Asia, Europe, and Africa and the surrounding oceans.

The sea was largely a place for military conquest. The earliest recorded naval battle was in 1210 BC, when the Hittites defeated the Cypriots near Cyprus, and naval battles continue to the present. From the late 8th to 11th century, the Vikings settled wide areas of Europe, Asia, and the North Atlantic as far as North America using wooden longships. In early 1400, the Chinese admiral Zheng He led maritime expeditionary voyages to Southeast Asia, South Asia, the Middle East, and East Africa to impress neighbor states and explore new unknown regions.

Likewise, commerce and military imperatives drove humans underwater. Yet technology severely limited our scope of exploration. Humans free-dove underwater as early as 3000 BC, motivated by the prospects of finding food, sponges, corals, mother-of-pearl, and salvaged items.[15] They used weights to speed their decent, allowing them to reach depths of up to 30 m for as long as 5 minutes.[16]

Divers also used reeds as snorkels and animal skins as breathing sacks. A 900 BC Assyrian frieze gives the oldest evidence of divers using devices to assist breathing

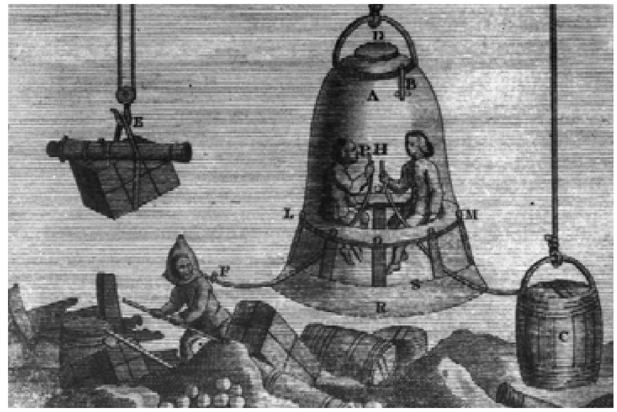
Figure 2: Assyrian Frieze from 900 B.C., depicting an ancient diver breathing from an inflated animal skin. This frieze was excavated in 1845 from the palace of Nimrud in modern Iraq (Credit: U.S. Navy Diving Manual).

underwater (Figure 2).[17] The problem with ancient diving devises, such as snorkels and breathing sacks, however, was that at a depth of just one meter, it is nearly impossible to breathe through a tube using only the body's natural respiratory ability, as the water exerts a total force of almost 90 kg on a diver's chest. In addition, breathing sacks require the diver to wear a significant amount of added weight to compensate for buoyancy. And thus, humans turned to more advanced technology.

The ancient Greek historian Herodotus recorded the first-known military diving operation by a Greek named Scyllis. In about 500 BC, Scyllis escaped imprisonment by the Persian King Xerxes I by jumping into the Gulf of Malis and breathing through a hollow reed as a snorkel. Not only did he remain undiscovered by Xerxes's men, but he also managed to cut each of the Persian's ships loose from their moorings, saving the Greek flotilla from attack. And thus, diving, not just ships, was important to military operations.

The diving bell allowed humans to dive longer and deeper. The diving-bell is a structure that encloses a diver and air underwater, similar in concept to a bucket flipped upside-down and pushed underwater. The Greek philosopher Aristotle referred to the first diving bell on record in 332 BC, when Alexander the Great used a diving bell in the siege of Tyre (Figure 3a).[18] Since Alexander the Great's time,

(a)



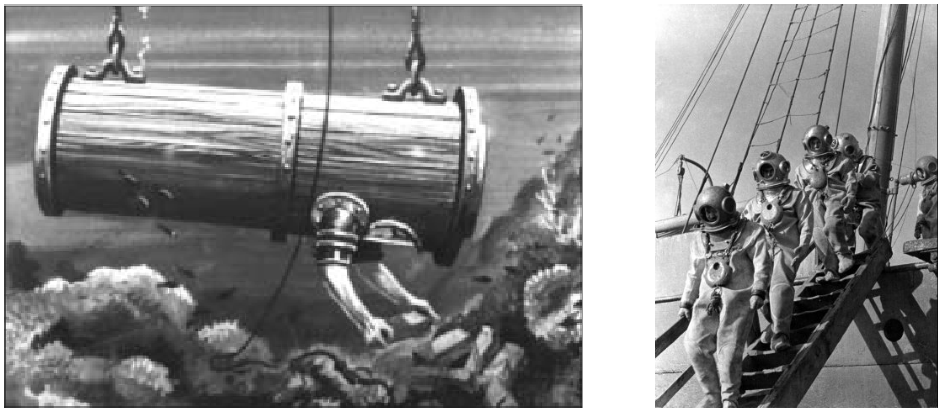
(b)

Figure 3: (a) 14th century depiction of Alexander the Great descending in an early diving-bell, circa 332 BC (Credit: Oxford University Bodleian Library). (b) 19th century diving bell (Credit: Hulton Archive/Getty Images)

diving-bell designs improved. They began including a weighted pulley system to lower the bell and barrels of supplementary air to the divers (Figure 3b).

After the diving bell came the more versatile diving dress. In 1715 AD, John Lethbridge designed the first diving dress[19] (Figure 4a), which resembled a diving bell with arm-holes. By the mid-1800s, however, the dive dress evolved into a versatile suit suitable for commercial and military applications[20] (Figure 4b). The dive suit, for example, enabled the construction of New York's Brooklyn Bridge in 1869-1883.[21]

From 1872 - 1876, the Royal Society of London lead the *Challenger* expedition, using a warship from the Royal Navy converted to research vessel. This scientific voyage laid the foundation of oceanography. Under an order from Her Majesty's government, the researchers then published the *Report Of The Scientific Results of the Exploring Voyage of H.M.S. Challenger during the years 1873-76* which, among many other discoveries, catalogued over 4,000 previously unknown species.[22] In addition, scientists aboard the *Challenger* publised subsequent scientific accounts, including "The Science of the Sea" by The Challenger Society, "The Dephts of the Ocean" by Sir John Murray and Dr. Johnan Hjort, and "The Ocean" by Sir John Murray.[23] The *Challenger* mission brought Great Britain enormous pride, and it seemed ocean



(a) (b)

Figure 4: (a) 18th century diving dress designed by John Lethbridge (Credit: U.S. Navy Diving Manual). (b) Russian Navy divers in early 20th century diving dresses (Credit: Ivan Shagin/Hulton Archive).

exploration was in an excellent state. As one one *Challenger* shipmate wrote,

> [I]n the past fifty years [since 1926] man has for the first time in history set himself to explore thoroughly the globe he lives on. That the ocean has received good attention is proved by the fact that up to 1912 about 6,000 soundings have been made in depths greater than 1,000 fathoms. Of these, 491 were in depths greater than 3,000, and 46 in depths greater than 4,000 fathoms.[24]

In the following century, the US in particular made great strides in improving diving equipment, in large part thanks to the United States Navy Experimental Diving Unit (NEDU) established in 1927. The group improved diving decompression tables, wrote the first United States Navy Diving Manual, and studies the physiological effects of deep sea diving, including nitrogen narcosis and oxygen toxicity. They also discovered adding helium to a diver's breathing gas mixture could reduce the negative effects of diving. Funding for the diving program came, in large part, because of the possibility for diver's to salvage US and enemy submarines. In addition, during WWII divers sunk battle ships, guided torpedoes, and disposed of bombs.[25]

In 1943, Jacques Cousteau and Emile Gagnan invented the Aqua-Lung, which closely resembles modern the modern Self-Contained Underwater Breathing Apparatus (SCUBA). Their invention used the demand regulator, which could match the pressure of supplied air to the surrounding environment, and a closed-circuit breathing system, both developed firstly for military applications.

Simultaneously, submarines evolved from dive bell-like contraptions, to human powered and then electric-powered systems. The Germans installed the first diesel engine on a submarine in 1912 with their U-19 class submarines, and proceeded to develop the feared German U-boats of WWI and WWII.

Submarines and robotic technology eventually brought two men to the deepest point in the ocean (see Section 3.2), but in the following decades, nations' sights and pocketbooks turned sharply to space rather than the sea. Global leaders feared "The meek will inherit the earth. The rest of us are going to the stars"[26], and so the earth and ocean were left behind post-WWII. Section 3 highlights the widening gap in space and ocean exploration, making T.S. Eliot's words ring true: "the end of our exploring / Will be to arrive where we started / And know the place for the first time."

3 Cold War & Beyond

Knowledge of the oceans is more than a matter of curiosity. Our very survival may hinge upon it.
— President John F. Kennedy, message to Congress 1961

Both space and the ocean became "more than a matter of curiosity" to the US in the decades succeeding World War II. Space received the bulk of research attention, however. The differential was in large part due to the German advancement of rocket technology during WWII and its consequent potential for missiles in space. With the late WWII development of rocket-propelled missiles, technology that was appropriated by both the US and Soviet Union, space became a frightening new stage for war and geo-political competition. Both the US and Soviet Union turned their sights and ambitions toward space, spending lavishly in competition with each other.

