The Space Race between the 1960s and 1970s

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ABSTRACT "The Space Race Between the 1960s and 1970s and its Lasting Impact on Space Exploration" is an analysis of the progression of science throughout the aforenamed decades and the impact that space exploration had on these achievements. With a focus on the telemetry system of the Voyager Missions, this paper explores topics such as colour photography, satellites, and radio waves. It will explain concepts such as Golay coding, which allows higher resolution photographs to be transmitted from space and radio waves, thus allowing scientists to measure characteristics of other planets in our solar system (i.e., atmospheric composition). This paper will discuss how public support, and consequently funding, for space exploration has declined over time and how this trend has affected the progress of organizations such as NASA. The international space race was an instrumental part of scientific development in human history, and this paper aims to bring light to both its successes and failures.

INTRODUCTION: THE SPACE RACE AND THE COLD WAR

The Space Race began in the wake of World War II, when scientific development was at an all-time high. Motivated by military, economic, and exploration-based interests, the Americans, Russians, and Chinese competed for prominence in space exploration, resulting in significant technological and scientific advances throughout the 1950s and 1960s. However, as goals were met and priorities shifted, funding and public support for space exploration began to decline among the American population. For example, the 1977 launch of the Voyager Missions—two of the most groundbreaking space exploration missions in history—were affected more directly by this cultural shift than any project before them. This paper will explore pivotal moments of the Space Race during the 1970s. It will describe the development of colour imaging in spacecrafts and the necessary coding techniques required for its transmission, radio science used for communication with the spacecrafts, and extraterrestrial communication efforts. In addition, this paper will examine the reasons for both the success of space exploration in this period as well as the failure of the Race to maintain its initial enthusiasm and optimism. Through a detailed discussion of how international competition for dominance fueled technological and scientific throughout the aforementioned decades, the devastating decline of funding and interest in space exploration will be explained.

Space Exploration in the Kennedy Era

In his first speech as an honorary visiting professor at Rice University in the autumn of 1962, US President John F. Kennedy said that "[t]he exploration of space… is one of the great adventures of all time, and no nation which expects to be the leader of other nations can expect to stay behind" (National Archives, 1962). In the post-World War II environment, leadership of nations was also presumed to require nuclear dominance. Rockets would play a key role in both the Space Race and the Cold War, and the United States had made great efforts to ensure that the best wartime scientists, having emerged during the scientific advancements of WWII, were on the side of the Americans as opposed to the Soviets or the United Kingdom. This was done through Operation Paperclip, a program organized by the American Office of Strategic Services (OSS) and the Joint Intelligence Objectives Agency (JIOA) to recruit Nazi German scientists in the years between WWII and the Cold War (Huzel, 1995, p. 1). Americans chose this particular group of scientists not only for their expertise in explosives and other military-based advancements, but also to remove them

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(and their knowledge) from Germany and prevent them from providing further insight to the USSR and/or UK (Huzel, 1995, p. 1). Many of the leading scientists recruited through this program were rocket scientists including Wernher von Braun and Arthur Rudolph (Huzel, 1995, p. 1). Further, the American government formed the National Advisory Committee for Aeronautics (NACA) in an attempt to streamline government advancements (River).

Despite American post-war efforts, however, Soviet plans for space satellites were already in place in the 1950s. The Space Age was initiated by the Soviet Union with the creation and launch of the first of the Sputnik spacecraft in 1957 and claimed the title of the first space satellite (Klein, 2003, p. 6). The National Aeronautics and Space Administration (NASA) was established by the United States in the following year (Dick, 2008; Newell, 2011, "No page number" section). NASA was created as a specialized branch of NACA and as a means to compete with the Soviets (River). Between 1962 and 1967, NASA planned to "double the number of scientists and engineers" dedicated to space exploration and "increase its outlays for salaries and expenses to $60 million a year;" to "invest some $200 million in plant and laboratory facilities;" and to "direct or contract for new space efforts over $1 billion," an amount equivalent to almost $9 billion today (National Archives, 1962). Setting foot on the moon became "a high national priority" for the Kennedy government (National Archives, 1962). Unfortunately, the opinion of the public did not quite match this political enthusiasm. By the time that goal was accomplished in 1969, the American public had become increasingly less interested in funding NASA, especially as the Vietnam war increasingly occupied their minds and wallets (Bell, 2015). As the NASA Historical Data Book shows, "NASA's annual budget, which had reached $5 billion in the mid-1960s and stood at almost $4 billion in 1969, was reduced to $3.7 billion in 1970 and just over $3 billion in 1974" (NASA Historical Data Book). The progression from the Kennedy-era to Nixon's presidency played a large role in these budget cuts. During his years in office, Nixon declined funding for Apollo 18, 19, and 20 and declined the first proposal for the Grand Tour missions. However, after the price tag dropped more than two thirds of its original amount, Nixon approved a later proposal for the missions (Bell, 2015, p. 62-63). With cheaper missions being proposed, the Space Race was able to continue into the 1970s despite its diminishing of support.