To focus its efforts after the shock of Russia's Sputnik launch, the US government created an independent, heavily-funded agency for space research to compete with its Cold War-era enemy in this new arena. That agency, the National Aeronautics and Space Administration (NASA), brought knowledge of space to what it is today. Ocean exploration, on the other hand, presented neither a new nor a pressing military need. It had been militarized since the age of states, first with warships and then with submarines. Accordingly, the US government left responsibility for ocean research to a conglomerate of existing agencies that were poorly structured and ill-funded. The National Oceanic and Atmospheric Administration (NOAA) became the closest equivalent to a "wet-NASA,"[27] although ocean exploration was, and continues to be, conducted through a myriad of public and private ventures.

The organization of the US space effort, compared to the relative dis-organization of the US ocean effort, contribute greatly to the fact that we know more about the dark side of the moon than the depths ocean.

3.1 Pre-NASA

> *We can see no more clearly all the utility and implications of spaceships than the Wright brothers could see fleets of B29s bombing Japan and air transports circling the globe.*
>
> — *RAND Report No. SE11827, May 2, 1946*

The origins of the US military space program trace back to the feasibility studies the armed services conducted at the end of World War II. The influx of German rocket scientists and surplus V-2 rockets that came into the US post-WWII as part of Operation Paperclip helped to catalyze research in spacecraft, or at least the drafting of feasibility reports.[28] Space-related projects shuffled between the Naval Research Laboratory (NRL) and the Army Air Force until the Soviet Union shocked the world with the launch of Sputnik, spurring the US to create an organized space program.

Post-War Feasibility Reports on Rocketry & Satellites

Wernher von Braun, one of the leading rocket scientists of Nazi Germany, was one of select German scientists transferred to the US as part of the then-secret Operation Paperclip. Shortly after his arrival in the US in 1945, he deftly predicted:

> The whole of the Earth's surface could be continually observed from such a rocket [in Earth's orbit]. The crew could be equipped with very powerful telescopes and be able to observe even small objects, such as ships, icebergs, troop movements, construction work, etc.[29]

It took over a decade for von Braun's prophecy to materialize, however. Commanding General H. H. Arnold in his 1947 "War Report" recommended that the Army Air Force pursue further development of long-range rockets and artificial satellites. He foresaw a need to "launch them [rockets] from unexpected directions," and thought the design of such a launcher was "all but practicable today; research will unquestionably bring it into being within the foreseeable future."[30]

Yet, proponents for space research, including not only von Braun and General Arnold but also, notably, the Army Air Force Scientific Advisory group, did not get the support necessary to seriously pursue research.[31]

As early as 1945, the Naval Research Laboratory (NRL) began to review the technical feasibility of satellites, incentivize in large part by the Bureau of Aeronautics (BuAer) and in particular Commander Harvey Hall of the Bureau's Electronics Division, who later became chief scientist of NASA's Manned Space Flight Program.[32] After forming the Committee for Evaluating the Feasibility of Space Rocketry and commissioning feasibility studies from the Guggenheim Aeronautical Laboratory, Glen C. Martin Company, North American Aviation, and Douglas Aircraft Company, the Navy, represented by Commander Hall, concluded that the only financially viable way for them to pursue space research was through a cooperative venture with the Army Air Force.[33]

The Aeronautical Board, yet another government body involved in early research, assumed responsibility for negotiating the proposed research cooperation between the Navy and Army Air Force. The Air Force, to the Aeronautical Board's dismay, responded that they found "no obvious military, or purely naval applications to warrant the expenditure [of space research]."[34] With so many frowns at the expense and questionable utility of space research, it might have halted right there. Navy-Air Force rivalry, however, brought the program back to life.

When the office of the Commanding General Army Air Forces heard of the Navy's joint-research proposal, it decided, in the words of Robert Perry, that "the position of the air force in an interservice conference would be compromised unless its representatives could produce a paper demonstrating equal competence with the Navy–and equal interest–in space research." Moreover, even though the Air Force rejected the notion of collaborating with the Navy, the Commanding General's office felt that space was "essentially an extension of strategic air power," and therefore they should have claim to research in that area.[35] As a starting measure, General Curtis LeMay, then director of R& D for the Army Air Force, commissioned yet another feasibility report on space research. The report, drafted in 1946 by the Douglas Aircraft Company and its Project RAND, became one of the most important documents in early space research. The 321-page "Preliminary Design of an Experimental World-Circling Spaceship" (refered to as the "RAND report"), produced in just three weeks, dealt primarily with the technical challenges of building and launching a satellite. Regarding military applications, the report modestly concluded that "full military usefulness of this technique cannot be evaluated today," although it mentioned potential major military benefits of satellites, including reconnaissance, communication, missile guidance, attack assessment and weather forecasting.[36] Little did the authors, and administrators, know that in just a few decades satellites would provide services essential to a successful military, of exactly the kind mentioned in the RAND report.

Project Vanguard

The first dedicated US military space program was the development of the WS-117L reconnaissance satellite in 1954 by the Air Force.[37] The project was overshadowed, however, by the Naval Research Laboratory's Project Vanguard, started the next year, which aimed to launch the first artificial satellite into orbit using a Vanguard rocket.

Meanwhile, while the Navy and Air Force satellite programs were in their infancy, the Cold War was heating up. On July 29, 1955, the White House announced it intended to launch satellites by the spring of 1958, through Project Vanguard. Just two days later, the Soviets announced their intention to launch a satellite by the fall of 1957—a menacing half year before the US.

Rushed, the Vanguard rocket exploded during its first test in December 1957, after rising only four feet. The failure was embarrassing and worrisome for the federal

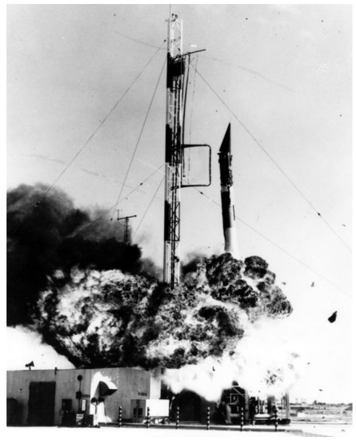


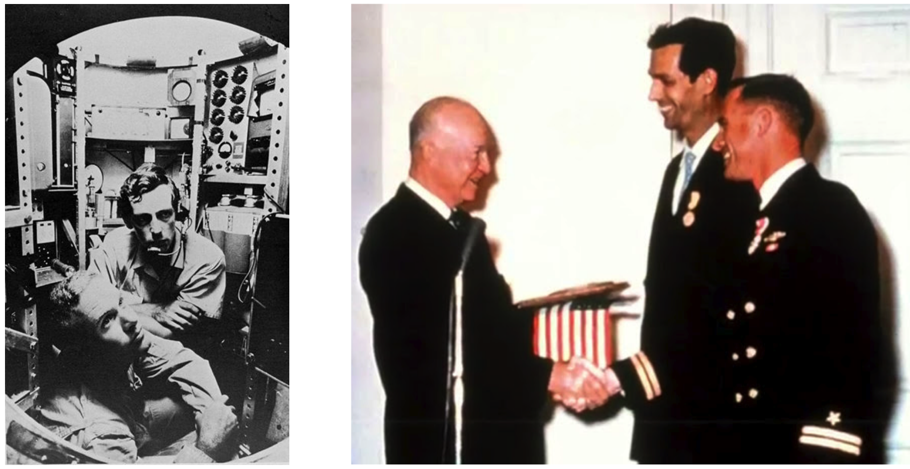
Figure 5: Dubbed “kaputnik,” “puffnik,” and “stayputnik” by the press, the Vanguard rocket exploded during its first test launch in December 1957, much to the Naval Research Laboratory’s embarrassment. (Credit: U.S. Navy)

government in the wake of Sputnik, which the Soviets launched successfully in October of that year. Rubbing salt on the Naval Research Laboratory’s wounded pride, the press (appropriately) dubbed Vanguard “kaputnik,” “puffnik,” and “stayputnik.”

In the words of author Paul Stares, the early days of the US space program were “hindered by a combination of factors, principally political indifference, military conservation, interservice rivalry and the austerity of the post-war defense budgets.”[38] In addition, there were problems at the onset as to whether space research should be pursued from a military or scientific standpoint, and therefore by a civilian or military department. These problems were “barely surfacing,” as Paul Stares stated, when the Soviet Union shocked the world with the launch of the first artificial satellite *Sputnik 1* on October 1957, however. “It was only with the shock of this Soviet achievement that the United States became sufficiently motivated to support a substantial space effort, reported Stares.[39]

3.2 Pre-NOAA

President Kennedy set the nation’s sights on the moon in a historic May 1961 speech to Congress, during which he made the ambitious goal of sending an American



(a) (b)

Figure 6: (a) Don Walsh (left) and Jacques Piccard (centre) in the bathyscaphe *Trieste*, where they descended to the deepest point in the ocean in 1960 (Credit: Steve Nicklas, NOAA Ship Collection). (b) President Eisenhower honoring Walsh and Piccard for their accomplishment. (Credit: John E. Fletcher).

safely to the Moon before the end of the decade. Shortly before, in a lesser known speech to Congress, Kennedy made another ambitious request: He asked Congress to nearly double the nation's budget for ocean research and to spend more than $2 billion over the next decade on Earth's "inner space."[40] It was during this speech that he said, "Knowledge of the oceans is more than a matter of curiosity. Our very survival may hinge upon it."[41]

Although Kennedy's request was never fulfilled, it coincided with a few major strides in ocean exploration supported by the US government, including the deployment of the *Trieste* and *Thresher* submersibles, a record-breaking dive to 1000 ft, and the constructions of the SEALAB underwater habitats. In addition, other governments and private organizations, particularly in France, Germany, and the USSR, made similarly great strides in ocean exploration.

The Submersible *Trieste*

Under a grant from the Office of Naval Research (ONR, established in 1946), the US Navy purchased *Trieste*, a Swiss-designed, Italian-built bathyscaphe from the

French Navy in 1958.[42] Two years later, the submersible brought the first humans—Swiss oceanographer Jacques Piccard and US Navy Lieutenant Don Walsh—to the deepest point in the ocean, the Mariana Trench (Figure 6).

Author Ben Hellwarth called the mission "the inner-space equivalent of a moon-landing,"[43] although the landmark achievement never captured the country's attention like the moon-landing did. President Eisenhower congratulated the pioneers (Figure 6(b)) and their story made the front cover of *LIFE Magazine* under the fantastical headline "Achieving the Ultimate Adventure on Earth."[44]

Yet, the nation's budget for ocean exploration did not change significantly, nor did other countries, to historian's knowledge, attempt to join, or start, a "race to the ocean." In other words, *Trieste*'s mission did not spark a fervor for the oceans like *Sputnik* did for space. Perhaps this was because the mission was not tied to nationalism, as it was from the beginning a joint project between Switzerland, Italy, France, and the US Navy. The bathysphere pilots, for example, brought down both US and Swiss flags (in President Eisenhower's hand, Figure 6(b)), but they could not plant them on the ocean floor, as the astronauts did on the moon, nor did they have the ability to in any way leave their capsule. In addition, they could not take pictures of, or clearly see, anything on the ocean floor because their vision was impaired by a cloud of sediment when they hit the ocean floor.[45] Moreover, even with the bright lights mounded on the submersible, it was difficult to see anything in the deep ocean, which is pitch black past about 200 m. Walsh later told the Daily Mail, in a not-quite reassuring account of life in the deep, "Just before we reached the bottom we saw a fish like a sole or halibut–it was about a foot long and white-ish coloured. It was just a quick glimpse but if there was one, there would be others as well."[46]

Also, with *Trieste* the Navy demonstrated that it was capable of handling such projects, and therefore there was seemingly no need to create an independent organization for ocean research. This differs from the government's situation regarding space exploration, where there was a clear need to create NASA for space research after the Naval Research Laboratory failed, very publicly, on Project Vanguard. Therefore, post-*Trieste* ocean research in the US continued primarily within the Navy, but also from within a conglomeration of other agencies, including the Department of Interior, industry sponsors, and later NOAA.

The Submersible *Thresher*

The same year the Navy purchased *Trieste*, it began constructing the nuclear-powered submarine *Thresher*. The most advanced submarine of its time, *Thresher* was faster, quieter, and able to dive deeper than any other submarine. In 1963, however, the submersible was lost at sea, killing 129, in tragedy that remains the deadliest submarine disaster in history.[47] The watershed event lead the Navy to establish the Deep Submergence Systems Review Group to develop what author Ben Hellwarth called "a five-year blueprint to nudge the nation's undersea know-how into the space age."[48]

Kennedy responded to the tragedy at the National Academy of Sciences by asking for the US "to use to the full our powerful new instruments of oceanic exploration, to drive back the frontiers of the unknown in the waters which encircle our globe."[49] Kennedy's plea, in addition to the establishment of the Navy's Deep Submergence Systems Review Group, seemed to be putting the nation on an ocean-exploration track similar to that of space-exploration.

In a October 22, 1963 speech to the National Academy of Sciences, Kennedy continued his call for national ocean exploration, and tied the cause to security and economic needs, as was done for the space program:

> I can imagine no field among all those which are so exciting today than this great effort which our country and others will carry on in the years to come. We need this knowledge for its own sake. We want to know what is under the sea, and we need it to consider its bearings on our security, and on the world's social and economic needs.

Regrettably, Kennedy did not get to see his plans through because he was assassinated exactly a month later, on November 22, 1963. Thus, another tragedy not only shocked the world, but further stymied the cause for ocean exploration.

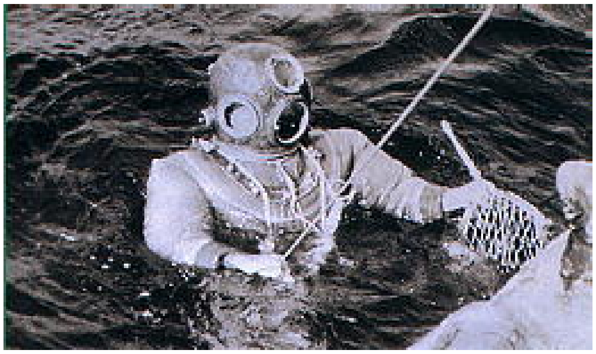
Keller's 1000 ft Dive

Just a year before *Thresher* was lost at sea, another tragedy befell ocean exploration. In 1962, Swiss mathematician Hannes Keller and British journalist Peter Small made the first 1000 ft dive, funded by the Navy and the Shell Oil Company. The two divers hoped to demonstrate methods that would make deep diving safer and more practical. They barely had time to exit their diving bell and place Swiss and American flags on the seafloor, however, when both Keller and Small blacked out. Keller survived, but Small and a 19 year-old rescue diver named Chris Whittaker lost their lives. [50]

From the Keller-tragedy onward, the Navy gave only "lukewarm" support to saturation diving and other experimental diving techniques.[51] The quest to live and work undersea continued, however.

Genesis & The Experimental Diving Unit

Starting in 1957, funded by the Office of Naval Research (ONR), Captain George Bond (Figure 3.2(b)), known as the "Father of Saturation Diving," led a set of pioneering experiments proving that humans could withstand the prolonged exposure to different breathing gases and increased atmospheric pressures that they would face undersea.[52] Final rounds of the experiments were completed in the Navy Experimental Diving Unit (NEDU), which the Navy established in 1927 to conduct research in diving for applications ranging from submarine-rescue to deep-sea exploration. Besides hosting Bond's experiment, NEDU's main accomplishments were researching the effects of oxygen toxicity, revising diving decompression tables, dis-



(a)

(b)

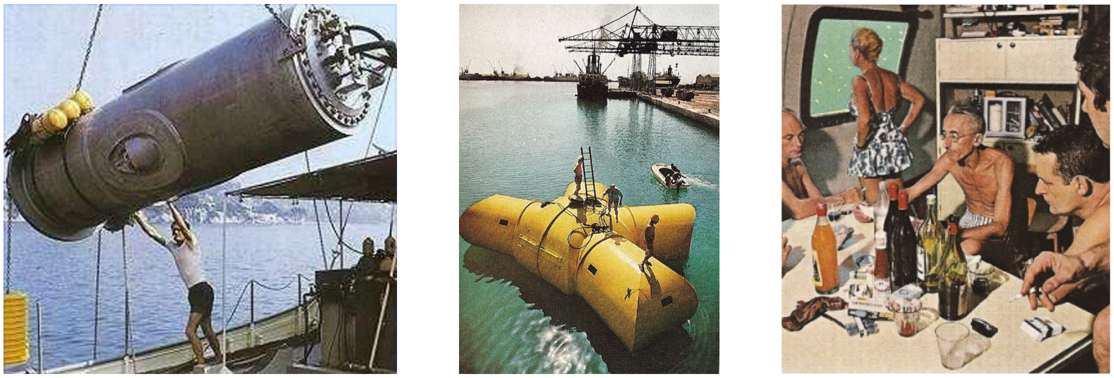
Figure 7: (a) Dive suit researchers at the Navy Experimental Diving Unit helped to develop and improve (Credit: Credit: Sandra Hendrikse & Andre Merks). (b) Drs. Walter Mazzone (left) and George Bond (right) in SEALAB I's Communication Center (Credit: US Navy).

covering helium as a diving gas, and transitioning standard Navy dive suits (Figure (a)) from the Mark V helmet to modern SCUBA systems.[53] The NEDU was, in some ways, the ocean counterpart to the US Bureau of Aeronautics (BuAer) referred to in Section 3.1, showing how how ocean and space were on equal footing before the heat of Sputnik.

Undersea Habitats

Bond went on to lead the design and construction of America's first undersea habitat, SEALAB I. Constructed from minesweeping floats recycled from a Navy salvage yard, SEALAB started in many ways as a shoestring operation. Bond began designing the structure and recruiting aquanauts even before receiving formal Navy approval.[54] The Navy Mine Defense Laboratory took on the project, however, from the Office of Naval Research.