The Voyager Missions

In the 1960s and 70s, NASA designed and launched multiple spacecraft. Mariner 2 (1962) was the "first successful interplanetary mission of the human species," Viking 1 and 2 were a pair of landers which touched down on the planet Mars in 1976, and the Voyager 1 and Voyager 2 missions in 1977 were robotic probes that reached interstellar space in 2012 and 2019 respectively (The Planetary Society, 2019). Their missions continue to the present day (Bell, 2015, p. 16; The Planetary Society, 2019)

The Voyager spacecrafts were launched on what became known as the Grand Tour, a "once-every-176-year planetary alignment" allowing a single spacecraft to travel past all of Jupiter, Neptune, Uranus, and Saturn in a sort of slingshot motion (Bell, 2015, p. 14). Equipped with the best technology that the 1970s could offer, Voyager featured

> wide-angle and resolution cameras for imaging and spacecraft navigation; radio systems for studying gravitational fields and planetary radio emissions; infrared and ultraviolet spectrometers to measure chemical compositions; a polarization sensor for surface, atmosphere, and planetary ring composition; a magnetometer measuring magnetic fields; four devices for studying charged particles, cosmic rays, plasma, and plasma waves (Bell, 2015, p. 23).

Despite the decline of public support in the late 70s, the most advanced technology available was being applied to space exploration, just as President Kennedy had promised. After Voyager 1 and 2 "swept by the Jupiter, Saturn, Uranus, and Neptune systems," influential planetary scientist Carl Sagan suggested that "[i]t is our great privilege to be alive at that first moment when ignorance is converted into knowledge" (pangea, 2010; The Planetary Society, 2019)

NASA's strong connection to the US military, primarily via space science, gave them access to technology and funding at a time when direct support was lagging (Newell, 2011, "No page number" section). In fact, "[m]ost of the space scientists who came to NASA in the fall of 1958 had been associated with the Army, Navy, or Air Force rocket or satellite research programs" (Newell, 2011, "No page number" section). Due to mutual benefit and interest, through the 1940s and 1950s, rocket research was supported by the military and NASA as well as the aerospace companies who were also recorded as participating in the satellite program of the International Geophysical Year (IGY) (Newell, 2011, "No page number" section). Collaboration between NASA and the military was organized as a "10-man group with 5 members from each organization" that met monthly from 11 August 1959 onward; they called themselves the Unmanned Spacecraft Panel of the Aeronautics and Astronautics Coordinating Board (Newell, 2011, "No page number" section).