In 1964, the four SEALAB I aquanauts lived underwater for 11 days at 58 m and completed tasks, such as salvage and maintenance work, that would have required a year using conventional surface dives. Despite limited funding, SEALAB I was "successful beyond expectation" according to the assistant secretary for research and



(a) (b) (c)

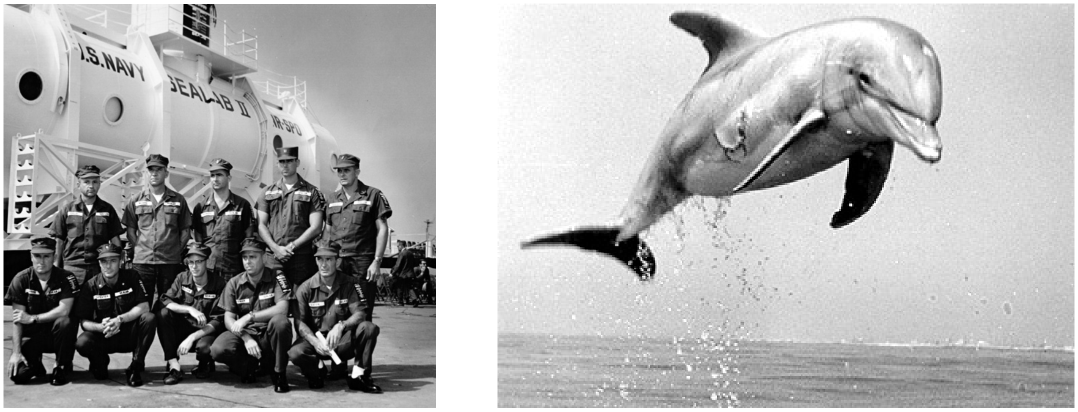
Figure 8: Cousteau's Conshelf I (a), II (b), and III (c) underwater habitats.

development in the Navy, Robert W. Morse.[55]

As the aquanauts returned ashore, *The New York Times* and other newspaper were running spectacular lunar photographs that had just been sent from the spacecraft *Ranger 7*. The only press coverage SEALAB I got was a sixteen paragraph column in the *Times* underwhelmingly titled "Navy Men Set Up 'House' Under Atlantic and Find Biggest Problem Is Communication." Only with considerable understatement did it mention the record depth and duration set by the divers.

Although SEALAB I did not return stunning photographs like its counterpart space expeditions, a similar underwater habitat created by Jacques Cousteau's team in France did. Cousteau's mission garnered significantly more media attention than SEALAB, particularly outside the US, although not enough to significantly turn the nation's eyes, nor pocketbook, towards the ocean.

Cousteau's team created the first-ever undersea habitat, Conshelf I, short for Continental Shelf Station, in 1962 (Figure 8(a)). Two men lived in the steel cylinder that was Conshelf I for seven days at a depth of 10 m. Conshelf I was just a proof-of-concept compared to its successor, Conshelf II, however, which Cousteau's team launched the following year (Figure 8(b)). The main house of Conshelf II, referred to as the Starfish house because of its shape, was complete with a hangar for a mini-submarine, a tanning bed, a kitchen with an electric stove, a full-time chef, and a



(a) (b)

Figure 9: (a) SEALAB II's crew pose in front of the habitat before it is lowered into the ocean (Credit: US Navy). (b) Tuffy the dolphin delivered supplies to SEALAB II (Credit: US Navy Museum).

proper bathroom with heated water, all located 10 m deep in on a coral reef in the Red Sea. The Starfish divers breathed standard compressed air from an umbilical from the surface, and did not need to decompress at that shallow depth. Conshelf II also included the "Deep Cabin," located about 25 m deep, where two oceanauts spent seven days breathing a pressurized mix of helium and oxygen.

National Geographic featured a forty-two page spread on the Conshelf II mission, and Cousteau's documentary about his team's month-long stay, *World Without Sun*, earned him his second Oscar for Best Documentary. Although the Conshelf I and II missions provided little scientific data, they certainly captured the public's eye in a way the Navy's SEALAB experiments never did.

While Cousteau and his team were busy hatching Conshelf III, Bond's team in the US was planning Sealab II (Figure 9(a)) from within the Navy's new Man-in-the-Sea Program, an outgrowth of the Deep Submergence Systems Project that was established in response to the *Thresher* loss. With a budget close ten times that of SEALAB I,[†] SEALAB II was another success. In 1965, off the coast of California, twenty-eight aquanauts lived 62 m undersea for fifteen days, and former astronaut

[†]Exact budget amounts unknown.

Date	Underwater Habitat	Depth	Max. Duration
1962	Conshelf I	10 m	7 days
1963	Conshelf II	10 m	30 days
1965	Conshelf III	100 m	14 days
1964	SEALAB I	58 m	11 days
1965	SEALAB II	62 m	30 days
1969	SEALAB III	185 m	-
1969	Tektite I	15 m	58 days
1970	Tektite II	15 m	20 days

Table 1: Undersea habitats pre-1970. The SEALAB III mission was cancelled soon after it landed on the ocean floor due to the death of aquanaut Berry Cannon and lack of funding.

Scott Carpenter remained below for a full month. The aquanauts performed experiments in oceanography and marine biology devised by the Scripps Institution of Oceanography and underwent physiological testing on the effects of undersea living. They also trained the dolphin Tuffy to deliver supplies to them underwater (Figure 9(b)).

Also in 1965, Cousteau's team launched Conshelf III (Figure 8(c)). Six divers lived at 100 m deep inside the habitat in the Mediterranean for two weeks. With an interior like a "modest yacht,"[56] the steel sphere that was Conshelf III aimed to show how an undersea habitat could be self-sufficient. Although the habitat's power and communication lines came from shore, the habitat had its own supplies of fresh water, breathing gas, and everything else the divers needed. While on the mission, the divers worked on a mock oil rig to prove that divers could performed useful industrial tasks, much to satisfaction of the mission's principal sponsor, the French Petroleum Office.[57]

Back in the US, excited by SEALAB's success, the Navy spent five times as much as was spent for Sealab II to Bond's team for the development of SEALAB III.[58] A few months before the moon landing in 1969, Sealab III was lowered to 185 m, deeper than any habitat before it.

SEALAB III "looked as though it might be the undersea counterpart of the moon shot," according to author Ben Hellwarth. This might have been true, if not for a tragic turn of events. Due to malfunctioning breathing gear, aquanaut Berry L. Cannon died during the first few days of the mission. The program abruptly halted after the death and subsequent investigation, and the Navy cancelled the SEALAB program. According to Ben Hellwarth:

> The Sealab crew–Navy divers and marine scientists alike–found this [the cancelling of the Sealab program] utterly perplexing. Three astronauts had died in a launch pad fire inside the Apollo 1 capsule two years earlier and that didn't spell the end of the space program.[59]

Unfortunately, Cannon's death only added to those from the *Thresher* and Keller tragedies, which occurred in the same decade. One of the personnel on both the Genesis and SEALAB experiments, Captain Walter Mazzone (Figure 6(b)), tried to explain why so many more deaths were associated with the ocean program than the space program:

> Unlike the space program, we've been forced to redesign on the basis of trial and error. In the space program, at least according to the papers, before the first man was put into a rocket to go up, they had to guarantee to the president of the United States his absolute safety. There had to be precautionary ejection mechanisms developed and tested and tried over a period of time. Funds were no problem. When you have to build one of these for the first time and in many cases are actually taking dollars out of your own pocket to buy little things for it, then the empirical becomes the best way to build one. [60]

Also in 1969, the same year as SEALAB III, the undersea habitat Tektite was lowered into the ocean, funded by a completely different set of institutions. Built by General Electric and funded by NASA, the Office of Naval Research, and the Department of the Interior, Tektite reached 15 m, not nearly as deep or expensive as SEALAB II & III. The four aquanauts on the mission set the present record for saturation diving at 58 days.[61]

Since the Tekite mission, there have been several other underwater habitats deployed, reaching depths and durations similar or less those discussed (and listed in Table 1). Those habitats are: Hydrolab (1970), Helgoland (1968), Aquarius (1992), Marine Lab (1984), La Chalupa Research Laboratory (1971), Scott Carpenter Space Analog Station (1997), Galathèe (1977), Hippocampe (1981), and Lloyd Godson's Biosub (2007). The quest to live and work undersea, however, has came more or less to a halt. Author Ben Hellwarth explains:

> [T]he Sealab program, for all its successes during the 1960s, was allowed to sink. Since then, despite some noble, if relatively low-budget, efforts, it's become clear: Where manned undersea ventures are concerned, we are not boldly going anywhere, or not nearly as boldly as once envisioned, anyway. History suggests that we have a habit of throwing in the towel when it comes to the glorious but perpetually underfunded and underappreciated field of manned sea exploration.[62]

3.3 Founding of NASA & Subsequent Space Research

Without doubt, NASA, was founded in response to the Sputnik launch. The Soviet satellite did more than orbit the earth; it threatened American security and pride. Dr. James Killian, Science Advisor to President Dwight D. Eisenhower, described the psychological effect of Sputnik and the aura of fear it case over the country:

> As it beeped in the sky, Sputnik 1 created a crisis of confidence that swept the country like a windblown forest fire. Overnight there developed a widespread fear that the country lay at the mercy of the Russian military machine and that our government and its military arm had abruptly lost the power to defend the mainland itself, much less to maintain US prestige and leadership in the international arena. Confidence in American science, technology, and education suddenly evaporated.[63]

The US National Security Council's June 20, 1958 report on "US Policy on Outer Space" made Killian's concerns official. Space was a matter of national security:

> Perhaps the starkest facts which confront the United States in the immediate and foreseeable future are (1) the USSR has surpassed the United

> States and the free world in scientific and technological accomplishments in outer space, which have captured the imagination and admiration of the world; (2) the USSR, if it maintains its present superiority In the exploration of outer space, will be able to use that superiority as a means of undermining the prestige and leadership of the United States; and (3) the USSR, if it should be the first to achieve a significantly superior military capability in outer space, could create an imbalance of power in favor of the Sino-Soviet Bloc and pose a direct military threat to US security.
>
> The security of the United States requires that we meet these challenges with resourcefulness and vigor.[64]

Eisenhower knew his government urgently needed to create a dedicated space program. His preference was to concentrate the authority of such a program within the Department of Defense.[65] If his plans had come through, *i.e.,* space research was conducted primarily through the defense department, the US likely would not have sent a rover to Mars or accomplished other forms of "non-military" exploration. Eisenhower did not get his way, however. He met with members of the Presidential Science Advisory Committee, lead by Killian, who advised him to create the civilian agency that became NASA.

In addition to the debate over whether the agency should be military or civilian-focused, there was great discussion over whether the agency should be new or part of established institutions. The National Science Foundation (NSF), the Atomic Energy Commission (AEC), and the National Advisory Committee for Aeronautics (NACA) were popular candidates for absorbing civilian missions, while the Army Air Force was keen to absorb the military work.

The end result was that in April 1958, Eisenhower sent Congress a bill calling for the establishment of an independent agency to develop and manage a national space program. On July 28, the bill was passed and signed into law. It called for the creation of the NASA, with the existing National Advisory Committee for Aeronautics (NACA) as its foundation. NACA was a distinguished, 43-year-old agency that employed some 8,000 people, with major laboratories across the US, so it was

Figure 10: President Eisenhower handing T. Keith Glennan (to his left) his commission as administrator of NASA at his swearing-in ceremony on August 19 1958. (Credit: J. D. Hunley)

an excellent starting platform for NASA.

Eisenhower called upon T. Keith Glennan, former board member of the National Science Foundation, to be the first NASA administrator (Figure 10). Glennan, although caught by surprise, accepted. He admitted that he "had taken no more than casual interest in the efforts of this nation to develop a space program" prior to his appointment. Perhaps in modesty, he reflected "Imagine my surprise when on 7 August 1958, I received a call from Jim Killian asking me to come immediately to Washington," in his later-published diary.[66] He summarized his meeting with Eisenhower, the meeting that christened the new agency, as follows:

> The meeting with President Eisenhower was brief and very much to the point. He said he wanted to develop a program that would be sensibly paced and vigorously prosecuted. He made no mention of concern over accomplishments of the Soviet Union although it was clear he was concerned about the nature and quality of scientific and technological progress in this country. He seemed to rely on the advice of Jim Killian.[67]

Glennan had NASA up-and-running by October 1, a full month before the opening date Eisenhower set originally.[68] Glennan successfully negotiated the merging of The Advanced Research Projects Office (ARPA) and the Jet Propulsion Laboratory (JPL)

FY	Inflation Factors	NASA Total			
1959	5.860	1,940	...		
1960	5.769	3,023	1984	1.841	13,727
1961	5.700	5,495	1985	1.775	13,443
1962	5.620	10,257	1986	1.719	13,422
1963	5.558	20,413	1987	1.680	18,352
1964	5.489	27,993	1988	1.637	14,838
1965	5.424	28,477	1989	1.587	17,413
1966	5.332	27,595	1990	1.528	18,832
1967	5.221	25,926	1991	1.473	20,651
1968	5.057	23,199	1992	1.420	20,331
1969	4.884	19,493	1993	1.385	19,822
1970	4.671	17,496	1994	1.354	19,735
1971	4.429	14,664	1995	1.326	18,370
1972	4.218	13,949	1996	1.299	18,031
1973	4.028	13,719	1997	1.274	17,468
1974	3.858	11,716	1998	1.252	17,092
1975	3.598	11,618	1999	1.237	16,893
1976	3.259	11,570	2000	1.221	16,611
TQ*	3.040	2,833	2001	1.197	17,035
1977	2.946	11,249	2002	1.169	17,388
1978	2.828	11,482	2003	1.148	17,631
1979	2.650	12,178	2004	1.125	17,298
1980	2.452	12,849	2005	1.096	17,757
1981	2.254	12,440	2006	1.062	17,657
1982	2.053	12,410	2007	1.027	16,731
1983	1.922	13,212	2008	1.000	17,117

Table 2: NASA budget from 1959 - 2008 in millions of FY 2008 dollars (Source: Aeronautics and Space Report of the President FY 2008, p. 147).

into NASA. His agency's budget "jumped overnight" to more than three times the original NACA budget.[69]

The rest of the space exploration story is history. In 1961, the Soviet Union sent the first person, cosmonaut Yuri A. Gagarin, into orbit. In 1969, the US sent the first two men, Neil Armstrong and Edwin "Buzz" Aldrin, Jr., to the moon. Other important events are recorded in the timeline in Appendix A. As Table 2 shows, NASA's budget reached unprecedented highs in the Cold War-era and has remained at about $17 billion through the 21st century.[70]

As author Paul Stares summarizes, "In just three short years, from the autumn of 1957 to the end of 1960, the US space programme was transformed from a small and struggling effort to a large and multifaceted enterprise with considerable public and congressional support. The key to that change was, of course, the psychological and political impact of Sputnik."[71]

3.4 Founding of NOAA & Subsequent Ocean Research

The US ocean program also began as a "small and struggling effort," but it never garnered governmental support on the same level as the space program. What author Paul Stares said of the early space program was, and is, very much true of the ocean exploration program: It was "hindered by a combination of factors, principally political indifference, military conservation, interservice rivalry and the austerity of the post-war defense budgets."[72]

NOAA started with the potential to become a "wet-NASA,"[73] however. President Johnson jump-started the creation of a marine science-focused government agency by enacting the Marine Resources and Engineering Development Act of 1966, which declared it a policy of the US to: "develop, encourage, and maintain a coordinated, comprehensive, and long-range national program in marine science for the benefit of mankind, to assist in protection of health and property, enhancement of commerce, transportation, and national security, rehabilitation of our commercial fisheries, and increased utilization of these and other resources."

The grounds for the National Oceanic and Atmospheric Administration (NOAA) were laid the following year, in 1967, when President Johnson appointed a blue-ribbon commission to consider the nation's undersea activities. The commission produced a three-hundred-page report entitled "Our Nation and the Sea: a Plan for National Action," but referred to as the "Stratton report" after the commission's chairman, Dr. Julius Stratton. The report called for a "wet-NASA," a civilian agency that could concentrated effort and money into undersea research and exploration.

In 1970, a year after the publishing of the Stratton report, President Nixon proposed to Congress the creation of NOAA to serve a national need "for better protection of life and property from natural hazards…for a better understanding of the total environment ... [and] for exploration and development leading to the intelligent use of our marine resources..."[74] Like the early debates on the structure of NASA, government leaders debated the proper structure of NOAA. Should it be a purely civilian organization? Should it be a new agency, or under existing agencies?

The results was that in 1970, NOAA was formed from what Ben Hellwarth describes as a "smorgasbord" of government agencies,[75] including the Coast and Geodetic Survey, Weather Bureau, Bureau of Commercial Fisheries, Environmental Science Services Administration (ESSA) and some Navy research programs.[76] As Hellwarth aptly notes, "The acronym NOAA, pronounced *Noah*, was fitting since the new agency's responsibilities would be about as diverse as the animals on the Ark." For example, under the Department of Commerce, NOAA's duties include predicting weather, charting seas and skies, guiding the use and protection of ocean and coastal resources, and conducting research to improve understanding and stewardship of the environment. In addition, NOAA has a reserve of uniformed service members, the NOAA Corps, to support its missions.

Unlike the founding of NASA, the founding of NOAA was not tied up in matters of national pride. Rather, NOAA's goal was more closely tied to environmental and fisheries protection. Interestingly, reports that the Soviets were planning mobile undersea laboratories did not spark a Sputnik-like reaction regarding ocean research in the US.[77] For that reason, NOAA and subsequent ocean exploration projects were far less funded and more subdued than those in the space program. In 2014, for example, NASA's space exploration budget is $3.8 billion,[78] which is *150 times* more than NOAA's office of exploration and research budget of $23.7 million.[79‡]

[‡]It is difficult to determine the US government's exact spending on ocean activities for a number of reasons, detailed in Appendix C. The key is that annual government spending on ocean exploration is on the order of millions, whereas space exploration is on the order of billions.

4 Misconceptions

Your rockets are pointed in the wrong goddamn direction!
— Graham Hawkes, at the suggestion that space is the final frontier

The dramatic divergence in the trajectories of space and ocean research, as evidenced by the sky-rocketing funding for space exploration in the 1950s onward, was driven by perceived geopolitical-military imperatives that were grossly exaggerated. Misconceptions about the relative importance of space and our knowledge of the ocean led the United States to prize space more than sea as a new frontier. Consequently, we know more about the moon than the oceans and the vital role they play in maintaining human life.