In 1979 and 1980, researchers at NASA recovered the first colour pictures of Jupiter and Saturn from Voyager imaging systems (Cherewitzo, n.d.a). NASA believed these cameras would be able to "observe and characterize the circulation of the planetary atmosphere, provide limits on atmospheric composition, determine the wind velocities… search for new rings… [and] [p]rovide support images to assist other onboard investigations" (Imaging Science Subsystem). These imaging systems were a modification of those used on the earlier Mariner missions, which were not in colour. Acquiring these colour transmissions required sending three times the amount of data from three copies of the vector space in which we find our data, and thus, required more advanced methods of error coding to be able to successfully receive the images on Earth (Cherewitzo, n.d.a; Curtis, 2016, p. 54). The purpose of error coding is to remove as much error as possible from images being transmitted and received from space; as error coding became more advanced, error-correcting capabilities allowed for clearer reception imaging from the spacecrafts (Cherewitzo, n.d.b). Coding theory had originally been introduced when digital computing still relied on unreliable mechanical relays. If a single relay failed, the entire calculation would fail. It was thus necessary to be able to detect when and where errors had occurred, so the data could be retransmitted (Cherewitzo, n.d.b). The introduction of colour images from the Voyager systems required a version of error-detecting coding called the Golay (24,12) code, which uses only 3-error correcting but is capable of a much higher transmission rate (Cherewitzo, n.d.a). This means that Golay (24,12) is able "to correct three or less errors and to detect the presence of four errors" within an incoming transmission code from the Voyager spacecraft (Truong et al., 1989). More specifically, if there are less than three errors in the transmitted code, then the older and less advanced, Golay (23,12) is sufficient as a decoding technique; however, as soon as the number of errors detected in the transmission code is greater than or equal to three, the Golay (24,12) is required (Truong et al., 1989). Later, when Voyager 2 moved through its course onto Uranus and Neptune, the error code methodology changed again, switching to a Reed-Solomon code for higher error correcting capabilities and the use of VLA data gaps (Cherewitzo, n.d.a; Dolinar, 1988, p. 113). VLA data gaps are the "basis for a theoretical calculation of the performance" of the Reed-Solomon concatenated code; the "regularity of the gap cycle helps to eliminate the possibility of larger than average numbers of errors due to the gaps," allowing the decoder to correct the errors during the gaps (Dolinar, 1988, pp. 113-14). These developments in coding methodology are another example of the quickly developing scientific field in the 1970s and the application that it had to space exploration.

Since launching 38 years ago, the Voyager missions have maintained communications with Earth through their complex telemetry systems (Manz, n.d.). The primary method of communication between Voyagers 1 and 2 and Earth is via radio link (Langston, 2017). This connection runs between tracking stations on Earth and a dual-frequency radio system on the spacecraft (Langston, 2017). Since 1960, radio frequency channels have been expanded by eight orders of magnitude and the resolution used for tracking a spacecraft has been improved by a factor of 105 (Manz, n.d.). Because of advancements like these, four of the instruments on Voyager 1, as well as five on Voyager 2, are still being tracked, including the Cosmic Ray Subsystem, Low-Energy Charged Particles, Magnetometer, and Plasma Wave Subsystem (Mission Status, 2021). These developments have allowed the Voyager missions to achieve more complex goals than any NASA mission before them. Using high-resolution hyperspectral imagers, scientists at the Jet Propulsion Laboratory (JPL) at NASA could capture images from the Voyager spacecrafts at hundreds or even thousands of wavelengths simultaneously; this allowed JPL and NASA to view mineral content and other aspects of the spacecrafts' surroundings that would be impossible to see from a single visible-wavelength image (Manz, n.d.).

Radio science is now the last available form of communication with the Voyager spacecrafts, which featured

> harmonic, dual-frequency, high-power, spacecraft transmissions; use of new, highly-stable, temperature-controlled, radiation-hardened quartz; improved phase, group-delay, and amplitude stabilities in the spacecraft and ground radio systems; a novel attitude-control thruster configuration that minimizes accelerations along the Earth-spacecraft line-of-sight; planned trajectories that provide multiple planetary and satellite encounters with radio occultations by Jupiter, Saturn and its rings, Titan, Uranus, and possibly Callisto (Eshleman et al., 1977, p. 208).

The behaviour of radio waves has allowed scientists at NASA to study the atmosphere and ionosphere of Earth's neighbouring planets. As the spacecraft moves behind a planet and the radio wave connection attempts to pass through the planet, the characteristics of the radio frequencies that are returned to Earth are affected (Eshleman et al., 1977, p. 208). The angle of refraction that is returned to Earth as the radio signals pass through the planetary atmosphere is read as a function of time; this, combined with the information gained from the spacecraft trajectory, allows scientists to estimate the "refractivity of the atmosphere as a function of height" (Eshleman et al., 1977, p. 212). This, in turn, allows for the calculation of planetary temperatures and pressures (Eshleman et al., 1977, p. 209). Gravity fields of these planets give information about the average mass density of the surrounding moons as well as the internal structure of the planets Saturn and Uranus (Eshleman et al., 1977, p. 209).