4.1 Space as a Military Imperative

In politics, what begins in fear usually ends in folly.
— Samuel T. Coleridge

Americans panicked after the Soviet Union's launch of Sputnik, and their fears extended beyond the possibility of space-related weaponry into the fantastical. "Nothing less than control of the heavens was at stake," author Tom Wolfe reflected.[80] Lyndon Johnson, the Senate majority leader at the time of Sputnik, cautioned that whoever controlled "the high ground" of space would control the world. "The Roman Empire," he continued, "controlled the world because it could build roads. Later–when it moved to sea–the British Empire was dominant because it had ships. In the air age we were powerful because we had airplanes. Now the Communists have established a foothold in outer space."[81]

The press exacerbated Johnson's fear. A *New York Times* editorial, for example, proclaimed the United States was in a "race for survival."[82] Panic became even "more apocalyptic" thereon, as author Tom Wolfe notes. After the Soviets launched the satellite Mechta in 1959, the House Select Committee on Astronautics, headed by House Speaker John McCormack, said that the United States faced "national extinction" if it did not catch up with the Soviet space program. "It cannot be overemphasized that the survival of the free world–indeed, all the world–is caught up in the stakes." [83]

The truth was, however, that apart from nuclear weapons, which were developed separately, the fear over space weapons and perceived need to control space was seriously overblown. The Purcell Panel report, commissioned by President Eisenhower, explained in 1958:

> Much has been written about space as a future theatre of war, raising such suggestions of satellite bombers, military bases on the moon and so on. For the most part, even the more sober proposals do not hold up well on close examination or appear to be achievable at an early date... In short, the earth would appear to be after all, the best weapons carrier.[84]

This rejection of space weapons repeated the findings of the The White House National Security Council (NSC).[85] The reality was that space exploration provided benefits for science, reconnaissance, communication, weather forecasting, *etc.*, but not for active weaponry of the kind that Johnson, the press, John McCormack, *et. al.* imagined and drove hundreds of billions of dollars into space research[§] over the past half-century.

4.2 Ocean's Impact on Human Life

> *Unless someone like you cares a whole awful lot, nothing is going to get better. It's not.*
>
> — *Dr. Seuss, The Lorax (1971)*

The misconceptions that drove spending on space were mirrored in our lack of knowledge about the ocean's importance. Our ambivalence about the ocean is reflected in the vast disparity in research funding. Today, however, we are beginning

[§]See Appendix B for the US government's expenditures on space activities for 1959 - 2008.

to understand how dependent we are on the ocean, and how the impact of human-induced climate change, pollution, and overfishing on the ocean are far more threatening to our survival than whether we "control the heavens."

The ocean, which cover's 71% of Earth's surface, produces at least half the oxygen we breath and filters deadly carbon dioxide.[86] It is a crucial regular of global climate and weather, but one we do not understand.

Since 1950 there has been a dramatic increase in extreme weather,[87] requiring billions of dollars spent globally towards repair and response efforts.

Moreover, eight of the world's top ten largest cities are located on the seacoast. The ocean they adjoin is profoundly changing in complex ways we do not understand. Marine species are disappearing before we know of their existence. These species are not only matters of curiosity, but can hold secrets to understanding life and medicine, and are integral to the health of marine ecosystems.[¶] The oceans have become 26% more acidic since the start of the Industrial Revolution and continue to acidify at an unprecedented rate.[88] Acidification affects marine ecosystems; it especially harms shelled creatures such as oysters and muscles that filter water,[89] but can benefit sea grass and other invasive plants that will overwhelm ecosystems and accelerate the extinction of marine animal species.[90]

At the same time acidification from climate change is threatening entire ecosystems, industrial and agricultural pollution, plus increasing volumes of human trash are threatening to overwhelm the ocean's ability to regenerate. The National Academy of Science estimated that in 1975 more than 750 tons of garbage was dumped into the ocean *every hour*.[91] Fortunately, in 1987 the US ratified Marpol Annex V, an international treaty that made it illegal to throw nonbiodegradable trash overboard from ships in the waters of signatory countries. While this is progress, the MARPOL law is difficult to enforce. Governments do not know where or when dumping hap-

[¶]See Ellen Prager's *Sex, Drugs, and Sea Slime: The Ocean's Oddest Creatures and Why they Matter* (University of Chicago Press, 2011).

Figure 11: Researchers walk around a grey whale found dead washed ashore in Puget Sound in April 2012. In November 2013, another grey whale washed up ashore in the Netherlands, with a stomach full of plastic trash. The cause of death was intestinal blockage due to the garbage. Unfortunately, such incidents are not uncommon. (Credit: Associated Press/ Cascadia Research).

pens because there is no infrastructure for monitoring or policing the vast oceans. Sadly, *Nature* magazine reported that during the 1990s debris in the waters near Britain doubled, and debris in the Southern Ocean encircling Antarctica increased one hundred fold.[92]

Today we do not know how much trash is in the ocean. Author Donovan Hohn noted in 2008, “Not even oceanographers can tell us exactly how much floating scruff is out there; oceanographic research is simply too expensive and the ocean too varied and vast.”[93] But the number is not good. Stranded whales and other marine life with trash filling their bellies serve as a powerful harbinger for what is to come (Figure 11), and more oceanographic research is needed.

Along with pollution and climate change, overfishing is among the greatest threats facing our ocean and human wellbeing. A study in *Science* projected that all commercial fish and seafood species will collapse by 2048.[94] Already, populations of large fish, including tuna, swordfish, marlin, cod, halibut, skates, flounder, and others, have reduced by 90% since 1950, according to a 2003 study in *Nature*.[95]

A world without seafood will harm developing nations the most. More than 3.5

billion people globally depend on the ocean for their primary source of food, and most of those people are in fast-growing developing regions of Asia and Africa.[96] In 20 years, the number could double to 7 billion.[97]

Fortunately, according to a pivotal paper published in *Science* in 2006, overfishing is proven to be a reversible problem, but only if humans act effectively within the next decade.[98] Otherwise, global malnutrition and famine is on the horizon as so far aquaculture has not been able to keep up with the dramatic losses of wild catch.

"Unless we fundamentally change the way we manage all the oceans species together, as working ecosystems, then this century is the last century of wild seafood," marine ecologist Steve Palumbi warned.[99] NOAA has made substantial progress in regulating US fisheries, although that fact must be taken with a grain of salt because the US imports 91% of its seafood.[100] Moreover, the most catastrophic overfishing is occurring in international waters where traditional industrial fishing nations continue to resist stronger efforts at global regulation.

Realizing the ocean's importance to humankind, President Kennedy became a staunch advocate for ocean research shortly before he died. Exactly a month before his assassination, he asked Congress to double the nation's ocean research budget and greatly expand ocean research for the sake of worldwide security and health. He called for a global ocean research initiative:

> The ocean, the atmosphere, outer space, belong not to one nation or one ideology, but to all mankind, and as science carries out its tasks in the years ahead, it must enlist all its own disciplines, all nations prepared for the scientific quest, and all men capable of sympathizing with the scientific impulse.[101]

He had no chance to see his plans through, however, and his successor, Lyndon Johnson, was focused on space as the "high ground" and "control of the heavens" for perceived military and geo-political reasons.

4.3 Extent of Oceanographic Knowledge

During the space race, leaders believed that the ocean was an already conquered territory. In 1962, President Kennedy called space a "new ocean,"[102] although 95% of the ocean remains unseen by human eyes.[103] As mentioned previously, Johnson suggested space technology would be to the 20th century what ships were to the British Empire for the past millennia,[104]. Kennedy echoed Johnson's words:

> We set sail on this new sea because there is new knowledge to be gained, and new rights to be won, and they must be won and used for the progress of all people. For space science, like nuclear science and technology, has no conscience of its own. Whether it will become a force for good or ill depends on man, and only if the United States occupies a position of preeminence can we help decide whether this new ocean will be a sea of peace or a new terrifying theater of war.[105]

The truth remains, however, that we have not conquered the seas. As discussed in Sections 2.2 and 3.2, ocean exploration has largely been a surface affair. 90% of the ocean's volume, the dark, cold environment we call the deep sea, is largely unknown.[106]

In 1960, when Jacques Piccard and Don Walsh became the first men to reach the deepest part of the ocean, they saw only saw two fish,[107] so it was mistakenly envisioned that the deep ocean was essentially lifeless. In reality, however, it is teaming with life. Tim Shank, a deep-sea biologist at Woods Hole Oceanographic Institution, explained why the explorers did not see much life near the Mariana Trench: The waters above the Challenger Deep are extremely unproductive in part because algee at the surface prevents food from being cycled in deeper waters. "If it had been a trench with a productive water column, like the Kermadec Trench near New Zealand, I think he would have seen much more biology," he told *Nature*.[108] Fantastic photos from Cousteau's shallow water missions helped to fill the gap, showing brilliant life in sea, but those only scratched the surface. An estimated two thirds of marine species are yet to be discovered.[109]

In 2014, NASA's budget is $17 billion. Its space exploration budget alone is $3.8 billion,[110] hundreds of times more than NOAA's office of ocean exploration and research budget of $23.7 million.[111‖] The discrepancy in funding for ocean exploration, particularly in comparison to that for space, has lasting effects that inhibit efforts for continued exploration.