How the Voyager Missions Changed Our Outlook

In the seven years following the Voyager launches, humans have flown past every planet in our solar system, gaining a better understanding of the environment and qualities of each one. This allowed researchers to gain a much better understanding of the formation of our solar system and provided an opportunity to search for extraterrestrial life (The Planetary Society, 2019). An important antecedent for the latter was 1971's Project Cyclops (Project Cyclops, p. 1). The objective of this mission was "to assess what would be required in hardware, manpower, time and funding to mount a realistic effort, using present state-of-the-art techniques, aimed at detecting the existence of extraterrestrial intelligent life" (Project Cyclops, p. 1). The project was motivated by a lack of accurate estimates for how much intelligence was in the universe and, therefore, no way of knowing how far into space scientists should search (Project Cyclops, p.1). Since physics and chemistry are presumed to remain unchanged throughout our universe, "composition of the primordial material is commonly repeated elsewhere" as well as processes such as natural selection (Project Cyclops, p. 4). Planetary systems around the stars were thus thought to be the most probable location for life (Project Cyclops, p. 4).

In 1974, Search for Extraterrestrial Intelligence (SETI) transmitted the first-ever message dedicated to reaching extraterrestrials located 25,000 light-years away; this message was sent through the Arecibo radio telescope (Bell, 2015, p. 97). This decision, however, was quite controversial. The astronomer Sir Martin Ryle, a Nobel laureate, saw these efforts as irresponsible and a way of revealing the human location to possible interstellar enemies (Bell, 2015, p. 97). Stephen Hawking, Cambridge theoretical physicist and cosmologist, said that reaching out to alternate life forms might force us "to see how intelligent life might develop into something we wouldn't want to meet" (Bell, 2015, p. 98).

The Voyager missions also included a message for aliens— one that was unlike any before it. Called the 'Golden Record,' this message was created by Frank Drake, astrophysicist and radio electronics expert and Carl Sagan's Cornell University colleague. Drake is well known for the "Drake equation" which was "an attempt to mathematically estimate the number of intelligent civilizations in our galaxy by stringing together a bunch of probabilities" (Bell, 2015, p. 94). The Golden Record that he designed was a gold-plated 12-inch copper disk: it was a longplaying phonograph record (LP), as opposed to the engraved plaques used in all the other attempts to communicate with life beyond earth (Bell, 2015, pp. 91-94). The record included scientific and mathematical diagrams such as the composition of air as well as “an hour and a half of music (27 pieces in all), 116 digitized photographs, and a catalogue of terrestrial sounds (such as the chirping of crickets) and voices (such as short greetings in fifty-five languages, including a “hello from the children of Planet Earth” in English from Carl Sagan’s then six-year-old son, Nick)” (Bell, 2015, pp. 101-103).

CONCLUSION

The Space Race took shape in the 1960s. With the United States and NASA entering this race by extending their funding in an effort to chase Sputnik, more data was collected, research was improved, and scientists were able to advance technology tenfold, not only for space exploration but also for general use by the population. However, as the 1970s approached and public support declined, it became increasingly difficult to achieve the international goals set for space exploration. Further, as time goes on and space exploration becomes increasingly privatized (i.e., SpaceX), the declining government support for this scientific field is becoming more apparent. For example, in 2018, 45th President of the United States Donald Trump proposed to the US Congress that it might be a good idea to cut the budget of a number of missions – including Earth Science Missions and NASA Astrophysics’ flagship missions - for the 2020s, as well as discontinuing NASA’s Office of Administration (Siegal, 2019).

There is no doubt that massive scientific achievements can be credited to the concentration of brain power that came together after the second world war in the effort to get man into space after the second world war. From launching the first space satellite to collaborations with the military on the first colour pictures of Saturn and Jupiter, it is undeniable that many great accomplishments came out of this era. However, after at least a decade of major funding and attention was given to the international Space Race, the public began to realign its focus and NASA fell low on America’s list of priorities. With inadequate funding for new missions and a controversial search for extraterrestrial life, space discovery was limited to the work of mathematicians and scientists who could only hope to have their work applied to live exploration in the future.

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Conflicts of interest

The author declares no conflicts of interest.

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