After his mission to the Mariana Trench in 2012, James Cameron candidly told the press that the state of today's ocean exploration is "piss poor."[112] He continued,

> The public needs to understand that the US government is no longer in a leadership position when it comes to science and exploration, as they were in the 1960s and 1970s. We have this image of ourselves in this country as number one, leading edge, that sort of thing and it is just not the case.[113]

Cameron, who privately funded his journey to the Mariana Trench, noted that private individuals such as Eric Schmidt, Google's former chief executive and founder of the Schmidt Ocean Institute, have made strides in trying to up for what governments are not doing, but progress is still slow due to lack of government infrastructure. Author Ben Hellwarth explains:

> [P]rivate groups—including the team of Jacques Cousteau, who was as great a pitchman and fundraiser as anyone—would find sea dwelling and exploration a tough business to pursue, especially without a government-primed infrastructure and market like the one that evolved for space travel. The situation was something like tech mogul Elon Musk trying to launch SpaceX without the benefit of a space station or the many trails NASA blazed with its billions.[114]

To illustrate, Hellwarth elaborates with the recent history of the undersea habitat Aquarius:

> The kind of public interest and unbridled enthusiasm that has long sustained the space program and NASA's multibillion-dollar budgets has never materialized for like-minded quests into the ocean. Last year's near closure of the world's only sea base was the latest case in point. If you can't

‖Budgets for US government-sponsored space and ocean activities detailed in Appendices B and C, respectively.

> name this unique, American-run undersea outpost, you are not alone, and that's at least part of the problem. It's called the Aquarius Reef Base, and for the past two decades, this school-bus-sized structure has been operating a few miles south of the Florida Keys and a few fathoms below the surface. From its beginning Aquarius has typically had to squeak by on less than $3 million a year, sometimes much less than a drop in the fiscal bucket by space program standards. (NASA's estimated cost of a single space shuttle launch, for example, was $450 million.) Then last year the National Oceanic and Atmospheric Administration, which owns Aquarius, decided to pull the plug on the base. An organized effort to save Aquarius created an unusual surge in media and other attention, not major front-page headlines, to be sure, but there was at least a discernible spike.[115]

Even after the Cold War ended in the early 1990s with fall of Berlin Wall, NASA's budget remained dramatically larger than budgets for ocean research. The reason for the budget disparity has less to do with commercial or military reasons, and more to do with lingering geo-political issues and inertia from the Cold War, including constituencies in Congress, an independent governmental agency, and established defense contractors that benefit from government-funded space exploration. Contractors such as Boeing and Lockheed Martin, for example, have immense capacity to lobby Congress for further funding. Ocean exploration, on the other hand, had almost no constituency outside of the scientific community, which alone has little political clout.

Because of the lingering effects of misconceptions, ocean exploration lags far behind space exploration, to the point that our dearth of oceanographic knowledge may result in serious harm to humankind in the next generation.

5 Conclusion: Will There Be a Sputnik for the Ocean?

> The sea, the great unifier, is man's only hope. Now, as never before, the old phrase has a literal meaning: We are all in the same boat.
>
> Jacques Cousteau

Since 5000 BC, humans have progressed from star-gazers to moon-walkers and from shallow-water swimmers to deep-sea explorers. Technological innovation drove exploration in both space and sea to unprecedented levels, particularly during the mid-1900s. With the start of the Cold War, however, ocean exploration proceeded at a snail's pace compared to space research. This sudden shift in priority was due to misconceptions about the military and geopolitical importance of space and the ocean's importance to human wellbeing.

Looking back, there are many "what ifs" in the history of exploration. For example, what if Eisenhower had his wish of making NASA part of the Department of Defense? Then we most likely would not have reached the moon or Mars because those NASA missions were not primarily military-oriented. What if the Soviets launched the first deep sea vehicle rather than the first orbiting satellite? Might there have been a Sputnik-like reaction towards the ocean rather than space? What if Kennedy wasn't assassinated and got his wish of creating a global ocean research initiative in the 1960s?

Looking ahead, progress in ocean exploration and management looks dire. This is especially tragic because marine environments and ecosystems are degrading, even disappearing, at the fastest rate in 300 million years,[116] as they face the triple threat of acidification, warming, and deoxygenation. "The health of the ocean is spiraling downwards far more rapidly than we had thought.... The situation should be of the gravest concern to everyone since everyone will be affected by changes in the ability of the ocean to support life on Earth," Professor Alex Rogers of Oxford University emphasizes.[117]

The US government probably will not fund the necessary research anywhere near the scale it continues to fund space research. As such, scientists are increasingly looking for private and industrial support. James Cameron, the Cousteau legacy, and Eric Schmidt among others are showing that privately-funded ocean exploration is possible. The underfunded and oft-delayed "SeaOrbiter" project, which aims to be the ocean equivalent of a space station, shows how difficult fund-raising for such projects can be.[118] Yet SeaOrbiter would cost a tiny fraction of a single space shuttle flight.

That the ocean was a place for international collaboration probably hurt it during the decades of Cold War hysteria; but hopefully we can now use that to an advantage, to bring nations together. The European Organization for Nuclear Research (CERN) showed how large-scale multinational research, funded by a combination of governments and industry sectors, can be successful. The future of ocean exploration might depend on a oceanographic version of CERN. Or, it could be in research studies tied to national interests, like the space program. As a recent national forum on the future of the ocean stated, ocean exploration as an urgent necessity, and an issue of national security.[119] Let us hope that not only the US government, but also the entire global community recognizes the importance of aggressive ocean research and management before it is too late.

6 Acknowledgements

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Notes

[1]This is a commonly cited statistic by the National Ocean Service, National Oceanic and Atmospheric Administration, and various media; *e.g.,* it is cited in "Discovering Earth's Final Frontier: A U.S. Strategy for Ocean Exploration," Report of the President's Panel on Ocean Exploration (Oct 2000)). The closest scientific support for the statistic comes from Dr. Patricia Miloslavich's "Marine Biodiversity: State of Knowledge" in Ocean Biogeographic Information System, June 20 2012 (online at `iobis.org`). If you consider the volume of water in the regions of the ocean that humans have seen and divide that by the volume of the ocean it is reasonable that humans have only seen 5% of the ocean. However, if you consider the amount of ocean human-made devices, such as robotic vehicles and remote sensors, and redefine "seen" as "collect information–not necessarily visual–about," then the percentage would be higher. For this reason, the statistic is to be taken with a grain of salt. The message, however, is clear: Most of the ocean remains a mystery to humankind. Moreover, there is considerable uncertainty in existing research; one example is G. Gawarkiewicz, *et. al.*,"Chasing and Predicting Uncertainty in the Cold Dome," *Oceanography* vol. 24, no. 1, pp. 110-121 (online at `dx.doi.org/10.5670/oceanog.2011.99`) and P.F.J. Lermusiaux, *et. al.*, "Quantifying Uncertainties in Ocean Predictions," *Oceanography* vol. 17, no. 1 (2006), p. 110-121.

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A Space Versus Sea Exploration Timeline

	Space Exploration	Ocean Exploration
50th C BC	• The world's oldest observatory, the Gosec circle, dates back to 4900 BC.	• Egyptians develop sailing vessels around 4000 BC.
...		
3rd C BC		• Alexander the Great descends in the earliest version of the diving-bell.
2nd C BC	• Greek astronomer Eratosthenes measures the earth's circumference based on a mathematical understanding of the earth and sun's relationship.	
...		
1924	• USSR establishes Central Bureau Bureau for the Study of Problems of Rockets and the Study of Interplanetary Communications. The US, Germany, and Britain follow suit with similar agencies, including the American Interplanetary Society.	
1927		• US establishes Navy Experimental Diving Unit (NEDU).
1943		• Émile Gagnan and Jacques Cousteau invent the first self-contained underwater breathing apparatus, founding the modern practice of SCUBA diving.
1946		• US government establishes Office of Naval Research (ONR).

1951

- British ship *Challenger II* locates the deepest point in the ocean, the Marianas Trench.

1957

- USSR launches first satellite into orbit, *Sputnik 1*.
- USSR launches first animal into space, a dog.

1958

- NASA founded.

1960

- *Trieste* submersible brings two men to to deepest point in the ocean.

1961

- USSR cosmonaut Yuri A. Gagarin becomes the first to successfully orbit the globe.

1962

- Swiss diver Hannes Keller makes first 1000 ft dive.
- Jacques Cousteau's team spend one week living 10 m underwater in *Conshelf I*.

1963

- Cousteau's team spend one month living 10 m underwater in *Conshelf II*.

1964

- Woods Hole Oceanographic Institution launches *Alvin*, the first deep-sea submersible capable of carrying passengers.
- Divers live at 58 m deep for eleven days in the first U.S. underwater habitat, SEALAB I.

1965	• USSR cosmonaut Alexei Leonov making the first spacewalk upon exiting the *Voskhod 2* capsule.	• Cousteau's team spend two weeks living 100 m underwater in *Conshelf III*.
		• Divers spend one month living 62 m deep in SEALAB II.
1967	• Three astronauts die on *Apollo 1*, the first manned mission of the US lunar landing program.	
1968	• American astronauts snap stunning photos of earth as a blue-and-white marble during first manned moon orbital launch.	
1969	• American astronauts Neil Armstrong and Edwin "Buzz" Aldrin, Jr. make man's first walk on the moon.	• Death of an aquanaut at 185 m underwater ends SEALAB III program.
		• Tektite I divers set saturation diving record at 58 days, 15 m deep.
1970		• NOAA founded.
		• Sylvia Earle leads the first team of women aquanauts during the *Tektite II* mission and sets record for solo diving to a depth of 1,000 m.
1971	• USSR launches the first space station, *Salyut 1*.	
	• USSR Mars 2 & 3 probes are the first human artifacts to touch down on Mars.	
	• U.S. *Apollo 15* brings the first rover to the moon.	

1973	• First American space station, *Skylab*, launched.	
1976	• *Viking* probes are first U.S. devices to land on Mars; they return the first color pictures and extensive scientific information from Mars.	
1977		• Team led by Robert Ballard discover hydrothermal vents using submersible *Alvin*.
1985		• Team led by Robert Ballard discover the *Titanic* shipwreck.
1990	• NASA and the European Space Agency deploy the Hubble Space Telescope.	• 3,000 robotic probes are deployed through the oceans to monitor climate, weather, and sea surface height for project Argo, a collaboration between more than 30 nations.
1992		• TTOPEX/Poseidon satellite, the first major oceanographic research vessel in space, begins mapping the surface of the sea.
2004	• NASA's lands first rovers on Mars, *Spirit* and *Opportunity*. • First manned private space flight *SpaceShipOne* reaches an altitude of 100 km, winning the coveted ten-million-dollar Ansari X Prize for a privately funded reusable spacecraft. • NASA's *Cassini* is first probe to enter Saturn's orbit.	

2005

- European-built probe *Huygens* makes the first landing on another world's moon, Saturn's Titan.

2012

- National Geographic Explorer-in-Residence James Cameron becomes the third person to travel to the deepest known point in the ocean.

B US Government Expenditure on Space Activities, 1959 - 2008

HISTORICAL TABLE OF BUDGET AUTHORITY
(in millions of inflation-adjusted FY 2008 dollars)

FY	Inflation Factors	NASA Total	NASA Space	DOD	Other[a]	DOE[b]	DOC	DOI	USDA	NSF[c]	DOT	Total Space
1959	5.860	1,940	1,529	2,871	199	199	0	0	0	0	0	4,600
1960	5.769	3,023	2,665	3,236	248	248	0	0	0	0	0	6,150
1961	5.700	5,495	5,279	4,640	388	388	0	0	0	0	0	10,306
1962	5.620	10,257	10,099	7,295	1,118	832	287	0	0	0	0	18,513
1963	5.558	20,413	20,152	8,614	1,428	1,189	239	0	0	0	0	30,194
1964	5.489	27,993	27,532	8,777	1,169	1,153	16	0	0	0	0	37,477
1965	5.424	28,477	27,869	8,538	1,307	1,242	65	0	0	0	0	37,714
1966	5.332	27,595	27,008	9,006	1,141	997	144	0	0	0	0	37,155
1967	5.221	25,926	25,216	8,687	1,112	961	151	0	0	0	0	35,015
1968	5.057	23,199	22,405	9,720	881	733	142	1	5	0	0	33,006
1969	4.884	19,493	18,667	9,832	832	576	98	1	5	152	0	29,331
1970	4.671	17,496	16,567	7,837	659	481	37	5	5	131	0	25,063
1971	4.429	14,664	13,734	6,696	717	421	120	9	4	164	0	21,147
1972	4.218	13,949	12,954	5,935	563	232	131	25	8	166	0	19,451
1973	4.028	13,719	12,458	6,537	594	218	161	40	8	167	0	19,589
1974	3.858	11,716	10,644	6,813	610	162	231	35	12	170	0	18,067
1975	3.598	11,618	10,489	6,808	568	108	230	29	7	193	0	17,864
1976	3.259	11,570	10,511	6,463	549	75	235	33	13	193	0	17,522
TQ*	3.040	2,833	2,581	1,398	131	15	67	9	3	36	0	4,110
1977	2.946	11,249	10,135	7,107	570	65	268	29	18	190	0	17,812
1978	2.828	11,482	10,246	7,743	639	96	291	28	23	201	0	18,628
1979	2.650	12,178	10,678	8,044	657	156	260	26	21	193	0	19,379
1980	2.452	12,849	11,476	9,436	567	98	228	29	34	177	0	21,478
1981	2.254	12,440	11,254	10,884	528	92	196	27	36	176	0	22,667
1982	2.053	12,410	11,351	13,714	642	125	298	25	31	164	0	25,707
1983	1.922	13,212	12,161	17,333	629	75	342	10	38	163	0	30,123
1984	1.841	13,727	12,623	18,765	727	63	434	6	35	189	0	32,114
1985	1.775	13,443	12,292	22,664	1,036	60	751	4	27	195	0	35,992
1986	1.719	13,422	12,318	24,286	820	60	531	3	40	185	0	37,424
1987	1.680	18,352	16,480	27,364	783	81	467	13	32	188	2	44,628
1988	1.637	14,838	13,626	28,948	1,213	395	576	23	29	188	2	43,787
1989	1.587	17,413	16,029	28,425	889	154	478	27	33	192	5	45,343
1990	1.528	18,832	17,512	23,863	773	121	371	47	38	189	6	42,147
1991	1.473	20,651	19,221	20,894	1,138	370	370	43	38	311	6	41,253
1992	1.420	20,331	18,743	21,333	1,133	317	464	48	41	257	6	41,209
1993	1.385	19,822	18,096	19,540	1,012	229	449	46	35	249	6	38,649
1994	1.354	19,735	17,638	17,833	857	100	423	42	42	243	7	36,328
1995	1.326	18,370	16,632	14,114	1,006	79	467	41	42	369	8	31,752
1996	1.299	18,031	16,323	14,953	1,075	60	613	47	48	300	8	32,351
1997	1.274	17,468	15,873	14,942	1,006	45	571	54	50	280	8	31,821
1998	1.252	17,092	15,430	15,478	1,051	129	545	54	49	267	8	31,959
1999	1.237	16,893	15,416	16,336	1,215	130	711	73	46	247	7	32,967
2000	1.221	16,611	15,292	15,805	1,289	200	702	73	54	252	7	32,386
2001	1.197	17,035	15,926	17,150	1,271	174	691	72	43	278	14	34,347
2002	1.169	17,388	16,222	18,408	1,380	194	753	75	33	311	14	36,010
2003	1.148	17,631	16,478	22,248	1,498	219	745	85	48	387	14	40,224
2004	1.125	17,298	16,109	21,500	1,647	235	838	80	69	412	13	39,256
2005	1.096	17,757	16,700	21,585	1,700	251	885	77	80	395	13	39,986
2006	1.062	17,657	16,746	23,490	1,749	260	913	87	89	387	13	41,985
2007	1.027	16,731	15,994	23,032	1,726	205	937	89	67	415	12	40,752
2008	1.000	17,117	16,502	24,795	1,698	195	862	90	59	479	13	42,995

a. The Other column is the total of the non-NASA and non-DOD budget authority figures that appear in the succeeding columns. The total is sometimes different from the sum of the individual figures because of rounding. The Total Space column does not include the NASA Total column because the latter includes budget authority for aeronautics as well as in space. For the years 1989–1997, this Other column also includes small figures for the Environmental Protection Agency (EPA). Also includes $2.1 billion for replacement of Space Shuttle *Challenger* in 1987.

b. The DOE has recalculated its space expenditures since 1998.

c. The NSF has recalculated its space expenditures since 1980, making them significantly higher than reported in previous years.

* Transition Quarter

Table 4: US government expenditure on space activities, 1959 - 2008 (Source: Aeronautics and Space Report of the President FY 2008, p. 147).

C US Government Expenditure on Ocean Activities, 2014

It is difficult to list all the US government's historic spending on ocean activities for a number of reasons. First, pre-1993 budget data for NOAA is not readily available. Moreover, it is unclear what part of NOAA's budget goes to ocean exploration. The bulk of NOAA's budget goes to weather forecasting, fisheries management, and its other services. Second, the government supports ocean research through various channels, including not just NOAA and the Office of Naval Research, but also through DARPA and other DoD research organizations, and it is unclear what portions of their budgets go towards ocean exploration.

Regardless, the government's annual spending on ocean exploration is on the order of millions, whereas spending on space exploration is on the order billions. It is clear there is paltry funding for ocean research relative to space research.

NOAA Office of Exploration and Research	\$23.7 million
NOAA Total	\$5.4 billion
Office of Naval Research (ONR)	\$1.7 billion

Table 5: FY 2014 budgets for NOAA and ONR. NOAA's Office of Exploration and Research is the US government's principal means of ocean exploration. It was established at the recommendation of the President's Panel Report of 2000, which advised the nation to undertake a national program of ocean exploration with discovery and the spirit of challenge as cornerstones. These values are cited in Michael Conathan's 2013 piece *Rockets Top Submarines: Space Exploration Dollars Dwarf Ocean Spending* published on `americanprogress.org` and listed in NOAA's FY2014 summary.